Text No.18

ENERGY CONSERVATION IN BUILDINGS

ビルの省エネルギー技術

June 10, 2003

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CONTENTS

Energy Conservation in Buildings in Japan

1. The Energy Demand in Residential and Commercial Sector

Total final energy demand of Japan for 1998 was 337 million tons in terms of crude oil. Of that amount, 38.8% was spent in the industry sector, 27.5% in the transportation sector, and the remaining 27.1% in the residential and commercial sector. (Refer to Fig. 1)

The proportion of final energy demand in the residential and commercial (27.1%) is low when compared with that of advanced countries in Europe (30-40%). The reason is considered to be the fact that Japan is a warm country and that room heating energy consumption is relatively small.

However, as the people's living standard has been improved, energy demand in the domestic consumption sector is increasing, and the proportion to the total energy demand is expected to approach 30%. As a result, energy conservation for the domestic consumption sector has become more important than ever.

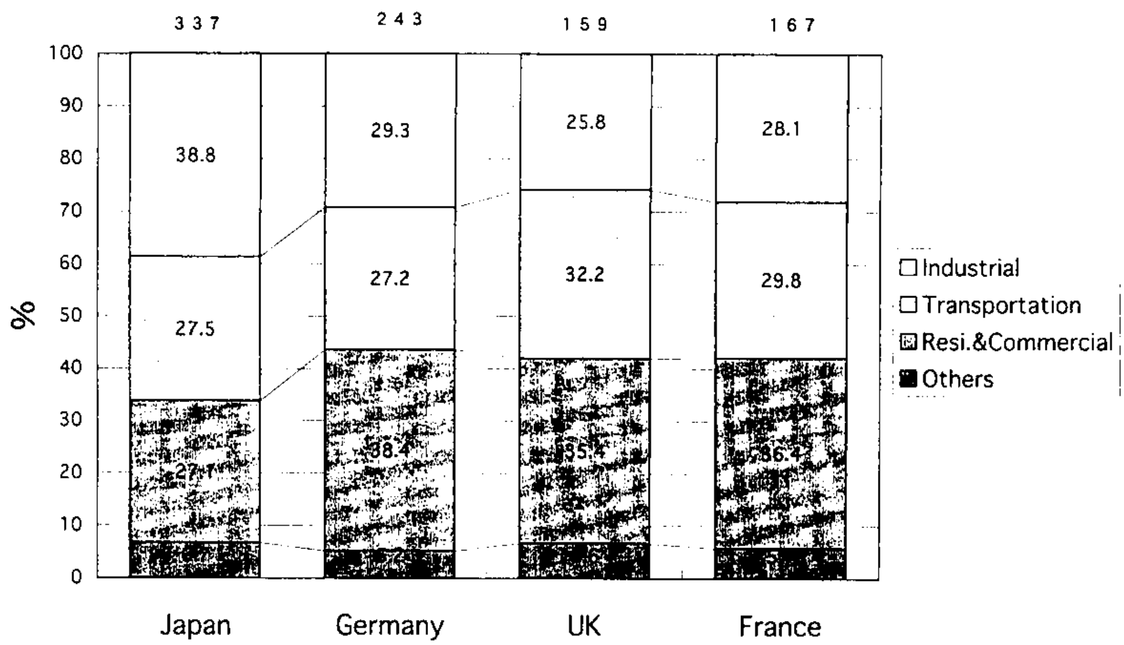


Fig. 1 Final Energy Demand in Major Countries
(million ton in crude oil OECD 1998)

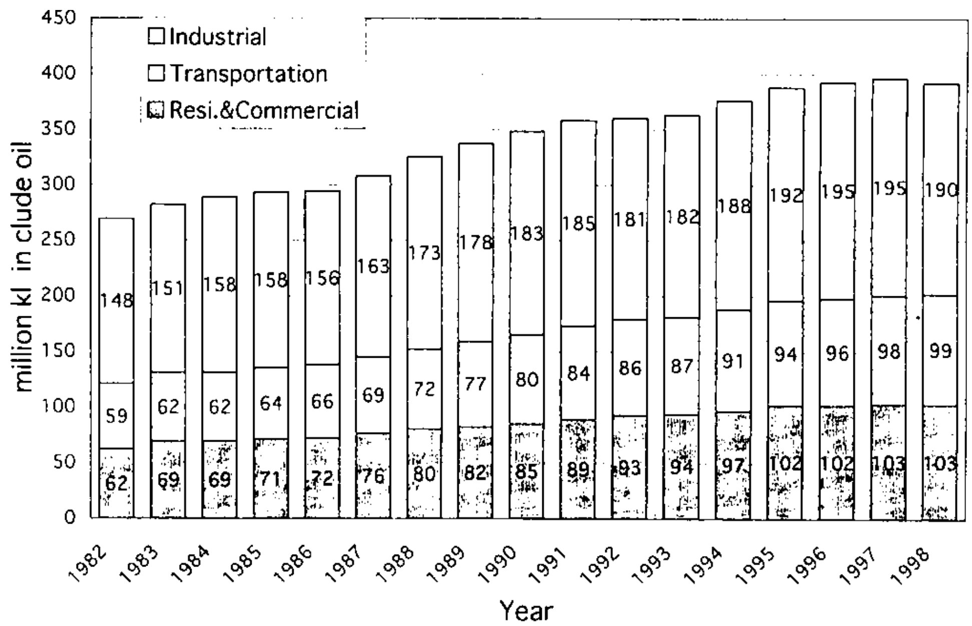


Fig. 2 Final Energy Demand in Japan

2. Energy Demand in the "Commercial Section"

The term "commercial section" refers to the tertiary industry, including commerce, service industries, buildings and business management. This section covers many different forms of energy consumption such as energy consumption in shops, department stores, hotels, movie theaters, restaurants, amusement parks, etc.

Fig. 3 shows the change of energy consumption per floor area by different form of energy. It is observed that the consumption of electric energy has been increasing.

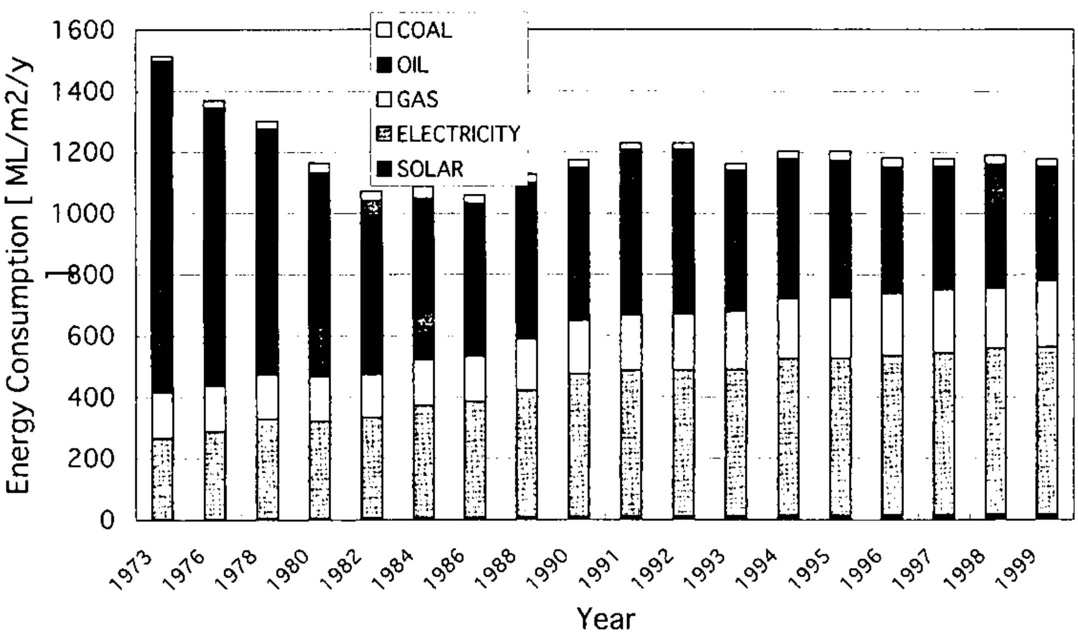


Fig. 3 Energy Consumption per Floor Area by Different Form of Energy

Fig. 4 shows the change of energy consumption per floor area for different uses. It is observed that the energy consumption for "others" has been increasing due to the increase of office automation equipments.

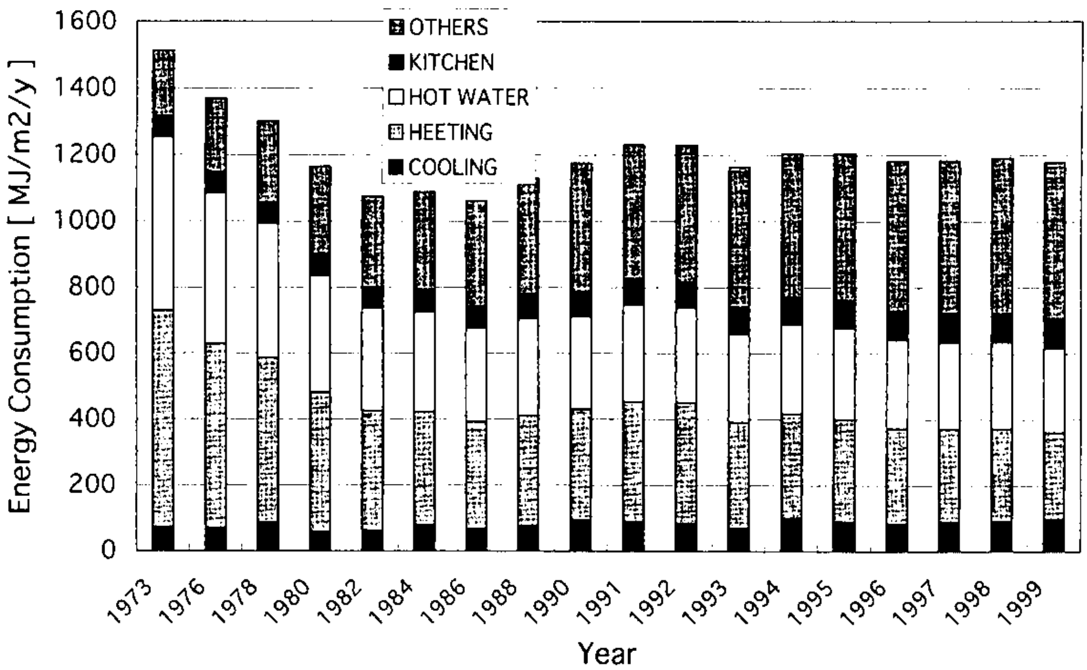
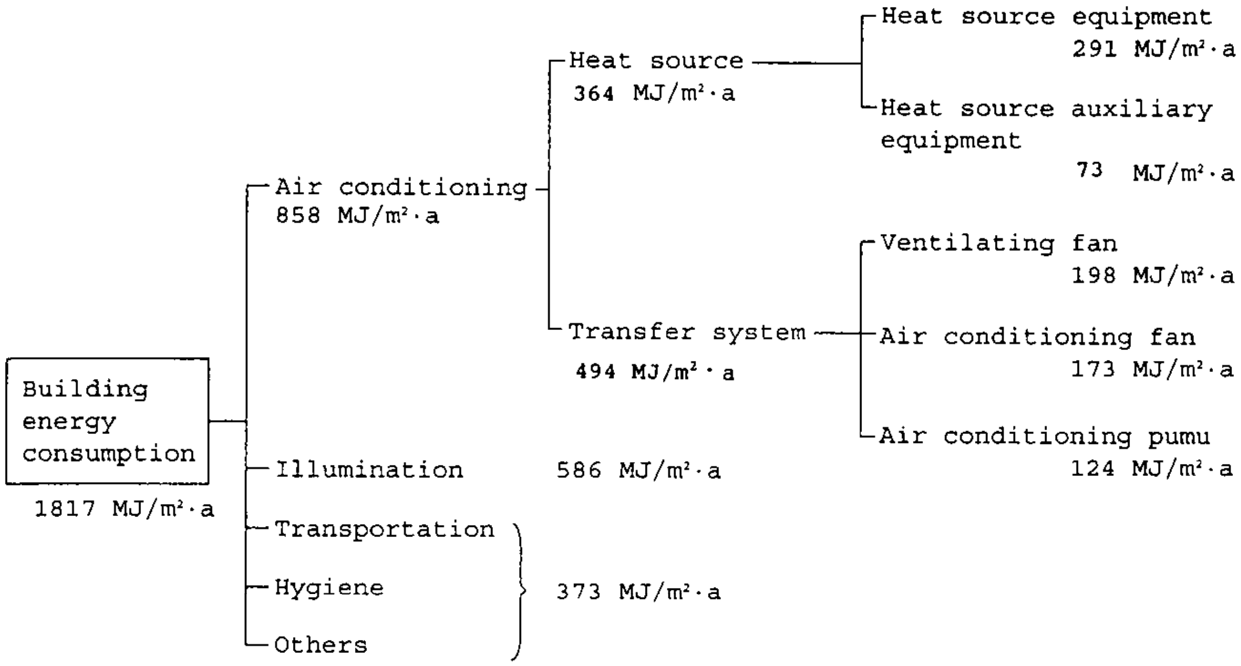


Fig. 4 Energy Consumption per Floor Area by Different Uses

Figure 5 shows energy consumption in a general office building.



Note: Figures are values calculated in terms of primary energy.
Area is extended floor space.

Fig. 5 Energy Consumption in General Office Building

3. Energy Conservation in Buildings

Most of the energy consumed in the "commercial section" is consumed in buildings such as office buildings. The features mentioned below need to be taken into consideration in promoting energy conservation in buildings.

Buildings have long lives. Therefore, once they are constructed, it is hard to perform large-scale remodeling. For that reason, the initial design and construction of the building is the principal determinant of its future energy consumption. In this respect, the "commercial section" differs from the industrial sector in which efforts are continually made to reduce energy consumption. This also means, however, that the "commercial section" has room for considerable energy conservation.

Since it costs a great deal to construct buildings, attention tends to be paid to reducing construction costs, but little attention is paid to reducing future operating costs. Despite the fact that preliminary calculations would reveal that the cost of energy consumed in the building over a long period of time becomes several times higher than the total construction cost, sufficient resources are rarely appropriated for energy conservation at the construction stage.

Since the actual users of tenants of ordinary buildings, hotels and amusement facilities sometimes do not own these facilities, it is hard for these users to undertake consistent energy conservation measures.

In order to carry out energy conservation in a building which has the above-mentioned difficulties, the following three approaches can be adopted.

(1) Reducing a building's energy demand

Roofs and windows of buildings can be insulated to minimize the need for heating and cooling inside the buildings. Since it is said that the outflow of heat from an ordinary house can be decreased by half or more by effectively utilizing heat insulation, it can be assumed that similar insulation installed in the building construction will produce great savings in energy use.

(2) Making M&E equipment of the building efficient

The energy efficiency of a building equipment can be enhanced by reducing ineffectiveness in their operation. Long-term energy conservation can be achieved by improving the construction and operation of boilers and air-conditioners and by rationalizing elevator operation.

(3) Effective utilization of waste and natural energy

Waste heat energy can be used to preheat rooms. A solar system employing solar energy can be introduced. In these ways surplus and natural energy are utilized effectively. (Refer to Table 2.)

4. Energy Conservation Policies in Japan

The following are the three main subjects on which Japanese Government attempts to publicize and promote energy conservation in the field of architecture: legal regulations, preferable treatment in terms of financing and taxation, and technological research and development.

Legal Regulations

According to the Law Relating to the Rationalization of Energy Use, promulgated in 1979, building owners are required to cooperate in energy conservation by meeting certain nationally established standards.

Standards

(1) Residential architecture: Heat loss must be kept below the established coefficient.

(2) Other kinds of buildings: All buildings must conform to standards set for the prevention of heat loss through exterior walls and windows (Perimeter Annual Load, PAL) and must be within the established values for air-conditioning energy-consumption coefficients. (Co-efficient of Energy Consumption for Air Conditioning, CEC).

PAL (Mcal/m^2 per year) This is obtained by dividing the intake and heat loss (Mcal/per year) from the periphery and roof by the total area of the perimeter of each floor and the area of the rooftop (m^2).

CEC is obtained by dividing the total value of energy consumed by air-conditioning equipment in a year (Mcal/per year) by the total of the cooling load plus the heating load plus the exterior-air load (Mcal/per year).

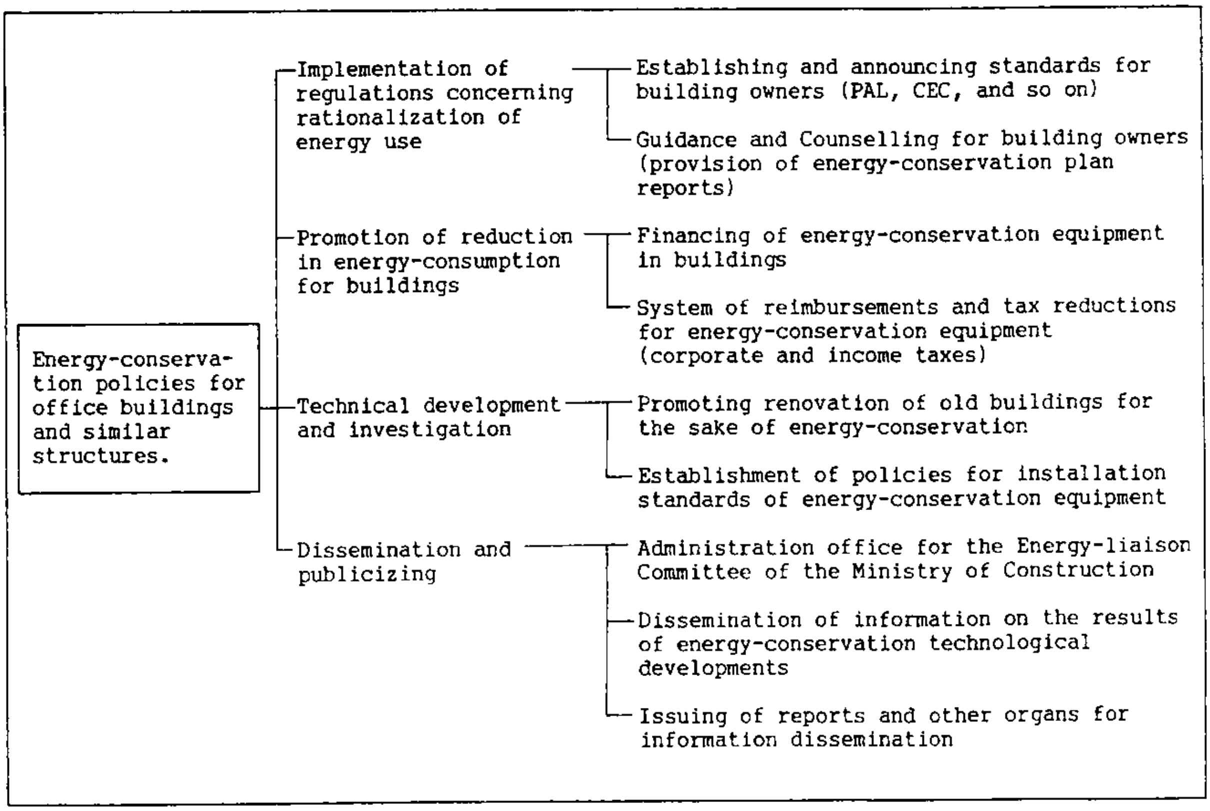
In the case of an office building with total floor area of more than 2,000 square meters, an energy-conservation plan must be submitted at the initiation of construction. The following values are stipulated: PAL $\leqq$ 80 (Mcal/m^2 per year); CEC $\leqq$ 1.6.

Financing and Taxation Measures

Public financing at low interest rates is provided for money invested in energy conservation in new buildings or in the renovation of old ones. A special system of reimbursement and deductions from corporate taxes too is in effect. Furthermore, financial subsidies and low-interest financing are available for the installation of solar systems.

Technological Research and Development

A vast national project called The Sunshine Project for research into utilization of solar energy, ground heat, coal, hydrogen, marine power, and wind power was initiated in 1974. Another project called The Moonlight Project for energy conservation was started in 1978 and is especially significant for its work on effective utilization of very small quantities of light. Major Japanese contractors participate in these nationwide projects as well as conduct their own related energy research programs.



5. Energy Conservation Design Method in Building ;

Energy conservation design method in buildings falls into the method relating to the planning and that relating to the building equipment. The important methods will be presented here selectively.

(1) Building planning method

1) Double Skin

2) Reduction of Building Outer Surface Area

3) Reduction of Opening Area

4) Optimization of Core Position

5) Optimization of Opening Bearing

6) External Blind

7) Flying Roof

8) Provision of Smoking Room

9) Atrium

(2) Building equipment method

1) Heat Storage Tank

2) Heat Recovery Heat Pump System

3) Co-generation System

4) Engine Heat Pump System

5) VAV System

6) VWV System

7) Large Temperature Difference System

8) Total Heat Exchanger

9) Ventilation Cooling

10) Drainage Utilization

11) Rainwater Utilization

12) Solar Heat Utilization

13) Computer Control system

14) Task/Ambient Illumination

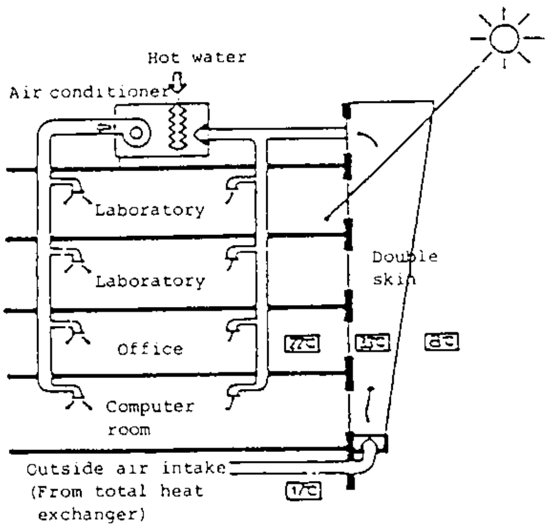
15) Illumination Control by Daylight Utilization

16) Solar Cell Utilization

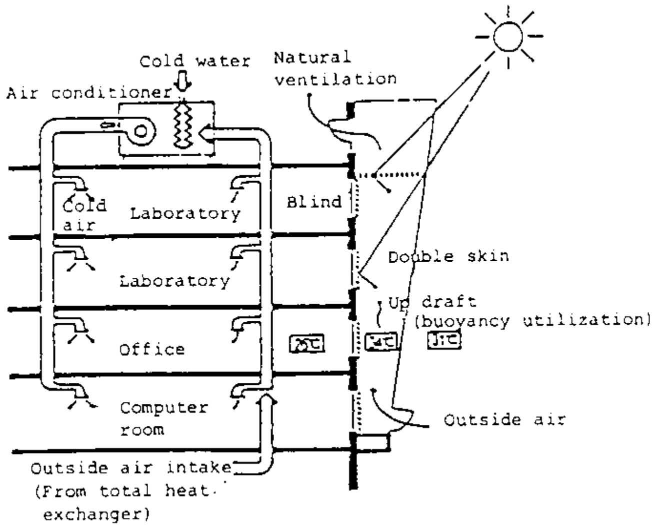
Double Skin

General

The air-conditioning load is reduced by providing glass-house space on the periphery of the building. For heating rooms, intake air is preheated at the double skin portion. For cooling rooms, waste heat is removed by natural ventilation.



In winter season
(room heating required)

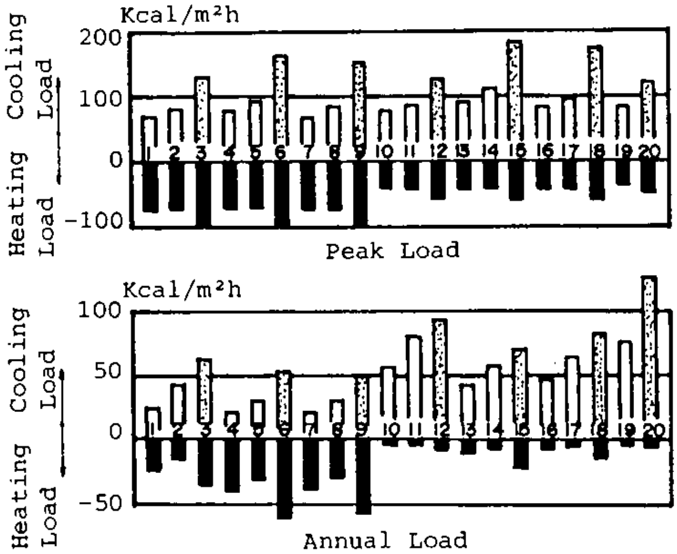


In summer season
(room cooling required)

Effect

Effect of double skin applied to office building is shown below.

This method can reduce air-conditioning load, and in addition release from the sense of confinement can be obtained by providing large opening. Further illumination energy conservation can be made possible through daylight utilization.



Case No.	Area	Bearing	Provision of Double Skin	External Glass Material
1	Sapporo	S	o	Heat reflective glass
2	Sapporo	S	o	Ordinary
3	Sapporo	S	x	
4	Sapporo	W	o	Heat reflective glass
5	Sapporo	W	o	Ordinary
6	Sapporo	W	x	
7	Sapporo	E	o	Heat reflective glass
8	Sapporo	E	o	Ordinary
9	Sapporo	E	x	
10	Tokyo	S	o	Heat reflective glass
11	Tokyo	S	o	Ordinary
12	Tokyo	S	x	
13	Tokyo	W	o	Heat reflective glass
14	Tokyo	W	o	Ordinary
15	Tokyo	W	x	
16	Tokyo	E	o	Heat reflective glass
17	Tokyo	E	o	Ordinary
18	Tokyo	E	x	
19	Kagoshima	S	o	Heat reflective glass
20	Kagoshima	S	x	

o: Provided x: Not provided

Application

a. Applicable to every building requiring room cooling/heating.

b. Applicable when building location is such that outside wall surface is exposed to sunshine.

c. Applicable regardless of area.

Building	Office	o
	Hotel	Δ
	Hospital	Δ
	Store	o
	School	o
	Multiple dwelling house	
	Factory	Δ
Region	Cold region	o
	Warm region	o
Location	Center of large city	o
	Suburbs	o

Example of Application

a. Obayashi Corporation Technical Research Institute Main Building (Tokyo)

b. Kintetsu Engineering Laboratory (Nara)

Reduction of Building Outer Surface Area

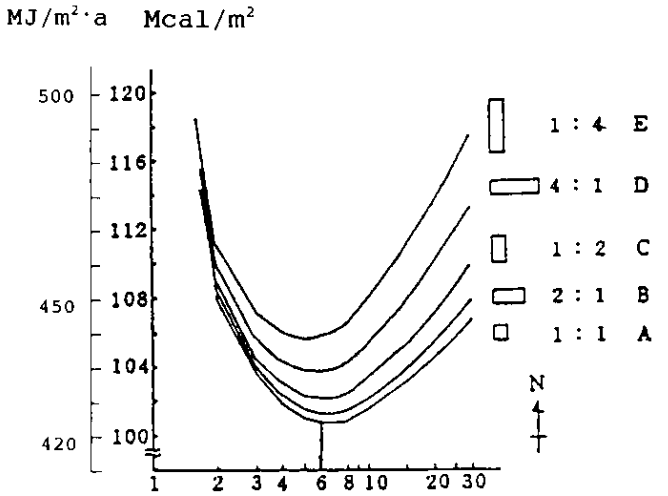
General

Effect of outside air on intra-building space appears through outer peripheral wall. For the purpose of reducing the thermal load by holding as much heat as possible, a building form with a small peripheral area is selected by taking the building use and site geography into account.

Effect

The difference in the annual thermal load due to building contour when the floor space is assumed to be constant, is shown below.

For example, in the case of 6-storied building whose ratio of short to long sides is 1 : 4, with the long side extending from north to south (E), annual thermal load is about 105 [$Mcal/m^2a$], while in the case of contour A whose peripheral area is the smallest, the annual thermal load is 101 [$Mcal/m^2a$], thus it is reduced by 3.8%.



Condition:

Area	Tokyo
Extended floor space	50,000 m^2
Insulating material thickness	25 mm
Window area ratio (4 sides)	30%
Height of story	3.7 m
Illumination	25 W/m^2
Draft	0.3 times/h
Temperature/humidity (cooling)	26°C, 50%
(heating)	22°C, 50%
Air conditioning area ratio	65%
Intake outside air	4.5 m^3/m^2h

Annual Thermal Load When Extended Floor Space is Assumed to be Constant
(Calculated value by experimental planning method)

Application

Applicable regardless of area, building use, and geographical feature.

Building	Office	o
	Hotel	o
	Hospital	o
	Store	o
	School	o
	Multiple dwelling house	
	Factory	
Region	Cold region	o
	Warm region	o
Location	Center of large city	o
	Suburbs	o

Example of Application

a. Obayashi Corporation Technical Research Institute
   Main Building (Tokyo)

b. Many others

Reduction of Opening Area

General

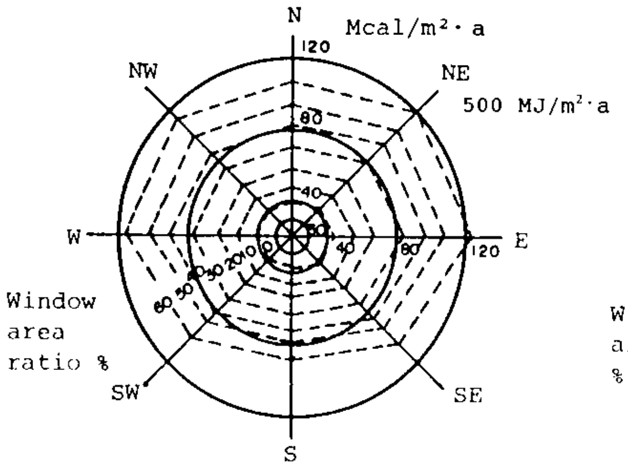
Openings are markedly inferior in insulation performance to the structural body. The heat loss and heat gain at the opening increase room cooling/heating load.

This technique is to reduce as much opening area as possible to reduce the annual room cooling/heating load.

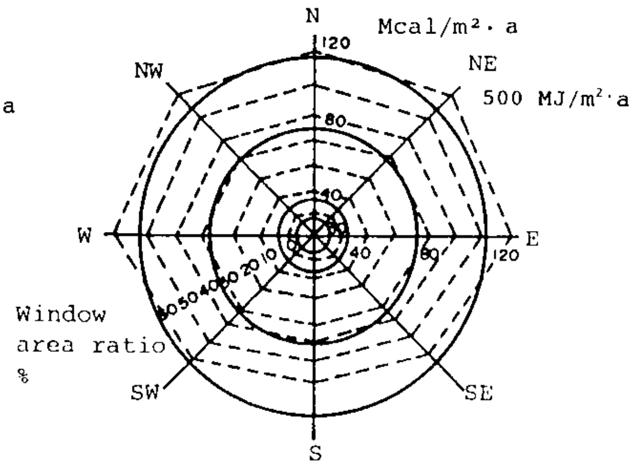
Effect

The following shows the trial calculation of the effect that the window area ratio has on the annual perimeter thermal load. For example, in Tokyo, when the window area ratio of the building south side is 60%, PAL value is 377 MJ/m^2·a [Mcal/ m^{2}a]. When the window area ratio is decreased to 40% (17% reduction), PAL value becomes 314 MJ/m^2·a [Mcal/ m^{2}a].

Tokyo (wall: overall heat transfer coefficient 1.16 W/m^{2}K, window: single layer glass, bright color blind)



Osaka (wall: overall heat transfer coefficient 0.81 W/m^{2}K, window: double layer glass, bright color blind)



Window Area Ratio and Annual Perimeter Thermal Load
(Calculation value by extended DD method
frontage 30 m, perimeter depth 5 m)

Application

No particular restrictions on the application.

However, a thorough consideration should be given to the area of opening since it affects lighting, person's sense of confinement, and disaster prevention seriously.

Building	Office	o
	Hotel	o
	Hospital	o
	Store	o
	School	o
	Multiple dwelling house	
	Factory	o
Region	Cold region	o
	Warm region	o
Location	Center of large city	o
	Suburbs	o

Example of Application

a. Obayashi Corporation Technical Research Institute Main Building (Tokyo)

b. Many others

Optimization of Core Position

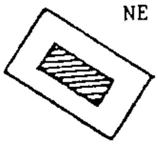
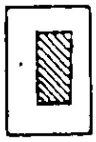
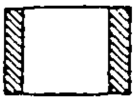
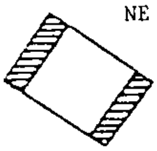
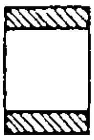
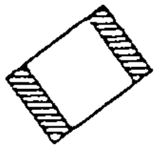
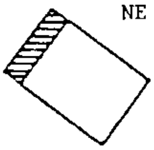
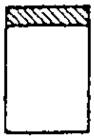
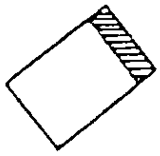
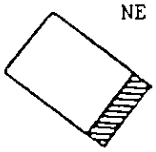
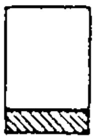
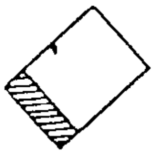
General

Machine room, elevator shaft, toilet, passage, etc. not requiring air-conditioning are "cores". The cores are arranged in the highest story and the periphery of the building where room cooling/heating load is large. Those areas become the buffer zones of heat, and thermal load reduction of air-conditioned rooms is designed.

Effect

The annual integrated thermal load according to core position is shown below.

It is evident as shown in the table, that compared with the center core type in which the core is provided in the center of the building, the double core type and side core type in which the core is provided in the perimeter part can better reduce the cooling/heating load.

	Annual Thermal Load According to the Bearing of Building Mcal/m² year				Mean Thermal Load
Bearing	N(S)	NE(SW)	E(W)	SE(NW)	
Center core	N  143.2	NE  147.0	 E 144.1	 SE 146.4	137% 145.2
Double core	N  104.5	NE  107.2	 E 106.4	 SE 106.1	100% 106.0
Side core	N  106.1	NE  107.9	 E 105.4	 SE 107.2	102%
	N  107.2	NE  110.5	 E 109.7	 SE 110.1	108.0

Condition				
	Area	Tokyo	Temperature/humidity room	
	Standard story floor		Cooling	26°C, 50%
	space	2,400 m²	Heating	22°C, 50%
	Height of story	3.7 m	Air-conditioning area ratio	65%
	Window area ratio	60%	Intake outside air	4.5 m³/m²h
	Lighting	30 W/m²	Side length ratio	1 : 1.5
	Draft	Once/h	Personal density	7 m²/person
			Insulating foam polystyrene	25 mm

Core Position and Annual Integrated Thermal Load
(calculated value by extended DD method)

Application

a. Applicable regardless of area

b. There are unapplicable cases due to difficulty of free selection of core position according to building contour, application, or site geography.

Building	Office	o
	Hotel	Δ
	Hospital	Δ
	Store	Δ
	School	
	Multiple dwelling house	
	Factory	
Region	Cold region	o
	Warm region	o
Location	Center of large city	o
	Suburbs	o

Example of Application

a. Obayashi Corporation Technical Research Institute Main Building (Tokyo)

b. Many others

Optimization of Opening Bearing

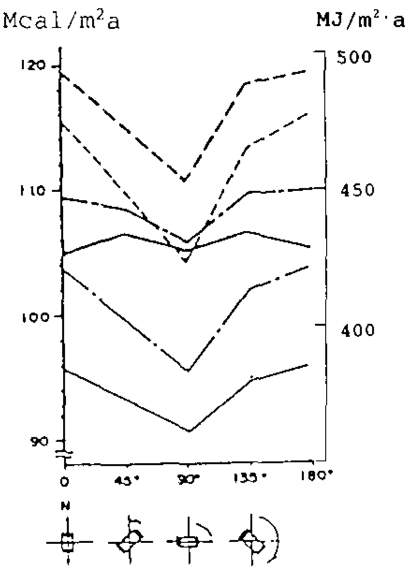
General

The heat gain by sunshine affects room cooling/heating load and varies according to the bearing of the opening. This method is to optimize the bearing of the opening so as to reduce annual room cooling/heating load. Particularly, it is effective for reducing maximum load.

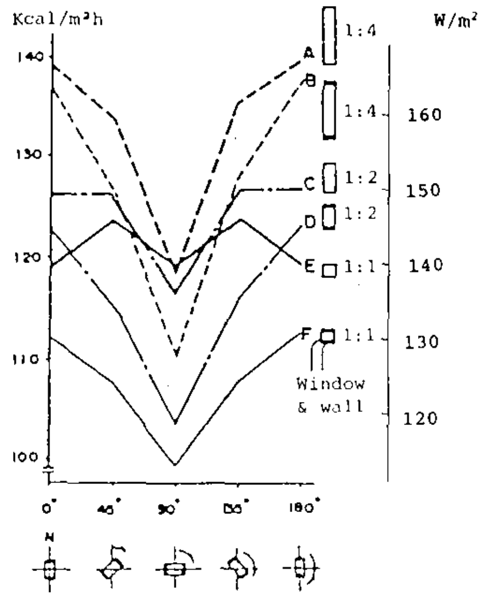
Effect

An example of thermal load change due to the bearing of opening (angle of deviation) is shown below.

For example, in building D where the ratio of short to long sides is 1 : 2 and where the windows are provided on the long side, the largest cooling/heating load occurs when the window surface is provided on the east and west sides and its value is 143 W/m^2. **When the window surface faces south and north, the maximum load is reduced by 15%, i.e., 121 W/m^2.**



Angle of deviation and annual thermal load per air-conditioned area



Angle of deviation and max. room cooling load per air-conditioned area

Condition:

Area	Tokyo
Standard story floor space	1,000 m^2
Insulating material thickness	25 mm
Window area ratio (4 sides)	30%
Height of story	3.7 m
Illumination	2.5 W/m^2
Draft	0.3 time/h
Temperature/humidity room	
Cooling	20°C, 50%
Heating	22°C, 40%
Air-conditioning area ratio	65%
Intake outside air	4.5 m^3/m^2h

Application

a. Applicable regardless of area and building use.

b. Bearing of building is determined by the relationship with site peripheral road. Accordingly for free selection, the site must have a margin to some extent.

Building	Office	o
	Hotel	o
	Hospital	o
	Store	o
	School	o
	Multiple dwelling house	
	Factory	o
Region	Cold region	o
	Warm region	o
Location	Center of large city	o
	Suburbs	o

Example of Application

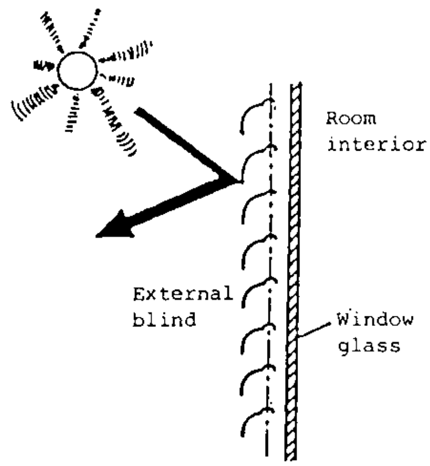
a. Obayashi Corporation Technical Research Institute Main Building (Tokyo)

b. Many others

External Blind

General

Blind is provided outside of glass window. The blind blocks sunshine radiated to the glass window, exhibiting great shielding effect.



It falls into two types: manual type and automatic type. The latter is for controlling the aperture of the blind so that air-conditioning load and illumination load become minimum, while maintaining the room illumination to a certain extent.

Effect

Since the sunshine is blocked directly, a high shielding effect can be expected, and the room cooling load can be reduced. Since the sunshine irradiating the glass window is reduced, radiation from the glass window is reduced, and the environment of the perimeter zone is improved.

In the nighttime, when the blind is fully closed, an insulating air layer is formed outside of the window, thus exhibiting room heating load reduction effect.

Sunshine Shielding Effect of External Blind

Sunshine Shielding Device				Shielding Factor	0.1 0.2 0.3 0.4 0.5 0.6 0.7
4 mm transparent glass double layer (air layer 12 mm)				0.72	
External blind	Aluminum 80 mm wide	White Alumi-num	Full close 45° Full open	0.13 0.15 0.14	
	Aluminum 80 mm wide	Dark brown	Full close 45°	0.19 0.23	
	Aluminum 97 mm wide	Bright gray	Full close 45°	0.13 0.15	

Application

a. Effective for buildings having a large window area

b. Since the blind is subject to be affected by external wind, countermeasure is required.

Building	Office	o
	Hotel	o
	Hospital	o
	Store	o
	School	o
	Multiple dwelling house	
	Factory	o
Region	Cold region	
	Warm region	o
Location	Center of large city	o
	Suburbs	o

Example of Application

Obayashi Corporation Technical Research Institute
Main Building (Tokyo)

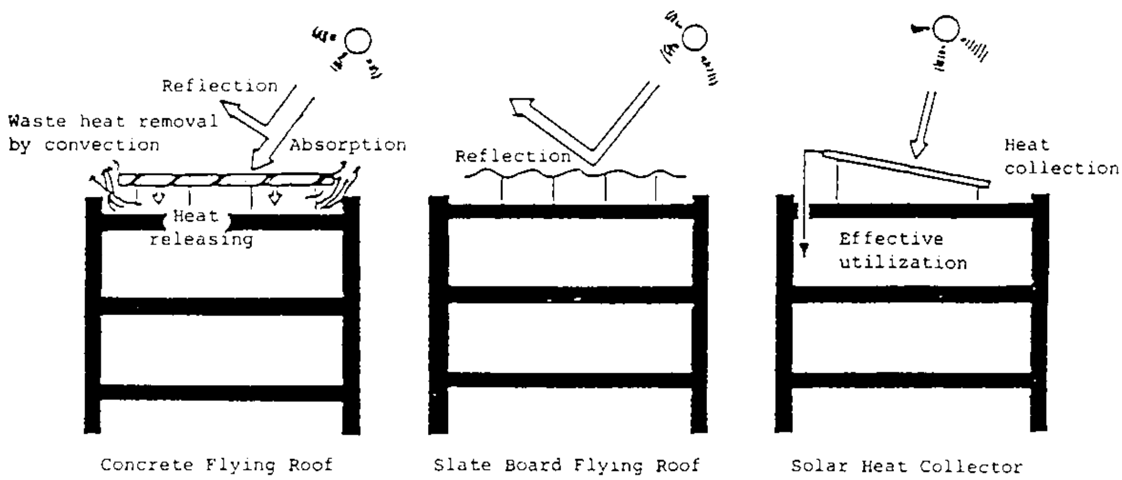
Flying Roof

General

Particularly, in the case of a low storied building, the proportion of the load from the roof due to sunshine is large.

A flying roof is a roof provided separately above the building roof top to block the sunshine falling on the roof top. Its material is slate, concrete, etc.

The solar heat collector to be provided on the roof top is a kind of flying roof.



Various Flying Roofs

Effect

By blocking sunshine falling on the roof top, room cooling load can be reduced. By considering effective utilization of space enclosed by two roofs, the effect is further increased.

Application

There is no particular restriction providing that the design is considered properly.

Building	Office	o
	Hotel	o
	Hospital	o
	Store	o
	School	o
	Multiple dwelling house	o
	Factory	
Region	Cold region	
	Warm region	o
Location	Center of large city	o
	Suburbs	o

Example of Application

Many

Provision of Smoking Room

General

In daily living, one major cause of air pollution is smoking. Provision of a smoking room localizes the air pollution due to cigarettes, and reduces the required air ventilation of general rooms.

Pollutant Generation from Cigarettes

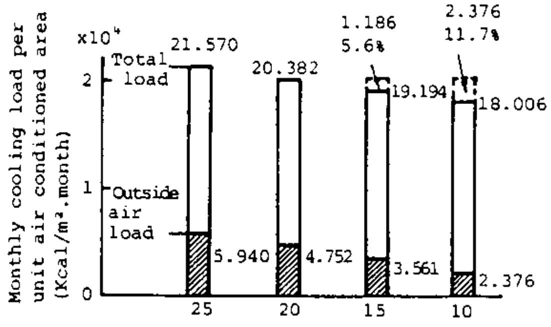
	Smoking (ml/piece)	Artificial Smoking (ml/piece)	Burning Cigarette (ml/piece)
CO	28 - 62	25 - 39	33 - 46
NO	0.36 - 0.70	0.42 - 0.60	0.45 - 1.05
NO_2	0.01 - 0.11	0 - 0.08	0.01 - 0.18
	Artificial Smoking (ml/piece)		Burning Cigarette (ml/piece)
CO	47 - 70		44 - 46
NO	1.1 - 1.4		1 - 1.2

Effect

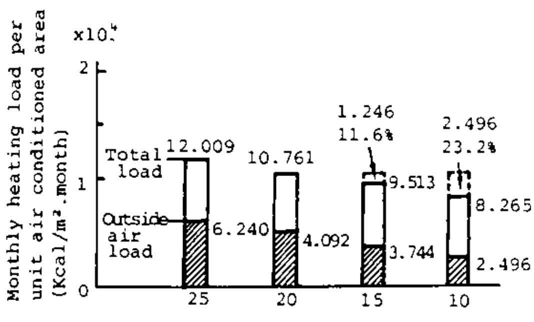
As a result of prohibiting smoking for other than in the smoking room, required ventilation and outside air directing quantity is reduced, and the room cooling/heating load is reduced.

The particle size of cigarette smoke is 0.01 - 0.5 μm and cannot be collected except with a high performance filter. Providing such removing equipment at the periphery of the smoking room is sufficient, and the equipment cost is lowered.

A favorable effect on personal health is evident.



Change in monthly room cooling load when the intake outside air amount is changed (August)



Change in monthly room heating load when intake outside air amount is changed (February)

Energy conservation effect when the outside air amount is reduced in a 5,000 m² office building (Tokyo)

Application

a. No particular restriction on application.

b. Application to every building is desired.

Building	Office	o
	Hotel	o
	Hospital	o
	Store	o
	School	
	Multiple dwelling house	
	Factory	o
Region	Cold region	o
	Warm region	o
Location	Center of large city	o
	Suburbs	o

Example of Application

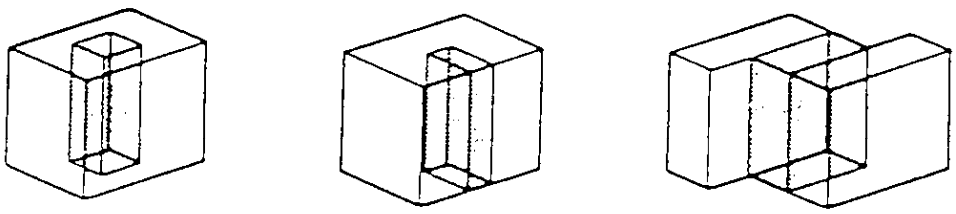
Many

Atrium

General

In the case of large buildings, etc., the distances from working places to windows become large and peoples sense of confinement becomes acute. On the other hand, for energy conservation, the area of window glass facing the outside must be minimized to avoid the effect of outside air.

Atrium is a means of solving the above problem. Atrium is a large space incorporated in a building having a transparent roof to enable day lighting without being affected by outside air to an appreciable extent. In addition, in the case of south side atrium, it also serves as a stack, and can reduce the room cooling load in the summer season.

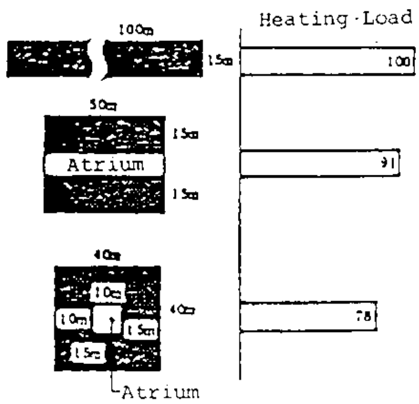


Atrium Arrangement

Effect

When building depth be limited from the aspect of lighting and or to ease person's sense of confinement, provision of atrium can keep the load from increasing.

An example is shown on the right. From that, it can be known that by providing the atrium in the building, room heating load is reduced by 22%.



Comparison of room heating load of the building whose depth is limited to 15 m.

Application

The effect of application is high under the following conditions.

① When the depth is limited from the aspect of openness of the room.

② When building depth must be small due to area per room such as hotel guest room and conference room.

③ When the necessity of hot-house type spaces is high.

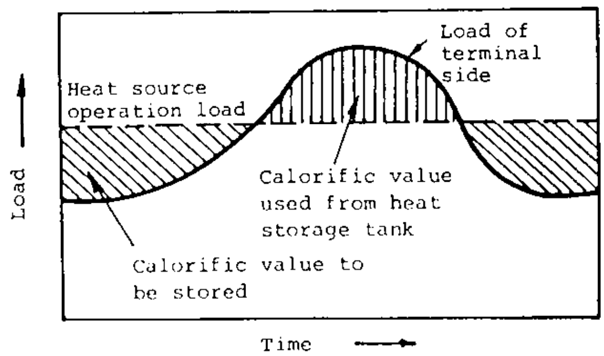
Building	Office	o
	Hotel	o
	Hospital	o
	Store	o
	School	o
	Multiple dwelling house	
	Factory	
Region	Cold region	◎
	Warm region	o
Location	Center of large city	o
	Suburbs	o

Example of Application

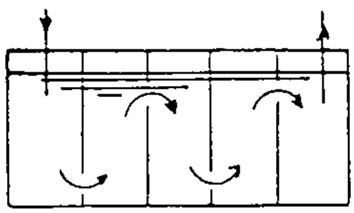
General

Heat storage tanks are equipment to store cold or hot water for room cooling/heating. By absorbing the time deviation between heat production and consumption and by using inexpensive off-peak power and secondary off-peak power, etc., the operation cost can be reduced.

Heat storage tanks come in many types. Continuous multitanks are those in which single tanks of the fully-mixed type are connected in series, and are designed to give a temperature gradient in the direction of water flow. They are capable of effectively utilizing the space between underground beams. The heat storing efficiency is low when compared with other types (about 60%).



An Example of Heat Storage Operation (peak cut)

Continuous multitank type		Inter-mediate	Effective utilization of underground beam space available. Insulation work difficult.

Effect

Effective utilization of underground beam space is possible, and this type has the following effects.

① The capacity of heat source equipment becomes small, and the total cost is reduced.

② Since the heat source equipment can be operated at a high load, reduction of operation cost through efficiency promotion is possible.

③ Nighttime low price power can be utilized, and the operation cost can be reduced together with peak cut.

④ Load increases after completion can be dealt with changes in the operation hours of the heat source equipment, while the degree of freedom for extension/modification is large.

Application

a. To promote complete mixing, the capacity of single tank must be small. Water depth should be less than 2 m.

b. For increasing the heat storage efficiency, the number of tanks must be increased. Doing so, however, increases the heat loss from the tanks. Accordingly, the number of tanks is determined on the basis of these considerations.

c. Heat insulation construction work is relatively difficult.

d. Since the water transfer system is open circuit, there are disadvantages, such as transfer power increase and requirement of water quality control.

Building	Office	o
	Hotel	o
	Hospital	o
	Store	o
	School	o
	Multiple dwelling house	
	Factory	o
Region	Cold region	o
	Warm region	o
Location	Center of large city	o
	Suburbs	o

Example of Application

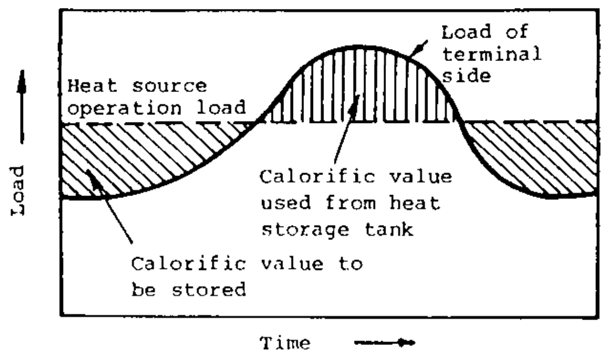
There are many including offices and hotels.

Temperature Stratified Heat Storage Tank

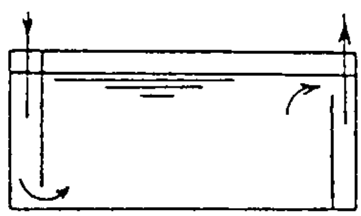
General

The heat storage tank is an equipment for storing cold or hot water for room cooling/heating. Time deviation between heat production and consumption is absorbed, and operation cost can be reduced by using low cost off-peak, and secondary off-peak power.

Heat storage tank are of various types. The temperature stratified heat storage tank is a partitionless single tank. By utilizing the density difference of high temperature water and low temperature water, mixing of tank water is avoided as far as possible. Compared with other types, the heat storage efficiency is high, and it has been recorded for as high as 95% for the system of the Technical Research Institute of Obayashi Corporation.



An Example of Heat Storage Operation (peak cut)

Temperature lamination type		High	Suitable for large type sets on the ground. Simple heat insulation work.

Effect

In addition to the general effects of heat storage tank as shown below, heat loss is small and heat insulation work is easy compared with other types.

(1) Heat equipment capacity is small, and total cost is low.

(2) Since the heat source equipment can be operated at a high load, operation cost reductions by increased efficiency are possible.

(3) Inexpensive off-peak power can be utilized, hence operation cost reduction is possible together with peak cut.

(4) Load increases after completion can be dealt with by changing in operation hours of heat source equipment, and degree of freedom for addition/modification is large.

Application

a. To maintain a favorable temperature stratification, the water depth should be at least 4 m. Space for the heat storage tank is selected taking this into account.

b. Since the water transfer system is open circuit, there are such disadvantages as transfer power increase and requirements of the water quality control.

Building	Office	o
	Hotel	o
	Hospital	o
	Store	o
	School	o
	Multiple dwelling house	
	Factory	o
Region	Cold region	o
	Warm region	o
Location	Center of large city	o
	Suburbs	o

Example of Application

a. TBS Midori-yama Studio (Kanagawa)

b. Sea Mall Shimonoseki (Yamaguchi)

c. Tore Okazaki Kojo (Aichi)

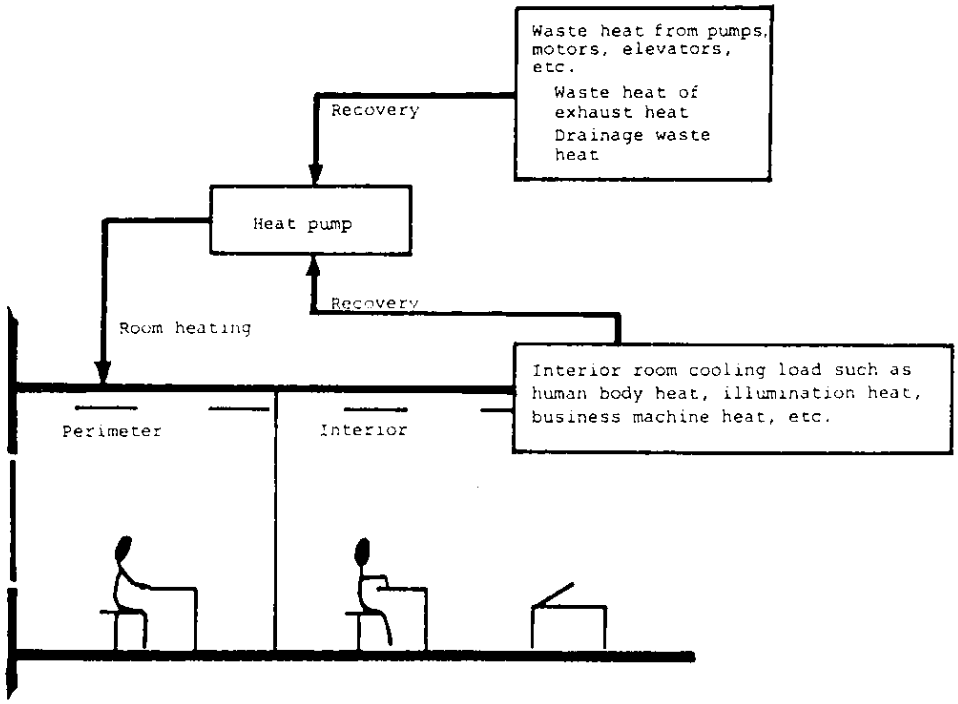
d. Obayashi Corporation Technical Research Institute
   Main Building (Tokyo)

Heat Recovery Heat Pump System

General

In air-conditioning systems in which the interior and perimeter are zoned, heat is recovered from the room cooling load of the interior system in the winter season and the room heating load of the perimeter system or oil supply load is born using it to achieve energy conservation.

Heat generated from various equipment and heat from drainage and exhaust gas can be utilized as the heat recovery heat source.



Approximate Heat Recovery Load

		Waste Heat Recovery Amount (m^2 wall area) (Kcal/h.m)		Remarks
1	Person	2.5	1 person per 20 m^2	
2	Fan pump power	6.3		Power of cooling tower, exhaust fan, etc. excluded
3	Business machine	2.0	per gross area 2.5 W	
4	Exhaust gas of toilets, etc.	1.8	1 person per 10 m^2 Hygiene equipment 85 m^2/h per 1 implement 15 persons per 1 implement	Amount 11°C cooling possible
5	Transformer	1.5	Winter 60 W/gross area as loss 3%	
6	Elevator	2.5	As usage 30%	
7	Drainage	3.8		Practical method for heat recovery is difficult.
8	Heat pump shaft power	7.5		For winter load
9	Illumination heat	21.0	800 lx For winter load 200 200 m^2 Reflection factor Floor 10% Wall 50% Ceiling 70% In buried fluorescent lamp with louver as 40 W/m^2	As effective area 75%, heat storage factor 70%

Effect

Using a heat pump and utilizing it effectively to recover the waste heat generated in the building, it is possible to reduce the consumption of the room heating energy and that of hot water supply energy.

Application

a. When the heat insulation of building is insufficient, the nighttime heat storage load from the perimeter side enters the interior side, the interior requires heating even in the daytime and heat recovery cannot be made. Accordingly, high heat insulation of building is mandatory for application.

b. When applying, recovery calorific value and heat load should be predicted as accurately as possible by non-steady calculations, etc. for the system design.

Building	Office	o
	Hotel	o
	Hospital	o
	Store	o
	School	
	Multiple dwelling house	
	Factory	o
Region	Cold region	o
	Warm region	o
Location	Center of large city	o
	Suburbs	o

Example of Application

a. NHK Osaka Broadcasting Building (Osaka)

b. Dojima Kanden Building (Osaka)

c. Osaka Obayashi Building (Osaka)

d. Dokkyo Medical University Hospital Building (Tochigi)

e. Toyobo Tokyo Building (Tokyo)

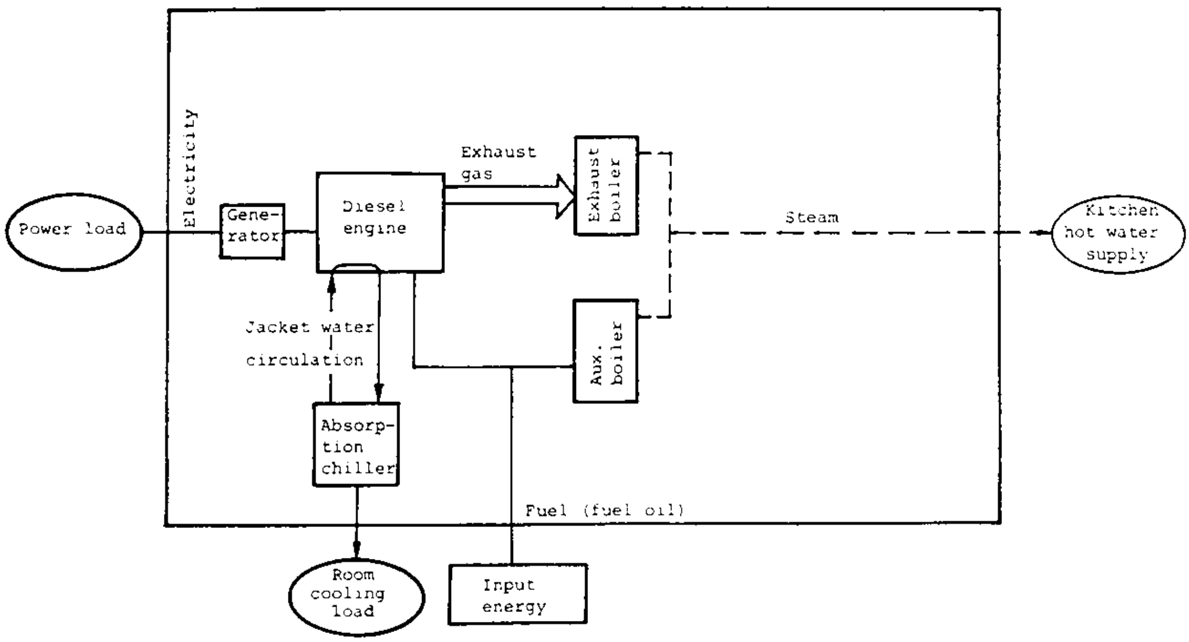
Co-generation System

General

Co-generation is also called "heat supply power generation" when private power generation is constantly performed on site. At the same time, it is used as a heat source for room cooling/heating and water heating supply by recovering exhaust heat (cooling water and exhaust gas) generated from the engine of generator. By this means, high efficiency utilization of energy is achieved.

An example of the system using a diesel engine for the drive is shown below. In this system, the exhaust gas from the engine is recovered as steam or hot water via the exhaust gas boiler, while the cooling water of the cylinder jacket as hot water via the heat exchanger, and is used for room cooling/heating and water heating.

The characteristics of the co-generation system vary according to the kind of the engine used. The main characteristics of the engine are as shown in the table below.



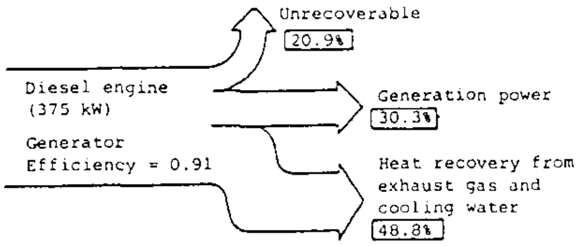
Example of Diesel Engine System

Engine Comparison

	Applicable Standard	Generation Efficiency	Fuel	Characteristics
Gas engine	20 kW to 1,000 kW	23 to 35%	Gas fuel (city gas, natural gas, digestion gas, LPG, etc.)	Easy exhaust heat recovery from exhaust gas, High price, easy maintenance, low noise, and low vibration
Diesel engine	50 kW to 10,000 kW	30 to 38%	Liquid fuel (diesel oil, kerosene oil, A fuel oil, B fuel oil, C fuel oil)	High generation efficiency, low fuel price, Abundant past record, requirement of exhaust gas treatment, large noise and vibration
Gas turbine	500 kW to 100,000 kW	18 to 28%	Gas fuel, liquid fuel	Small size, lightweight, compact, cooling water not required, low noise/vibration, low generation efficiency

Effect

Figure on the right shows an example of total efficiency of the system that uses diesel engine. Thus, about 80% of the input energy can be effectively utilized.



The following favorable effects can be expected by the adoption of co-generation system.

a. By utilizing multiple generators as service and emergency power sources, power receiving transformer can be reduced in scale, and equipment cost can be lowered.

b. Energy cost can be reduced by contract power reduction and exhaust heat recovery from the engine.

c. Effective as peak cut measure of power demand.

Application

In the following cases, application effect is great.

① A large amount of heat is used for room cooling/heating, and profiles of heat demand and power demand are very much alike. — Hotel, supermarkets, food factory, etc.

② Commercial power lead-in is difficult or the lead-in charge is high — ski resort, golf club house, resort apartments, etc.

③ Contract power must be controlled — when there is a possibility of changing from high tension power receiving to special high tension power receiving due to the enlargement of the building or the necessity of peak cuts, etc.

④ In the case of buildings with contract power of 200 kW or more.

Building	Office	Δ
	Hotel	o
	Hospital	o
	Store	o
	School	
	Multiple dwelling house	o
	Factory	o
Region	Cold region	o
	Warm region	o
Location	Center of large city	o
	Suburbs	o

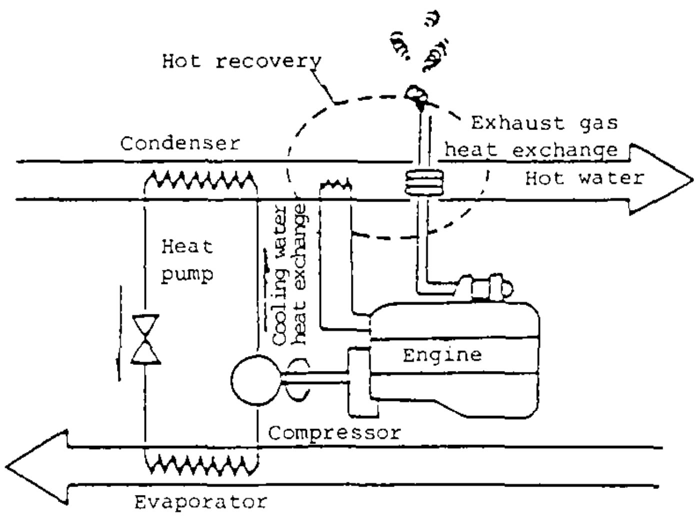
Example of Application

Toyota Tokyo Building (Tokyo)

Engine Heat Pump

General

Gas engines or diesel engines can be used as shown below so that compressors of heat pumps are driven, and so that at the same time, exhaust heat is recovered from engine cooling water and exhaust gas for the utilization for room cooling/heating and hot water supply.



Effect

Reduction of contract power.

Effective in power demand peak cut.

Example of trial calculation for the energy consumption reduction effect when a gas engine heat pump is introduced as the heat source system for an existing hotel.

a. Building outline

Location	Kyoto-shi
Stories	8 stories above ground and 3 below, penthouse 3 stories, SRC structure
Floor area	34,630 m²

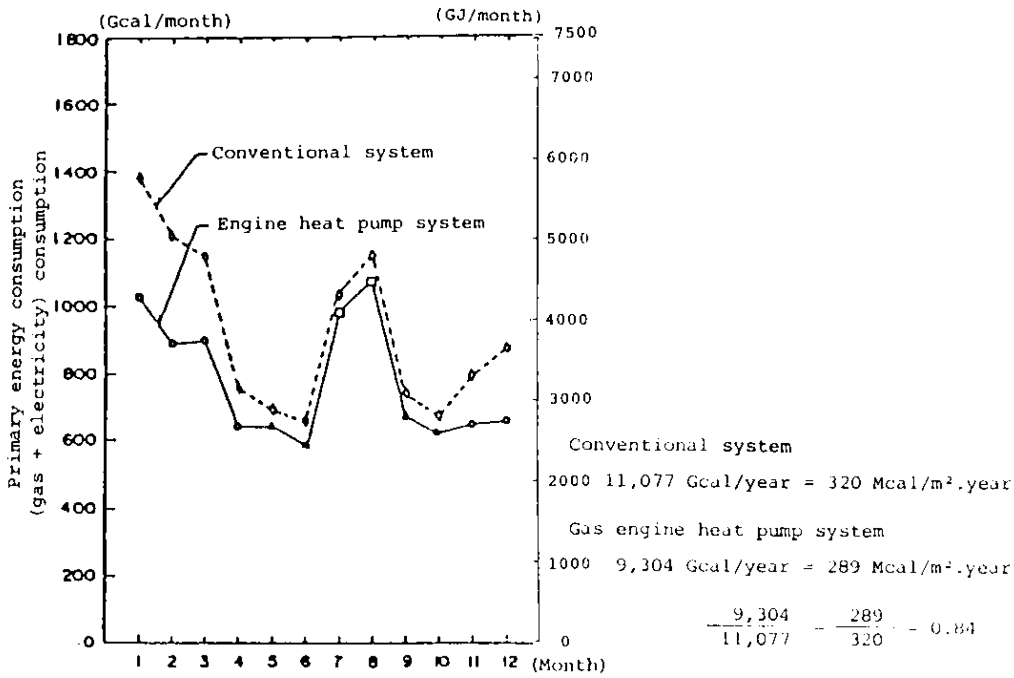
b. Present status of heat source equipment

Cold heat source	Centrifugal refrigerator
Hot heat source	Oil burning furnace smoke pipe boiler Hot water heat exchanger

c. Introduction of gas engine heat pump system

Change one centrifugal refrigerator to gas engine heat pump

Air source	Freezing capacity in operation	410USRT
Heat recovery	Freezing capacity in operation	390USRT



Primary Energy (Gas + Electricity) Consumption Comparison (Utilization System of Conventional System and Gas Engine Utilization System)

Application

a. Very effective for buildings requiring a large cooling and heating energy throughout year, such as pools (summer) and ice skate rink.

b. Effective when commercial power lead-in is difficult or the lead-in charge is high.

c. Applicability is high when the contract power must be kept down.

d. Effective in buildings in which hot water supply load is generated throughout year.

Building	Office	o
	Hotel	o
	Hospital	o
	Store	o
	School	o
	Multiple dwelling house	
	Factory	o
Region	Cold region	o
	Warm region	o
Location	Center of large city	o
	Suburbs	o

Example of Application

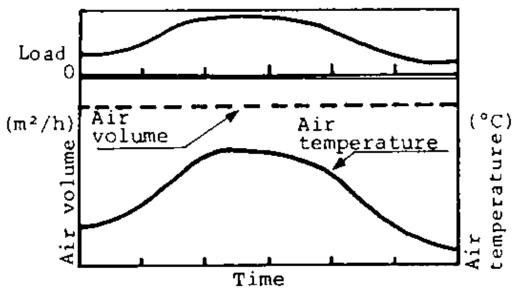
Osaka Obayashi Building (Osaka)

VAV System

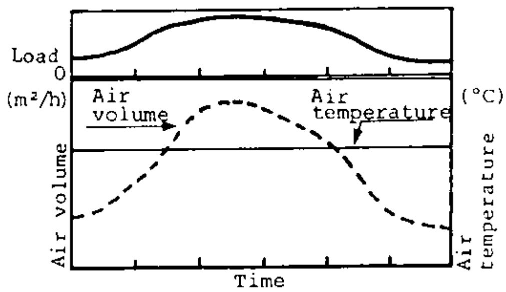
General

The conventional CAV (Constant Air Volume) system deals with the partial load by reducing the temperature difference between supply and return air while the air volume being constant. In contrast, the VAV (Variable Air Volume) system deals with the partial load by reducing the air volume while the air temperature being constant.

Since power to transport air is proportional to air volume, VAV system can make energy conservation operation more than CAV system.

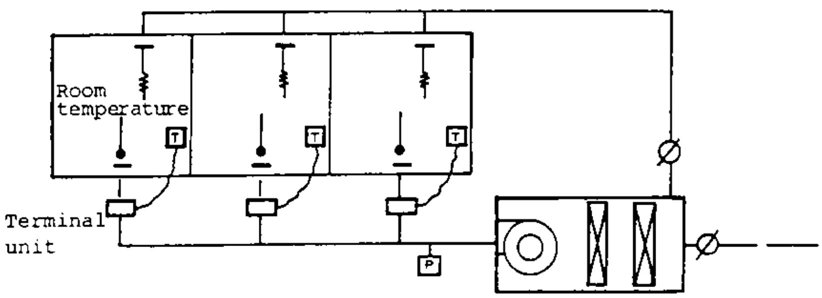


CAV System



VAV System

An example of a VAV system is shown below. The thermostat provided in each room detects thermal load of the room, and the terminal unit reduces air volume to the room according thereto.

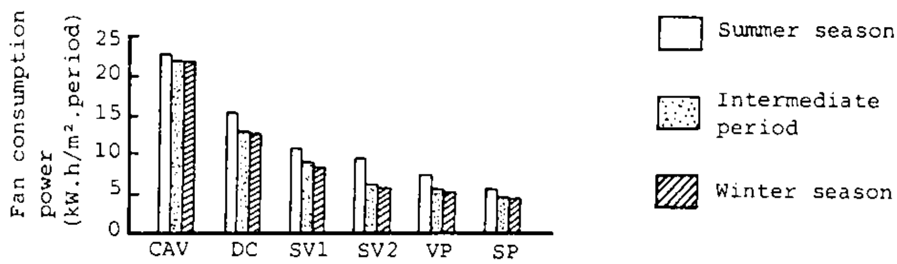


An Example of VAV System

Effect

Advantages of the VAV system are as follows:

a. Individual room control is possible since the terminal unit provided in each room adjusts the air volume according to the load. Accordingly, zoning according to the load characteristic is not required. Furthermore, by unifying the zoning for different load characteristics, simultaneous usage and simultaneous load factor increase, and reduction of equipment capacity become possible.



CAV: Constant air volume
DC: Damper control
SV1: Suction vane (1 set)
SV2: Suction vane (2 sets)
VP: Variable pitch
SP: Variable speed

Note: 6 stories = 1 air-conditioning zone, $\Delta\theta$ = 10°C
Duct resistance = 0.1 mm Aq
Power consumption per perimeter zone area 1 m^2

VAV Effect (Perimeter)

Application

a. The larger the partial load a building has, the greater the operation effect of VAV system. (Building having large personnel changes, etc.)

b. Particularly effective for application to perimeter portion where sunshine and conductive load change from time to time.

c. Note that the room environment tends to become poor since ventilation is reduced at the same time as the load decreases.

Building	Office	o
	Hotel	o
	Hospital	o
	Store	o
	School	o
	Multiple dwelling house	
	Factory	o
Region	Cold region	o
	Warm region	o
Location	Center of large city	o
	Suburbs	o

Example of Application

a. Obayashi Corporation Technical Research Institute Main Building (Tokyo)

b. Miyako Hotel (Kyoto)

c. AIU Tokyo Building (Tokyo)

d. Shiba Sanshin Building (Tokyo)

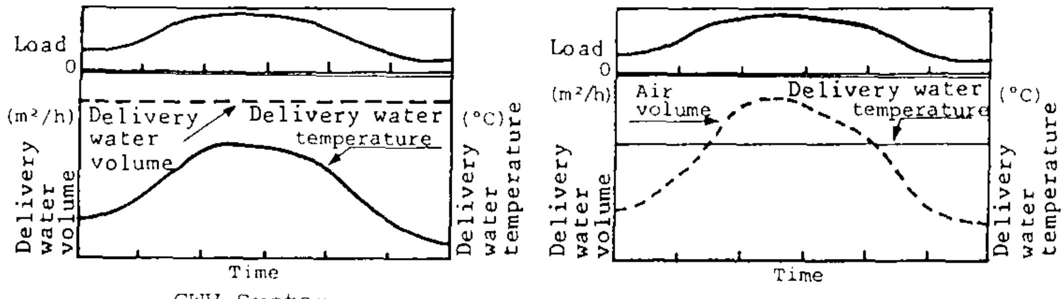
e. Osaka Obayashi Building (Osaka)

VWV System

General

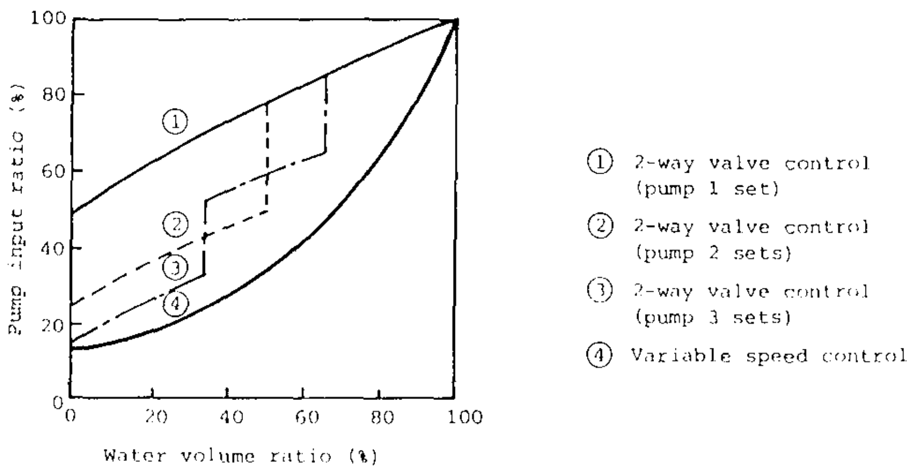
CWV (Constant Water Volume) system deals with the partial load with the transfer motor in full load operation. Accordingly, the transfer energy is spent wastefully at the time of partial load.

In contrast, VWV (Variable Water Volume) system reduces transfer power by reducing delivery water volume at the time of partial load.



The delivery pump is controlled in various ways. The graph shown below indicates relationship between water volume ratio and input ratio of each system.

Generally pump quantity control (② and ③) and number of revolution control (④) are used.



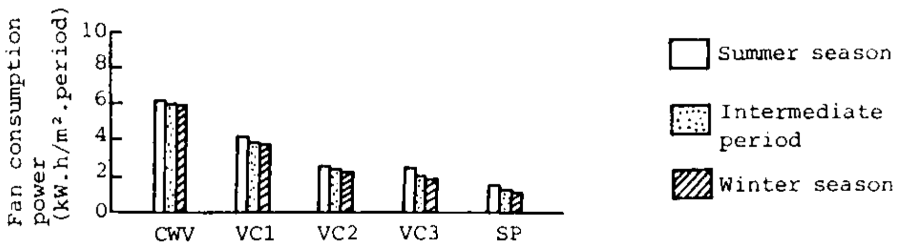
Pump Water Volume Ratio and Input Ratio

Effect

Effective in reducing transfer power.

An example of pump power (for air conditioning) conservation effect when VWV system is applied to air conditioning system of perimeter system is shown.

For example, variable speed control VWV system can reduce pump consumption power to 1/4 - 1/3 of CWV system.



CWV: Constant water volume
VC1: Valve control (1 set)
VC2: Valve control (2 sets)
VC3: Valve control (3 sets)
SP: Variable speed

Note: For 12 stories $\Delta\theta = 5°C$, 75 mm Aq/m

VWV Effect (Perimeter)

Application

Since the generation frequency of room cooling/heating load factor of office building deviates markedly to the low load side, the adoption of VWV system is desired for energy conservation.

Building	Office	o
	Hotel	o
	Hospital	o
	Store	o
	School	o
	Multiple dwelling house	
	Factory	o
Region	Cold region	o
	Warm region	o
Location	Center of large city	o
	Suburbs	o

Example of Application

Office, hotel, hospital, etc.

Cold/Hot Water Large Temperature Difference System

General

Water of temperature difference satisfying the following equation is delivered for transferring the calorific value q by means of water.

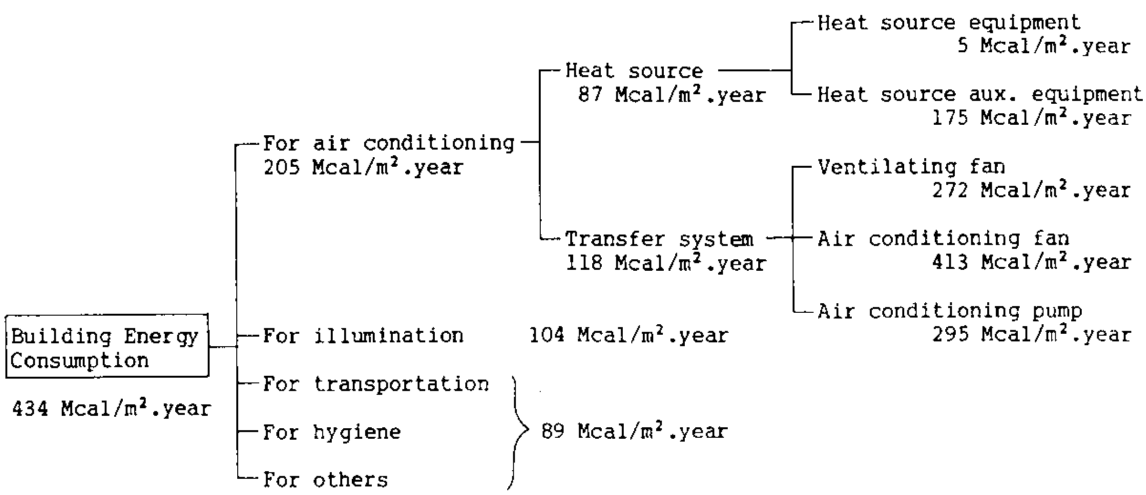
$$q = \frac{Cw}{Vw} \times Q \times \Delta t$$

- q: Transfer calorific value
- Cw: Specific heat of water
- Vw: Specific volume of water
- Q: Delivery water volume
- Δt: Utilization temperature difference

The table below shows an example of energy consumption for general office building, by use. As seen, the proportion of transfer energy is very high.

The cold/hot water large temperature difference system reduces the transfer energy by reducing the water delivery amount Q by taking the large utilization temperature difference in the above equation.

Energy Consumption of General Office Building



Note: Figures are values converted to primary energy, and area is total floor area.

Effect

Generally, required power of pump is proportional to water delivery amount. The transfer power can be reduced by reducing the delivery amount by taking Δt large.

Application

Though cold/hot water large temperature difference system is an effective energy conservation technique, it has disadvantages such as follows.

For application, temperature difference should be determined after a thorough examination of these.

① When, in the case of room cooling, temperature difference is made large, supply temperature of cold water become low, and the return temperature becomes high. Accordingly, compression work and shaft power of the freezer increase.

② As a result of increased coil line of the air-conditioner, blower power increases.

Building	Office	o
	Hotel	o
	Hospital	o
	Store	o
	School	o
	Multiple dwelling house	
	Factory	o
Region	Cold region	o
	Warm region	o
Location	Center of large city	o
	Suburbs	o

Example of Application

a. Osaka Obayashi Building (Osaka)

b. Sea Mall Shimonoseki (Yamaguchi)

c. Toyobo Building (Osaka)

d. Obayashi Corporation Technical Research Institute Main Building (Tokyo)

Cold/Hot Air Large Temperature Difference System

General

For removing room sensible heat load, a specified amount of air of a temperature difference satisfying the following equation is delivered.

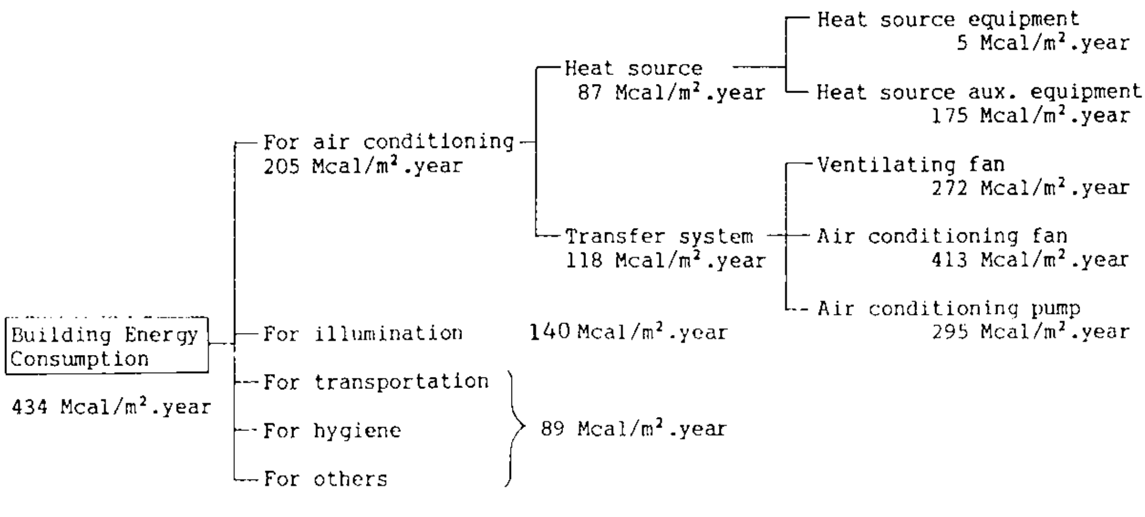
$$qs = \frac{Cp}{V} \times Q \times \Delta t$$

- qs: Room sensible heat load
- Cp: Specific heat of air
- V: Specific volume of air
- Q: Air delivery amount
- Δt: Utilization temperature difference, i.e., room temperature - delivered air temperature

An example of the consumed energy value of general office building by use is shown as follows. As is evident, the proportion of transfer energy is very high.

The cold/hot air large temperature difference system is designed to reduce transfer energy by reducing delivery air amount Q by taking large Δt in the above equation.

Energy Consumption of General Office Building



Note: Figures are values converted to primary energy, and area is total floor area.

Effect

Generally, the required power of the fan is proportional to the blower. When Δt is large and the air volume is reduced, transfer power is reduced.

In addition, by reducing the air volume, it is possible to reduce the capacity of duct and air-conditioner.

Application

Though the cold/hot air large difference system is an effective energy conservation method, it involves the following problems. For application, the air temperature difference must be determined taking them into consideration.

① Reduction of delivery air volume may affect room temperature distribution and lower dust removal effect.

② For lowering delivery air temperature in the room cooling mode, the temperature must be lowered below the equipment dewpoint, hence load increases.

③ When the supply temperature is low in the room cooling mode, condensation may occur at the air outlet.

Building	Office	o
	Hotel	o
	Hospital	o
	Store	o
	School	o
	Multiple dwelling house	
	Factory	o
Region	Cold region	o
	Warm region	o
Location	Center of large city	o
	Suburbs	o

Example of Application

a. Osaka Obayashi Building (Osaka)

b. Sea Mall Shimonoseki (Yamaguchi)

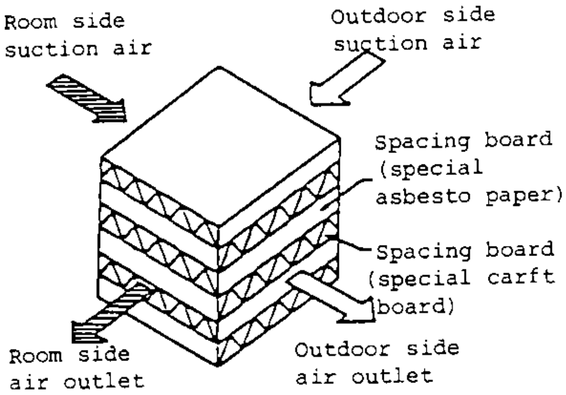
c. Toyobo Building (Osaka)

Total Heat Exchanger

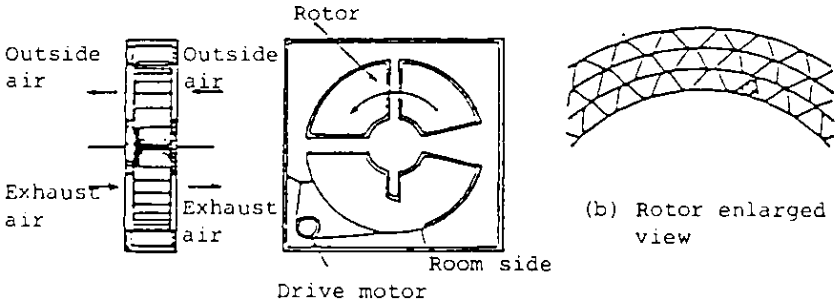
General

This is for reducing the outside air load which is said to account for around 30% of all air-conditioning load, and recovers heat of around 70% through direct (air to air) heat exchange from the air conditioning exhaust air. They are of the stationary type and the rotary type.

The rotary type total heat exchanger has the material (aluminum foil or the like) coated with moisture absorbing material formed into a honey comb-like rotor, and runs this rotor. Outside air is directed to the upper half of the rotor, and exhaust air from the room interior to the lower half. During the winter, since exhaust air temperature and humidity are high, temperature and moisture content of the rotor material increase, and it is given to the outside air. Conversely, in the summer, exhaust temperature/humidity is low, and the outside air temperature/humidity are removed.



Stationary Total Heat Exchanger



Rotary Type Total Heat Exchanger

Effect

Introduction of total heat exchange alleviates room cooling/heating load.

Application

Unapplicable when deterimental substance is contained in the exhaust air.

Building	Office	o
	Hotel	o
	Hospital	o
	Store	o
	School	o
	Multiple dwelling house	o
	Factory	o
Region	Cold region	o
	Warm region	o
Location	Center of large city	o
	Suburbs	o

Example of Application

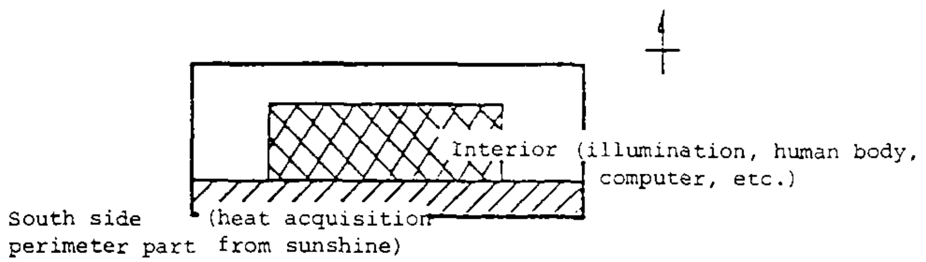
Many buildings

Ventilation Cooling

General

When the internal calorific value (illumination, human body, business equipment, etc.) increases as the building becomes large, the building interior is less and less influenced by the outside conditions, and room cooling is required throughout the year. In addition, the perimeter part requires room cooling even during winter due to the radiation of sunshine because of the bearing.

The ventilation cooling takes outside air at a temperature lower than the room temperature as much as matching the room cooling load, and performs room cooling using natural cold heat without using cold heat generated by the chiller.



Portion Requiring Room Cooling Even
in the Intermediate Period and Winter

Effect

The room cooling load is reduced.

The effect is largely affected by local characteristics, room temperature condition, building bearing, internal heat generation density, etc. Generally, in office buildings in Tokyo, the energy consumption of cooling water coil level is said to be lowered by 10 - 20%.

In addition, the energy conservation effect of outside room cooling is further enhanced when (1) room temperature/humidity condition is improved (for example, in the winter RH falls from 45% to 35%), and (2) when illumination density is high.

Application

a. The effectiveness is high in the cold region due to the extended room cooling period by outside air taking in.

b. Application in areas with excessively polluted air, such as the center of large cities, is not advisable.

c. Unapplicable warm areas exist depending on the outside air conditions.

Building	Office	o
	Hotel	o
	Hospital	o
	Store	o
	School	o
	Multiple dwelling house	o
	Factory	o
Region	Cold region	o
	Warm region	o
Location	Center of large city	o
	Suburbs	o

Example of Application

a. Obayashi Corporation Technical Research Institute Main Building (Tokyo)

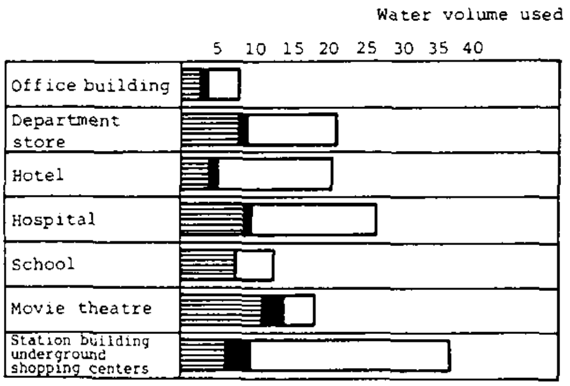
b. Many others

Drainage Utilization

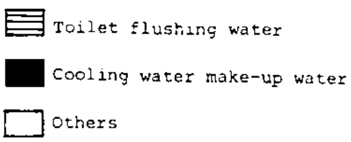
General

Drainage treatment systems are provided in the building or the site, and drainage from the building is treated and reused as miscellaneous water (toilet cleaning water, cooling tower make-up water, digestion water, etc.). They reduces the clean water usage and assist water resource conservation.

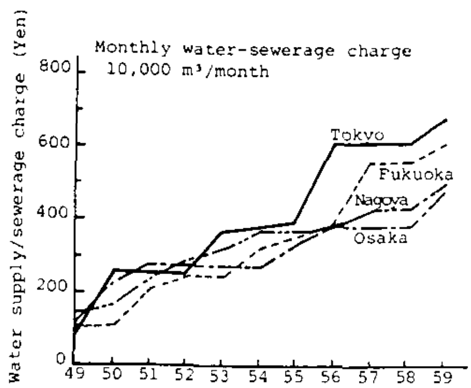
In addition, with the addition of high level treatment system, such as soil treatment, regenerated water can be used as emergency drinking water.



Toilet flushing water, watering, pool, car washing, cooling tower make-up water account for 30-80% of all usage. Regenerated water can be used for the above.



Water Usage and Use



Transition of Water-Supply/Sewerage Charge

Effect

The use of regenerated water as miscellaneous water which accounts for 30 - 80% of total usage of the building, supply-water usage can be reduced.

Example of Drainage Utilization

Building name		Nihon TV north Main Building	Shiba Sanshin Building	Dokkyo Medical Univ. Koshigaya Hospital	Miyako Hotel Tokyo
Building use		Office, restaurant, studio	Office (computer center)	Hospital	Hotel
Total floor space (m^2)		24,300	34,723		42,924
Regenerated water	Raw water	Total drainage	Cooling tower blow water, wash face drainage	General drainage	Kitchen drainage, cooling tower
	Application	Toilet flushing water, cooling tower make-up water, etc.	Toilet flushing water	Toilet flushing water, cooling tower make-up water	Toilet flushing water
	Water volume (m^3/day)	160	120	200	225
Remarks		A portion of the regenerated water is treated and used as emergency drinking water.	———	———	———

Application

The water situation for peripheral areas of large cities where water sources are hard to be found has become more and more severe due to water-supply/sewerage charge increases, and total control of drainage, etc. Drainage utilization is an effective means of coping with this.

Building	Office	o
	Hotel	o
	Hospital	o
	Store	o
	School	o
	Multiple dwelling house	o
	Factory	o
Region	Cold region	o
	Warm region	o
Location	Center of large city	o
	Suburbs	o

Example of Application

a. Nihon TV North Main Building (Tokyo)

b. Shiba Sanshin Building (Tokyo)

c. Dokkyo Medical Univ. Koshigaya Hospital (Saitama)

d. Miyako Hotel Tokyo (Tokyo)

e. Dunlop Golf Course (Hyogo)

* Regenerated to partially drinkable water.

Rainwater Utilization

General

Rainwater falling on buildings and the peripheral green ground, etc. is collected, and after being subjected to a simple treatment, such as sand settling and precipitation, the water is used as miscellaneous water (toilet flushing water, air-conditioning cooling water, etc.). In this way, the water-supply usage is reduced contributing to resources conservation.

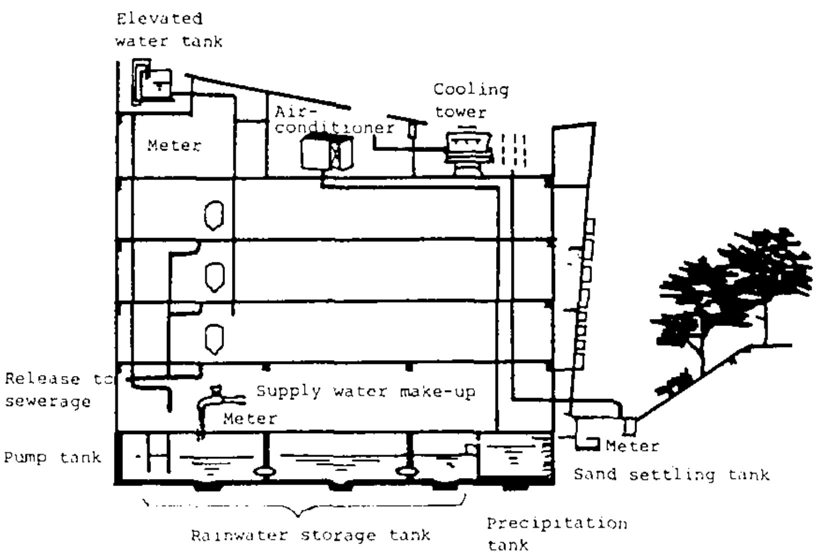
Basic System of Rainwater Utilization

Water collection → Storage tank → Treatment → Utilization

Water collection → Treatment → Storage tank → Utilization

Rainwater collection surface ... building top, pavement, green land around building, pool, playground, etc.

Treatment equipment .... optionally selected from screen, settling sand, coagulation and sedimentation, filtering, chlorine sterilization, etc.



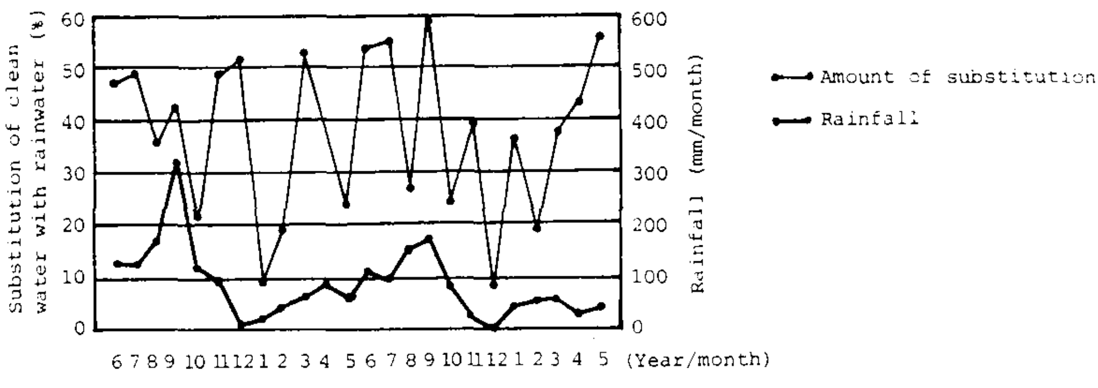
An Example of Rainwater Utilization Facility (Technical Research Institute main building rainwater utilization facility of Obayashi Corporation)

Rainfall of Main Cities

	Sapporo	Tokyo	Osaka	Hiroshima	Fukuoka	Naha
Jan	116	40	50	51	77	122
Feb	83	65	55	64	77	116
Mar	75	96	105	108	97	154
Apr	64	122	128	156	134	142
May	59	145	143	166	144	244
Jun	73	192	210	262	273	320
Jul	90	140	181	276	252	174
Aug	112	153	100	112	161	253
Sep	150	182	174	220	237	152
Oct	104	203	115	111	100	149
Nov	104	96	81	73	79	151
Dec	111	58	48	45	74	140
Year	1,141	1,503	1,390	1,644	1,705	2,118

Effect

The actual performance of rainwater utilization facilities at the technical laboratory main building of our company over the period of two years is shown below. Substitution of clean water by rainwater is 35% on average. Considerable clean water saving effect was noted.



Substitution of Clean Water by Rainwater

Application

a. Applicable regardless of the area. Particularly effective in the following areas.

   (1) Area with insufficient clean water

   (2) Area with high water rate

   (3) Area subject to rainwater drain control

b. Effective in the following building

   (1) Buildings having a wide water collection area (factory)

   (2) Buildings which can utilize underground double slabs as rainwater storage tank

   (3) Buildings requiring a large amount of miscellaneous water (hotel, etc.)

   (4) Buildings using a large amount of miscellaneous water intermittently (meeting halls, etc.)

c. In the case of multistoried buildings, the application effect is small since the amount of water collection is small compared with amount of water usage of entire building.

Building	Office	o
	Hotel	o
	Hospital	o
	Store	o
	School	o
	Multiple dwelling house	o
	Factory	o
Region	Cold region	o
	Warm region	o
Location	Center of large city	o
	Suburbs	o

Example of Application

a. Nihon TV Broadcasting network Co. North Main Building (Tokyo)

b. Taiyo Seimei Higashi-Ikebukuro Building (Tokyo)

c. Obayashi Corporation Technical Research Institute
   Main Building (Tokyo)

Solar Heat Utilization

General

Solar energy is inexhaustible, is non-polluting, and free of charge. On the other hand, it is low density (around 1 kW per m²) and cannot be used during the nighttime or on rainy days.

This method is to provide room cooling/heating and hot water supply energy effectively and economically by utilizing its advantages and by modifying its disadvantages.

Classification of Solar Systems

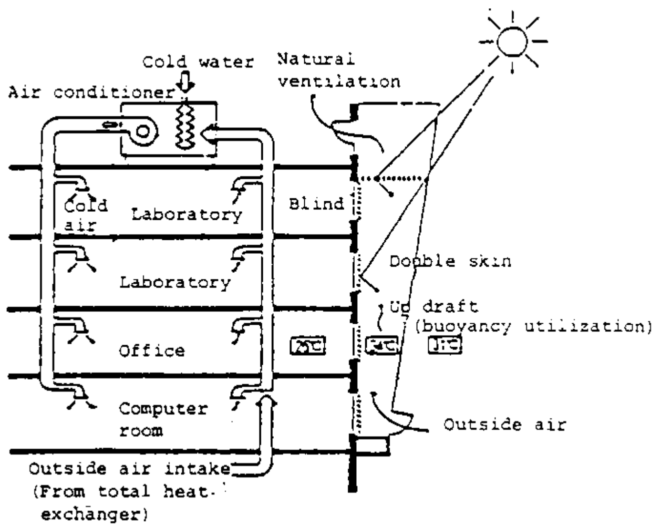
Level		30	40	50	60	70	80	90	100°C
Applicable system		Warm water pool	Room heating Panel heating	Hot water	Room heating	Room cooling (pre-cooling)		Room cooling	
Collector efficiency	Summer	70	60		50	30		20%	
	Inter-mediate	60	50		40	20%		—	
	Winter	50	40		30%	—		—	

① An example of passive utilization (double skin)

A glass walled hothouse space is provided on the perimeter of the building and room cooling/heating load is reduced.

Summer .... Blocking sunshine

Winter .... Preheating by outside air



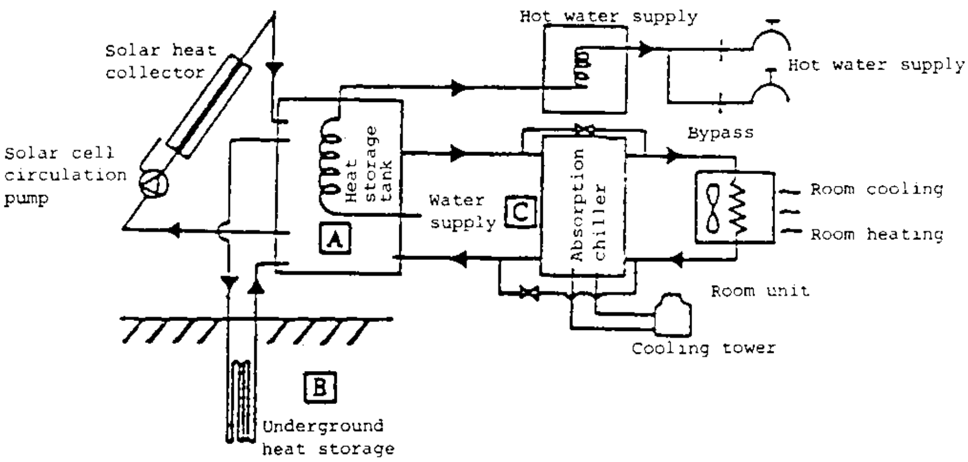
In the Case of Summer (During Room Cooling)

② Active utilization

A. Heat storage tank to absorb daily variation of solar energy

B. Heat storage tank to absorb seasonal variation of solar energy

C. Absorption chiller operable at heat source temperature below 90°C.



Example of Solar Energy Utilization

Effect

By the effective utilization of free solar energy as room cooling/heating energy and hot water supply energy, the annual energy consumption of building can be reduced.

Application

a. Effective in buildings with large hot water volume required.

b. Effective when running cost of room cooling/heating and hot water supply must be kept low.

Building	Office	o
	Hotel	o
	Hospital	o
	Store	o
	School	o
	Multiple dwelling house	o
	Factory	o
Region	Cold region	o
	Warm region	o
Location	Center of large city	o
	Suburbs	o

Example of Application

a. Obayashi Corporation Technical Research Institute Main Building (Tokyo)

b. Kintetsu Technical Laboratory (Nara)

c. Hirakata Solar House (Osaka)

d. Nissan Auto Sagamihara Part Center (Kanagawa)

Computer Control System

General

By the introduction of computers into the total building system, economical maintenance for building management and comfortable resident's service are assured. Main functions are as follows.

a. Monitoring

The equipment operation status and room environmental condition are displayed on the CRT screen, and the occurrence of any trouble is promptly transmitted to the supervisor.

b. Control

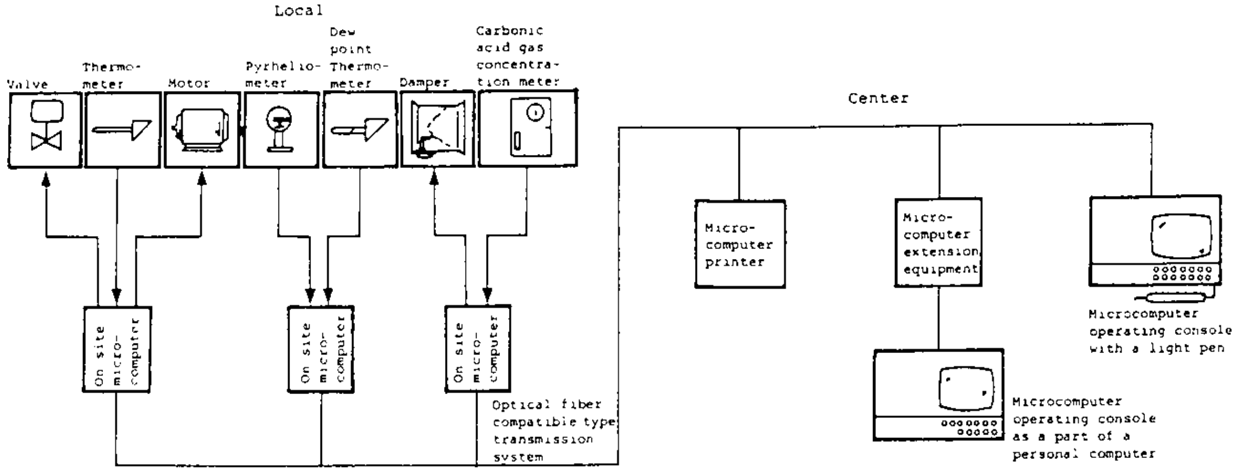
Through prevention of overcooling/overheating of room cooling/heating, and optimization control such as high efficiency operation of equipment, comfortable room environment is assured in all times.

c. Recording

Automatic recording of various measured values periodically.

d. Management

Through the comparison of current data with past data recorded, system performance evaluation and deterioration analysis of the system are performed.



Computer Control System

Effect

a. Energy conservation effect

By performing equipment system optimization control such as outside air take-in control and equipment quantity control, cost saving and energy conservation are possible.

b. Promotion of safety

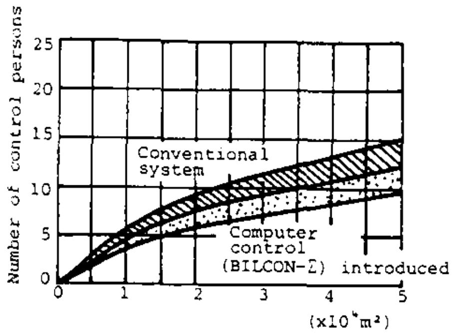
In case of emergencies such as power failures and fire, speedy counteraction can be taken by actuating disaster prevention system, electrics, air-conditioning, and hygiene system.

c. Labor saving

Through computerized centralized processing of judgment, operation, recording, etc. without manual intervention, labor saving in control is possible. (Refer to the following graph.)

d. Reliability enhancement

Reliability is promoted by narrowing the equipment/system down range through the adoption of decentralized control system.



Effect of Computer Control Introduction

Application

a. No particular restrictive conditions.

b. Even in the case of hard-to-standardize buildings, optimum system configuration is possible by selecting the required functions.

Building	Office	o
	Hotel	o
	Hospital	o
	Store	o
	School	o
	Multiple dwelling house	
	Factory	o
Region	Cold region	o
	Warm region	o
Location	Center of large city	o
	Suburbs	o

Example of Application

a. Miyako Hotel (Tokyo)

b. Dokkyo Univ. Koshigaya Hospital (Saitama)

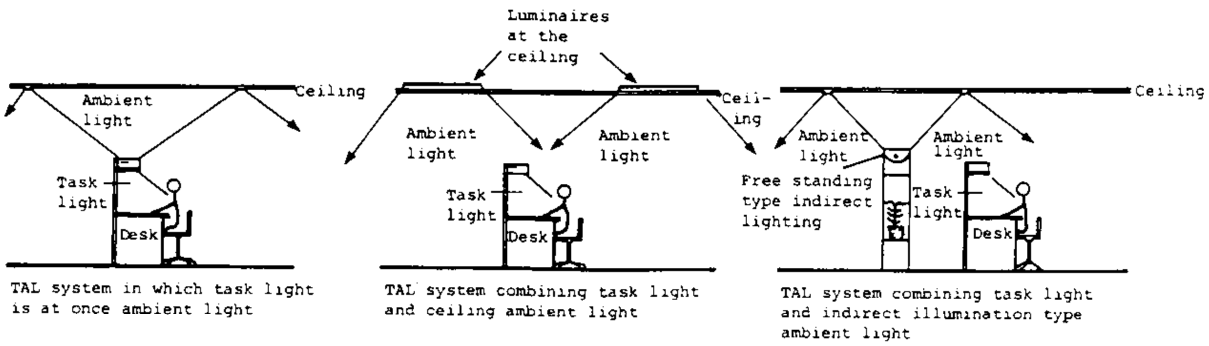
c. Obayashi Corporation Technical Research Institute Main Building (Tokyo)

* BILCON-Σ ... Integrated Building Computer Control System developed by Obayashi Corporation.

Task/Ambient Illumination

General

In contrast with conventional illumination in which task + ambient illumination is accomplished by lighting provided on the ceiling, the task/ambient illumination divides the illumination into that for the task and that for the environment, and the task illumination assures the required brightness by task light alone, while the ambient illumination performs low brightness illumination with ambient light.

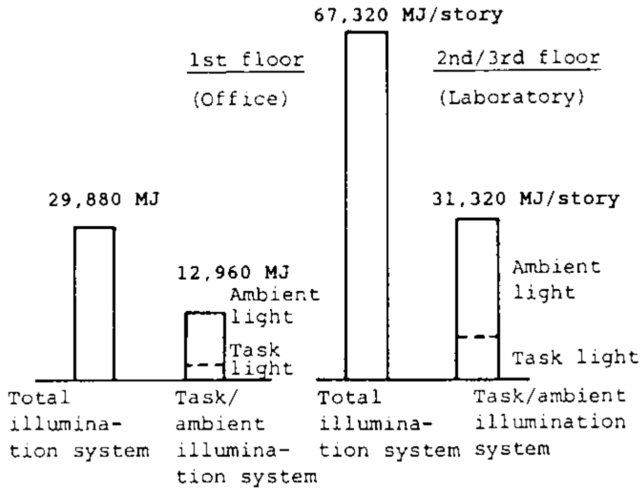


Classification of Task/Ambient Illumination System

Effect

Through the efficient use of light, illumination equipment load can be reduced within the total lighting system. Since task lights for persons absent can be switched off, the annual illumination energy can be reduced to a large extent.

According to the actual record of Technical Research Institute main building of Obayashi Corporation, the annual illumination energy consumption could be reduced to about 45% of total illumination system.



Comparison of Annual Illumination Energy
(Actual record of Technical Research Institute of Obayashi Corporation)

Application

When the personnel density is high, the energy conservation effect may be small, and the location of task lights must be examined according to layout.

Building	Office	o
	Hotel	
	Hospital	Δ
	Store	
	School	
	Multiple dwelling house	
	Factory	Δ
Region	Cold region	o
	Warm region	o
Location	Center of large city	o
	Suburbs	o

Example of Application

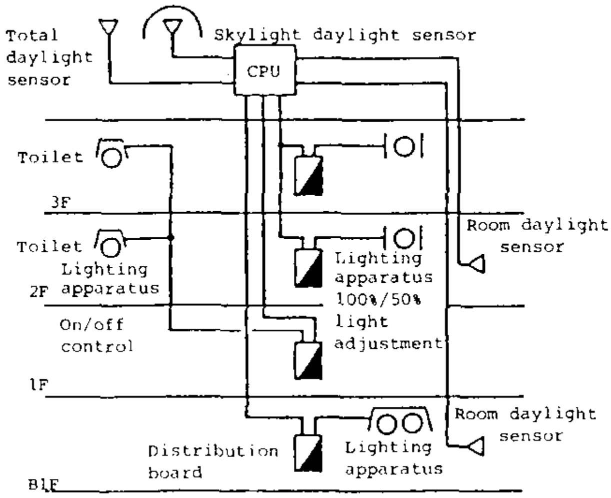
Obayashi Corporation Technical Research Institute
Main Building (Tokyo)

Illumination Control by Daylight Utilization

General

This method can be used for portions where daylight can be used as illumination, such as near windows of the building.

The intensity of daylight entering from the outside is detected by the sensor, and lighting apparatus by the window is switched on/off automatically.



Example of Illumination Control System by Daylight Utilization
(Obayashi Corporation Technical Research Institute Main Building)

Effect

Effective utilization of daylight for near window illumination, not only the illumination energy but also air-conditioning energy can be reduced.

Obayashi Corporation Technical Research Institute main building employs daylight utilization illumination control system as shown below. As a result, illumination power consumption could be reduced by 557 kWh/a.

Outline of Obayashi Corporation Technical Research Institute
Main Building Daylight Utilization Illumination Control System

Place	Object	Control Method	Remarks
Underground office	South side near window 1 row 37 W 2-lamp type x 14	100%/50% light adjustment through room daylight sensor	The weather is monitored by 2 outdoor sensors, and the control levels changed accordingly. Control is from microcomputer for central control.
2/3 story laboratory	South side near window 1 row 37 W 1-lamp type x 24		
Toilet	Toilet illumination 36 W 1-lamp type x 6	ON/OFF control by outdoor daylight sensor	

Application

In the case of building such as hotel, hospital, and store where illumination has a large psycological effect on persons residing, the effects must be thoroughly examined in advance.

Building	Office	o
	Hotel	Δ
	Hospital	Δ
	Store	Δ
	School	o
	Multiple dwelling house	Δ
	Factory	o
Region	Cold region	o
	Warm region	o
Location	Center of large city	o
	Suburbs	o

Example of Application

a. Obayashi Corporation Technical Research Institute
   Main Building (Tokyo)

b. Futaba Sangyo Takahashi Factory (Aichi)

c. Many others

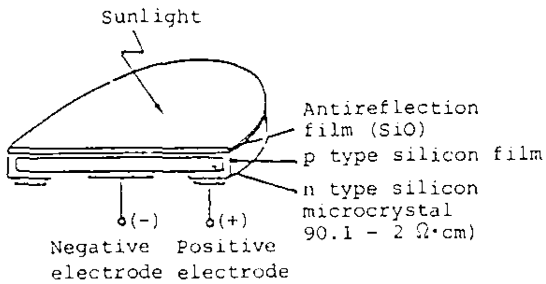
Utilization of Solar Cell

General

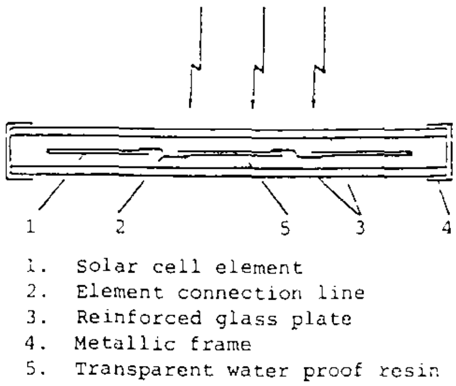
Solar cells are energy converters which convert light energy directly to electric energy utilizing the light emf effect of semiconductors. Since the light emf effect is a physical phenomenon, chemical change and wear do not exist. Accordingly, solar cells can generate power semipermanently as long as light exists.

Photoelectric conversion efficiency is 10 - 14% with silicon monocrystal solar cell. In the case of amorphous solar cells, it is around 7 - 10%.

Since power generated is DC, when using for AC equipment, the inverter (DC-AC converter) is required.



An Example of Construction of Ground Solar Cell Element



An Example of Construction of Solar Cell Module

Effect

Power generation by solar cells has the following advantages.

① Easy maintenance. Semipermanent power generation possible.

② Since sunlight is used, energy cost is not required.

③ Free of noise, waste, toxic gas generation.

Application

a. At present, due to low conversion efficiency, when generating large power, a tremendous area of installation is required.

b. When the generation time zone varies from the service time zone, power storage equipment is required.

c. Cost is high (¥1,500/Wp as of 1985). Considerably long depreciation years.

Building	Office	o
	Hotel	o
	Hospital	o
	Store	o
	School	o
	Multiple dwelling house	o
	Factory	o
Region	Cold region	Δ
	Warm region	o
Location	Center of large city	o
	Suburbs	o

Example of Application

Obayashi Corporation Technical Research Institute
Main Building (Tokyo)

Appendix 1

The Explanation for the Standards of Energy Conservation in Buildings

An Overview of Building Owners' Judgment Standards for the Rationalization of Energy Use in Buildings

These energy conservation standards cover five types of buildings: offices, merchandising stores, hotels, hospitals/clinics and schools. Separate guidelines have been established for residential buildings. While judgment criteria for residential buildings are "heat loss coefficient," "airtightness performance" and "insolation coefficient," those for the above five types of buildings are "perimeter annual load " and "coefficients of energy consumption concerning building equipment and systems." Building equipment and systems are classified into five categories: air-conditioning equipment, mechanical ventilation equipment, lighting equipment, hot water supply equipment and elevator equipment.

A conceptual diagram of energy conservation standards for nonresidential buildings is shown in Figure 1, covering perimeter annual load — which represents the thermal performance of the perimeter zone of a building — and the coefficient of energy consumption for air conditioning — one of the coefficients of energy consumption concerning building equipment and systems that measures the energy efficiency of air-conditioning equipment as a total system — as examples. Obviously, the coefficient of energy consumption for air conditioning only applies to buildings furnished with air-conditioning equipment, whereas perimeter annual load applies to all buildings, regardless of the presence of air-conditioning equipment. All coefficients of energy consumption are obtained by dividing actual annual energy consumption by annual imaginary standard energy consumption.

The energy conservation standards have been established as a performance code, rather than a specification code, for the following reasons:

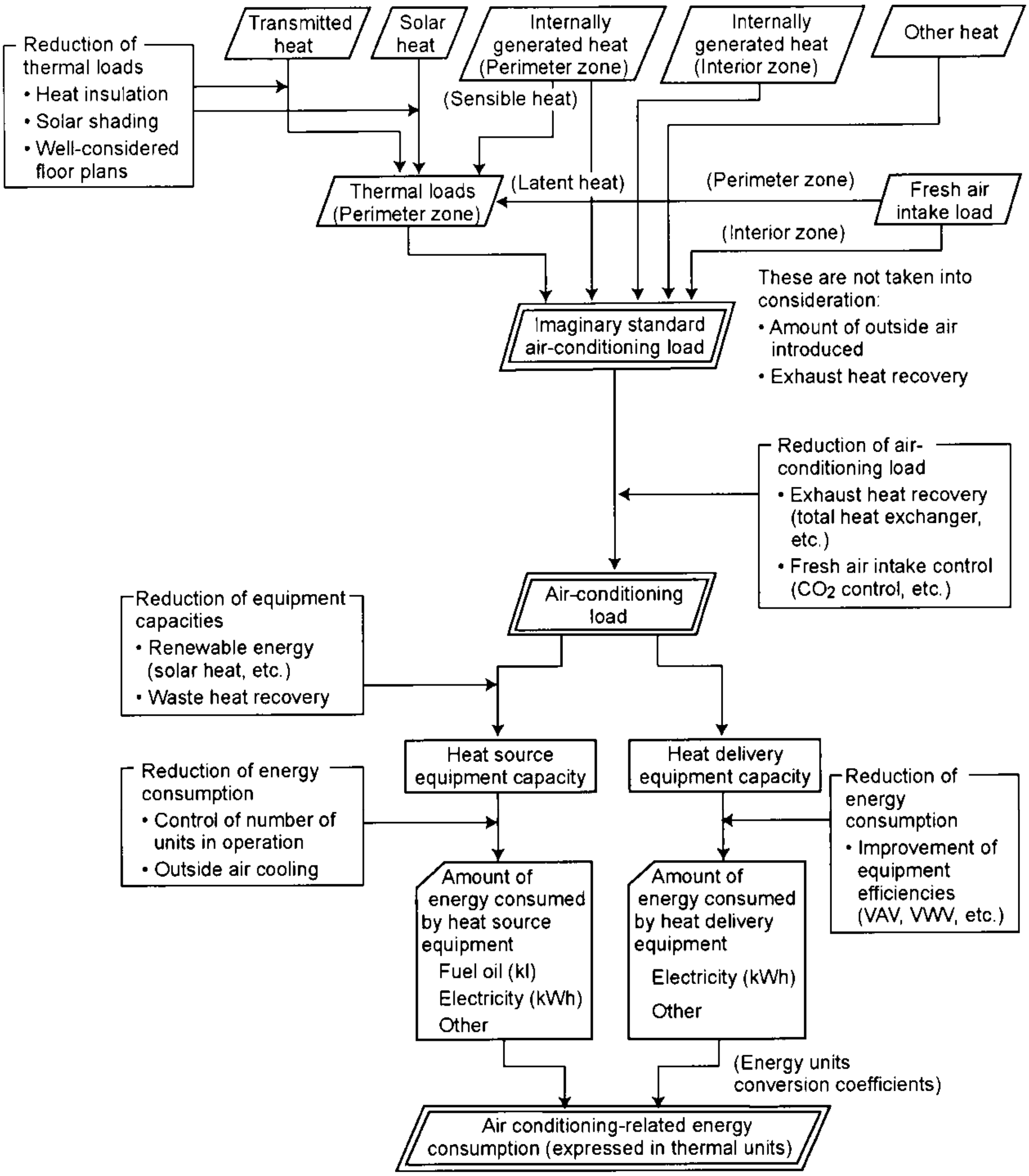
(1) A performance code can better deal with a diverse range of buildings.

(2) The effectiveness of energy conservation techniques, to a significant degree, depends on the effectiveness of their combination, and is not equal to a simple sum of the effects of individual techniques.

(3) A performance code does not unduly restrict design freedom.

(4) A performance code can better accommodate new energy conservation techniques.

In this regard, design and construction guidelines have been released for residential buildings.



Perimeter annual load (PAL)

$$= \sum_{\text{year}} \text{Thermal load in perimeter zone / Floor area in perimeter zone}$$

Coefficient of energy consumption for air conditioning (CEC/AC)

$$= \sum_{\text{year}} \text{Air conditioning-related energy consumption} \Big/ \sum_{\text{year}} \text{Imaginary standard air-conditioning load}$$

Figure 1 Conceptual Diagram of Energy Conservation Standards

1. Reduction of Heat Loss through Exterior Walls, Windows, etc. — Perimeter Annual Load (PAL)

(1) Concepts — definition

Energy conservation standards use perimeter annual load (PAL) as the judgment criterion for the reduction of heat loss through exterior walls, windows, etc., and this will now be explained in accordance with the Notification.

By way of an equation, PAL can be expressed as follows:

$$\text{PAL} = \frac{\text{Annual thermal load in perimeter zone (Mcal/year)}}{\text{Floor area in perimeter zone } (m^2)}$$

It is necessary that the PAL of a building be equal to or less than the relevant numerical standard shown in Annexed Table 1 of the Notification multiplied by a size correction factor as follows:

$$\text{PAL} \leqq \text{Judgement criterion} \times f$$

where f is a size correction factor.

To ensure this, all necessary measures, including the heat insulation of exterior walls, windows, etc., solar shading and well-considered floor plans, must to be taken.

(2) Perimeter zone

The perimeter zone refers to the indoor space of a building that is exposed to outside climatic conditions through exterior walls, windows, etc. The Notification defines the perimeter zone as shown in Figure 2, and evaluates the heat insulation (thermal) performance of exterior walls, windows, etc. through the annual thermal load that occurs in that part of the building. It should be noted that the perimeter zone as defined above does not necessarily coincide with the actual perimeter zone.

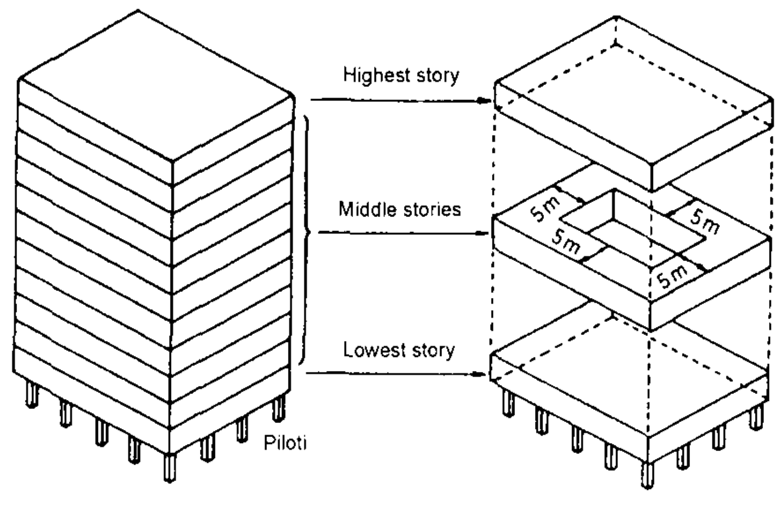


Figure 2 Perimeter Zone of Building

(3) Size correction factor

The size correction factor adjusts numerical standards to alleviate the demand on small-scale buildings, etc. The rationale behind the introduction of this factor is that the smaller the building or number of stories, the larger the ratio of perimeter surface area to perimeter zone floor area becomes, thus pushing up PAL. As shown in Figure 3, a size correction factor is determined according to the number of stories above ground and average per-story floor area.

In this regard, the average per-story floor area is defined as follows (see Figure 4):

$$\text{Average per-story floor area} = \frac{\text{Combined floor area of all stories above ground}}{\text{Number of stories above ground}}$$

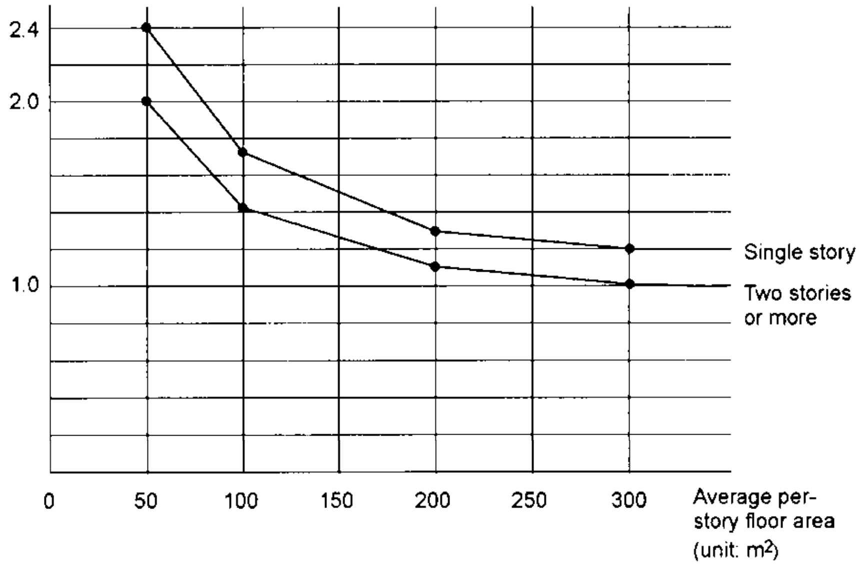


Figure 3 Size Correction Factor

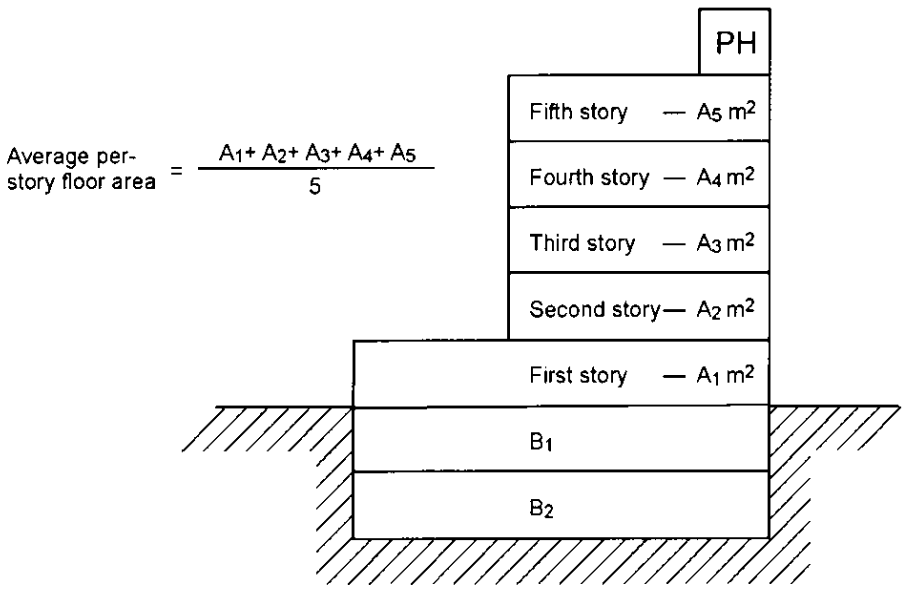


Figure 4 Average Per Story Floor Area

Apart from building size, correction factors could also be introduced to adjust for regions and coefficients of energy consumption (CECs) concerning building equipment and systems. However, regional differences have already been taken into account by adding together cooling and heating loads in arriving at annual thermal load, while CECs are better addressed independently since, among other things, the efficiencies of building equipment and systems do not have a direct impact on the thermal performance of the building perimeter zone.

(4) Annual thermal load

Annual thermal load is the sum of the heating and cooling loads accumulated over a period specified for each building use as the standard annual duration of the utilization of such a building (air conditioning). Namely, it represents the total thermal load generated in the perimeter zone over the period specified above regardless of the actual operation schedule of the air conditioning equipment and other factors.

In this regard, the following four types of heat are considered: transmitted heat, solar heat, internally generated heat in the perimeter zone, and heat gained or lost according to the temperature difference between fresh air introduced from outside and air present in the perimeter zone. Although the old energy conservation standards for office buildings ignored the thermal load attributed to fresh air intake, the new energy conservation standards take it into account to make equipment loading conditions as realistic as possible for all building uses.

Although transmitted heat is calculated by setting room temperatures to 20 or 22°C for heating and 26°C for cooling, these are merely calculation assumptions, and should not be taken as actual building usage conditions.

2. Efficient Use of Energy concerning Building Equipment and Systems

(1) Efficient use of energy concerning air-conditioning equipment

– Coefficient of energy consumption for air conditioning (CEC/AC)

The energy conservation standards use CEC/AC as the judgment criterion for the efficiency of energy use involving air-conditioning equipment. CEC/AC represents a value obtained by dividing the amount of energy consumed by air-conditioning equipment (hereinafter referred to as "air conditioning-related energy consumption") in a year by the annual accumulation of imaginary standard air-conditioning loads. By way of an equation, CEC/AC can be expressed as follows:

$$\text{CEC/AC} = \frac{\text{Annual air conditioning - related energy consumption (Mcal/year)}}{\text{Annual imaginary standard air - conditioning load (Mcal/year)}}$$

As can be seen from this equation, the smaller the value of CEC/AC, the more efficient the energy use involving air-conditioning equipment is.

Annual imaginary standard air-conditioning load and annual air conditioning-related energy consumption - the denominator and numerator of CEC/AC — are, as a matter of fact, calculated using the same set of conditions consisting of room temperature/humidity, the operation duration of air conditioning equipment, and the like. Unlike what is the case with PAL, however, room temperature/humidity, the operation duration of air conditioning equipment, etc. are not assigned specific values. This is because the effect of changes in room temperature/humidity and the operation duration of air conditioning equipment on CEC/AC is considered small, as the denominator and numerator of CEC/AC change more or less in the same manner with such changes. In principle, CEC/AC should be calculated on the basis of the temperature/humidity, duration of air conditioner operation and other conditions actually used in the design of the building concerned. However, it is permitted to use standard conditions in view of their convenience in relation to the comparison of energy conservation performances of different systems and restrictions arising from the application of simplified calculation methods.

Maintaining the required accuracy for the calculation of CEC/AC is not easy if it is simplified to a hand calculation level. Therefore, the use of a personal computer in conjunction with a program written for the calculation of CEC/AC is permitted. This method will lead to a dramatic improvement in accuracy, as well as allowing a greater degree of freedom in the design of an air-conditioning system. (For an overview of standard conditions and a CEC/AC calculation program, see the "Textbook on the New Energy Conservation Standards for Buildings," compiled by the Institute for Building Environment and Energy Conservation).

Since imaginary standard air-conditioning load, the denominator of CEC/AC, directly influences the value of CEC/AC, it must be understood correctly. To maintain clarity in our explanation, the types of heat listed in items A, B, C, D and E of the Notification are hereinafter referred to as "transmitted heat," "solar heat," "internally generated heat," "fresh air intake load" and "other heat".

Imaginary standard air-conditioning load is the sum of fresh air intake load and loads attributed to transmitted heat, solar heat, internally generated heat and other heat, and takes into consideration heat gained or lost through the mixing in of intake air — namely interactions between fresh air intake load, on the one hand, and transmitted heat, solar heat, internally generated heat, etc. on the other — including a reduction in fresh air intake load in winter due to internally generated heat.

Fresh air intake load is handled in two distinctive ways as described below, and this is why imaginary standard air-conditioning load is an "imaginary" load.

Firstly, a reduction in fresh air intake load through the recovery of exhaust heat is not considered. Despite the fact that fresh air intake load can be reduced through, for example, the transfer of heat carried by air expelled outside the building to fresh intake air based on a total heat exchanger or any similar technique, this is totally ignored. Instead, fresh air intake load is calculated simply as the difference between the enthalpy of indoor air, which is determined by indoor temperature and humidity conditions, and that of outside air before being introduced into the building.

Secondly, fresh air intake is assumed to be constant. Despite the fact that fresh air intake can be reduced through, for example, an adjustment of the amount of outside air introduced according to the quality of indoor air based on CO_2 control or any similar technique, this is totally ignored. Instead, fresh air intake load is calculated on the assumption that fresh air intake always remains the same.

This ensures that energy conservation techniques, such as fresh air intake control and a total heat exchanger, will reduce CEC, while excessive fresh air intake will increase it. In this manner, CEC functions as a judgment criterion for energy conservation.

As air-conditioning equipment consumes different forms of energy, such as electricity and fuel oil, their measurement units need to be converted to the same thermal unit as the one used for the denominator before CEC can be calculated. Annexed Table 3 of the Notification lists the conversion rates for fuel oil, kerosene, liquefied petroleum gas and electricity. With city gas, which is another form of energy widely used for air conditioning, the heating value varies depending on its composition and other factors, so that it must be calculated from correct data.

Basically, these conversion rates convert various forms of energy into primary energy, and power generating efficiency is taken into consideration with electricity. For oil, gas, etc., the higher heating value (gross heating value) is used

(2) Efficient use of energy concerning mechanical ventilation equipment other than air-conditioning equipment

— Coefficient of energy consumption for ventilation (CEC/V)

The energy conservation standards use CEC/V as the judgment criterion for the efficiency of energy use involving mechanical ventilation equipment other than air-conditioning equipment. By way of an equation, CEC/V can be expressed as follows:

$$\text{CEC/V} = \frac{\text{Annual ventilation - related energy consumption (kcal/year)}}{\text{Annual imaginary standard ventilation - related energy consumption (kcal/year)}}$$

The numerator represents the amount of energy consumed by the ventilation equipment of a building in a year, while the denominator represents the amount of energy that would be consumed imaginary standard ventilation equipment in a year. The following equation is used for the conversion of energy units:

Imaginary standard ventilation-related energy consumption (kWh)
= Design amount of ventilation (m^3/h) × Annual hours of operation (h) × 3.676 × 10^{-4}

For the amount of ventilation, the air flow rate set by the designer is used. This aims to prevent an attempt to reduce the amount of ventilation at the expense of the quality of the indoor environment, as well as ensuring design freedom. The constant 3.676 × 10^{-4} represents the blower motor rated output per unit ventilation air flow, and has been derived as follows:

$$\frac{\text{Total pressure (mmAq)}}{102 \times \text{Blower efficiency} \times \text{Transmission device efficiency} \times 3600} \times \text{ Allowance factor}$$

$$= \frac{45}{102 \times 0.4 \times 3600} \times 1.2 \;= 3.676 \times 3.676 \times 10^{-4}\,(\text{kW}/(\text{m}^3/\text{h}))$$

Strictly speaking, electricity consumption (amount of energy consumed on the input side of the blower motor) should be used when evaluating the energy consumption efficiency of ventilation equipment. However, the energy conservation standards use the blower motor rated output (roughly the amount of energy consumed on the output side of the blower motor), in view of the amount of work needed to convert it to the input side. Ventilation equipment expels indoor air and lets outside air in to replace expelled indoor air, and the term refers to any equipment designed to carry out ventilation class 1 to 3 for a parking room, machine room, electrical room, toilet, etc. In cases where such a room is provided with cooling via an air conditioner or the like, it is treated as ventilation equipment after applying a conversion formula.

Annual hours of operation are standard annual hours of operation as specified for each building use, except for cases where annual hours of operation are clearly known for each ventilation system. In general, annual hours of operation do not affect the value of CEC/V, as the same value is used for both the numerator and denominator. However, CEC/V does reflect the energy conservation effects of operation control based on room temperature, CO_2 concentration, or the like.

(3) Efficient use of energy concerning lighting equipment

— Coefficient of energy consumption for lighting (CEC/L)

The energy conservation standards use CEC/L as the judgment criterion for the efficiency of energy use involving lighting equipment. By way of an equation, CEC/L can be expressed as follows:

$$\text{CEC/L} = \frac{\text{Annual lighting - related energy consumption (kcal/year)}}{\text{Annual imaginary standard lighting - related energy consumption (kcal/year)}}$$

Annual lighting-related energy consumption (kcal/year) / Annual imaginary standard lighting-related energy consumption (kcal/year)

The numerator is the amount of energy expected to be consumed by the lighting equipment and control equipment designed for a building in a year, while the denominator is the amount of energy that would be consumed by imaginary standard lighting equipment in a year. Energy conservation techniques to be evaluated under this judgment criterion are classified into two groups: those relating to lighting equipment and those relating to control equipment. The former include the adoption of high-efficiency light sources, energy-saving ballasts and high-efficiency lighting fixtures, as well as the devising of effective lighting methods, while the latter include time schedule control, human presence detection control, daylight utilization control, power supply control based on room keys and initial illuminance control. What is special about CEC/L is the incorporation of lighting quality correction using the following two correction factors: 1) the non-illuminance quality correction factor, which gives a somewhat greater energy consumption allowance to lighting equipment with effective glare control, indirect illumination and balanced brightness in wall lighting; and 2) the design illuminance correction factor, which aims to prevent attempts to clear the numerical standard by simply lowering the design illuminance.

(4) Efficient use of energy concerning hot water supply equipment

— Coefficient of energy consumption for hot water supply (CEC/HW)

The energy conservation standards use CEC/HW as the judgment criterion for the efficiency of energy use involving hot water supply equipment. By way of an equation, CEC/HW can be expressed as follows:

$$\text{CEC/HW} = \frac{\text{Annual hot water supply - related energy consumption (kcal/year)}}{\text{Annual imaginary standard hot water supply - related energy consumption (kcal/year)}}$$

The numerator is the amount of energy needed for the hot water supply equipment of a building to supply various quantities of hot water at various temperatures for the range of purposes arising in the building concerned, while the denominator is the amount of energy needed to produce the same quantities of water at the same temperatures at the respective sites of use without energy loss. Namely, CEC/HW is the ratio of the amount of energy that can be effectively utilized by the users of hot water to the amount of energy used to produce it. Notably, CEC/HW only covers central hot water supply systems because the energy efficiency of local hot water supply systems mostly depends on the efficiency of their heat sources, thus making it more appropriate to set separate standards for them. In formulating this judgment criterion, no restrictions on water quantities were introduced due to a general lack of data on hot water supply, and numerical standards were not specified for offices, merchandising stores and schools.

Energy conservation techniques to be evaluated under this judgment criterion include the adoption of a high-efficiency heat source and high-efficiency circulation pump, effectiveness of heat insulation for the piping and water tank, optimization of piping sizes and capacities of the heat source, water tank, circulation pump and like, and effectiveness of feedwater preheating.

(5) Efficient use of energy concerning elevator equipment

— Coefficient of energy consumption for elevator service (CEC/EV)

The energy conservation standards use CEC/EV as the judgment criterion for the efficiency of energy use involving elevator equipment. By way of an equation, CEC/EV can be expressed as follows:

$$\text{CEC/EV} = \frac{\text{Annual elevator - related energy consumption (kcal/year)}}{\text{Annual imaginary standard elevator - related energy consumption (kcal/year)}}$$

The numerator is the amount of energy expected to be consumed by the elevator equipment of a building in a year under its design specifications (loading capacity (maximum number of passengers), speed, number of units and annual hours of operation) and design speed control method, while the denominator is the amount of energy that would be consumed by elevator equipment with the same specifications in a year under the most basic speed control method.

The denominator is subject to correction that would make it smaller than it actually is in the case of an excessive level of elevator service. The correction is based on the ratio of the design five-minute transportation capacity to the standard morning-rush-hour five-minute transportation capacity.

It should be noted that CEC/EV only covers rope-hoisted traction passenger elevators used to serve main traffic lines.

In an actual calculation, the numerator is obtained by first calculating energy consumption for each elevator bank consisting of elevators with the same loading capacity, rated speed, speed control method and operation control method and then adding the results together. Similarly, the denominator is obtained by first calculating energy consumption for each elevator bank consisting of elevators with the same loading capacity and rated speed and then adding the results together.

In formulating this judgment criterion, numerical standards were only set for office buildings for which elevator transportation techniques, typical service standards (five-minute transportation capacity, average operation interval, etc.), energy consumption calculation methods and the like have been well-established.

Appendix 2

Criteria for Clients on the Rationalization of Energy Use for Buildings

Ministry of International Trade and Industry / Ministry of Construction
Notice No.1, March 30,1999

1. Prevention of Heat Loss through the Outer Walls, Windows, etc., of Buildings

1-1. Proper measures shall be taken to prevent heat loss through the outer walls, windows, etc. of buildings. In doing so, the following practices shall be adopted:

(1) The directions of the outer walls, layouts of the rooms, etc., shall be considered in finalizing the plots and ground plans for buildings.

(2) Materials with high thermal insulation performance shall be used for outer walls, roofs, floors, windows, and openings.

(3) Thermal load due to insolation shall be reduced by adopting a method capable of properly controlling insolation through windows, by planting trees, or by taking other measures.

1-2. For each of the structures designed for the applications listed in column (a) of Table 1, the value calculated by dividing the annual thermal load of the inside ambient space of the building concerned (which means an inside space of 5 m or less in horizontal distance from the center line of the outer wall of each floor except the basement, plus the inside space of the top story, just beneath the roof, plus the inside space just above floors exposed to the open air: this definition is applicable hereafter) by the total of the floor areas (unit: m^2) of the inside ambient space of each floor shall be equal to or smaller than the value calculated by multiplying the value specified for each item in column (b) of Table 1 by the scale correction coefficient. In this case, the annual thermal load of the inside ambient space and the scale correction coefficient shall be as specified in (1) and (2) below:

(1) The annual thermal load of the inside ambient space shall be the total of the heating and cooling loads caused by heat (unit: megajoules) through a year (when the time each room is used for each application is set, the period is limited to that time; this definition is applicable hereafter), which are described in a to d below:

a. Heat penetrating through the outer walls, windows, etc., due to the temperature difference between the open air and the inside ambient space. (For heating load this temperature difference is the difference between the open air and 22 degrees Centigrade, and the difference between the open air and 26 degrees Centigrade for cooling load, except when calculating the heating load of structures for school classrooms and shops that sell goods, in which case it shall be the difference between the open air and 20 degrees Centigrade.)

b. Insolation heat through the outer walls, windows, etc.

c. Heat generated in the inside ambient space.

d. Heat of intake open air based on the amount calculated from any of the following expressions: (Expression 1) for guest rooms in buildings for Western and Japanese-style hotels; Expression 2) for sickrooms in buildings for hospitals and clinics; Expression 3) for spaces other than sickrooms in buildings for hospitals and clinics; Expression 4) for school classrooms and the dining spaces of restaurants; or Expression 5) for spaces other than the guest rooms in Western and Japanese-style hotels, for shop buildings where goods are to be sold, for office buildings, for spaces other than classrooms in school buildings, and for spaces other than dining spaces in restaurant buildings):

1) $V = 3.9A_p$
2) $V = 4.0A_p$
3) $V = 6.0A_p$
4) $V = 10A_p$

5) $V = \frac{20A_p}{N}$

Where, V, A_p, and N represent the values shown below:

V: Amount of intake open air (unit: m^3/hour)
A_p: Floor area of the inside ambient space (unit: m^2)
N: Occupied area per person according to actual situation (unit: m^2)

(2) The scale correction coefficient shall be the value shown in Table 2 according to the value calculated by dividing the total of the floor areas of all floors of the building except the basement (unit: m^2) by the number of floors except the basement (hereinafter called the "average floor area"), and according to the number of floors except the basement.

2. Efficient Use of Energy by Air Conditioning Equipment

2-1. Proper measures shall be taken to realize the efficient use of energy by air conditioning equipment. In doing so, the following practices shall be adopted:

(1) The load characteristics of rooms and other factors shall be taken into consideration in the design of air conditioning systems.

(2) Building plans shall include equipment with better heat retention in order to reduce energy loss in air ducts, piping, etc.

(3) A proper control method shall be adopted for air conditioning equipment.

(4) A heat source system with highly efficient energy usage shall be adopted.

2-2. With regard to air conditioning equipment to be installed in buildings for the applications specified in column (a) of Table 1, the value calculated by dividing the quantity of energy to be consumed by the said air conditioning equipment for a year to treat the air conditioning load, converted into a quantity of heat, by the virtual air conditioning load of the building in the same period shall be equal to or smaller than the value specified for the item concerned in column (c) of the table. In this case, when converting the quantity of energy for the energy type shown in the left column of Table

3 into a quantity of heat, the corresponding value in the right column shall be used for the calculation (if a smaller value than the value given in the right column can be calculated by installing equipment or appliances that ensure the efficient use of energy, the smaller value shall be used) (hereinafter called "equipment, etc. for efficient use of energy"), other energies shall depend on their actual states, such as composition, and the air conditioning load and the virtual air conditioning load shall be as specified in (1) and (2) below:

(1) The air conditioning load shall be the load generated by any of the heats listed in a to e below:

a. Heat penetrating through the outer walls, windows, etc., due to the temperature difference between the open air and the inside (limited to air-conditioned space; applicable to the rest of this Section 2).

b. Insolation heat through outer walls, windows, etc.

c. Heat generated inside.

d. Heat of intake open air.

e. Heat generated due to the actual states of the building.

(2) The virtual air conditioning load shall be the load generated by any of the heats listed in a, b, c and e in (1) above and by the heat of the intake open air based on any of the following expressions: (Expression 1) for guest rooms in buildings for Western and Japanese-style hotels; Expression 2) for sickrooms in buildings for hospitals and clinics; Expression 3) for spaces other than sickrooms in buildings for hospitals and clinics; Expression 4) for school classrooms and the dining spaces of restaurants; or Expression 5) for spaces other than the guest rooms in Western and Japanese-style hotels, for shop buildings where goods are to be sold, for office buildings, for spaces other than classrooms in school buildings, and for spaces other than dining spaces in restaurant buildings (or a proper quantity for the actual situation with regard to buildings for hotels or Japanese-style hotels of which the guest rooms are without a bathroom)). However, the reduction in load resulting from the collection of waste heat shall not be taken into consideration.

1) $V = 3.9A_f$
2) $V = 4.0A_f$
3) $V = 6.0A_f$
4) $V = 10A_f$
5) $V = \frac{20A_f}{N}$

Where, V, A_f, and N represent the values shown below:

V: Amount of intake open air (unit: m^3/hour)
A_f: Inside floor area (unit: m^2)
N: Occupied area per person according to actual situation (unit: m^2)

3. Efficient Use of Energy by Mechanical Ventilation Equipment Other Than Air Conditioning Equipment

3-1. Proper measures shall be taken to realize the efficient use of energy by mechanical ventilation equipment other than air conditioning equipment. In doing so, the following practices shall be adopted:

(1) A plan to reduce energy loss in air ducts, etc., shall be defined.

(2) A proper control method shall be adopted for mechanical ventilation equipment other than air conditioning equipment.

(3) The equipment used shall be capable of actuating the necessary level of ventilation and shall use energy with high efficiency.

3-2. With regard to the mechanical ventilation equipment (excluding air conditioning equipment; applicable to the rest of this Section) to be installed in buildings for the applications specified in column (a) of Table 1, the value calculated by dividing the quantity of energy to be consumed by the mechanical ventilation equipment concerned (hereinafter called the "quantity of energy consumed for ventilation") for a year, converted into quantity of heat, by the virtual ventilation consumption energy quantity of the building in the same period, converted into a quantity of heat, shall be equal to or smaller than the value specified for the item concerned in column (d) of the table. In this case, when converting the quantity of energy for the energy type shown in the left column of Table 3 into a quantity of heat, the corresponding value in the right column shall be used for the calculation (if a smaller value than the value given in the right column can be calculated by installing equipment, etc., for efficient use of energy, the smaller value shall be used), other energies shall depend on their actual states, such as composition, and the quantity of energy consumed for ventilation and virtual quantity of energy consumed for ventilation shall be as specified in (1) and (2) below:

(1) The quantity of energy consumed for ventilation shall be the total of electric power consumption by the units listed in a to c below for a year:

a. Air charger

b. Exhaust unit

c. Other units required for the mechanical ventilation equipment concerned

(2) The virtual quantity of energy consumed for ventilation shall be calculated using the following expression:

$$E = Q \times T 3.676 \times 10^{-4}$$

Where, E, Q, and T represent the values shown below:

E: Virtual quantity of energy consumed for ventilation (unit: kWh)
Q: Design ventilation quantity (unit: m^3/hour)
T: Annual operation time (unit: hours)

4. Efficient Use of Energy by Lighting Equipment

4-1. Proper measures shall be taken to realize efficient use of energy by lighting equipment. In doing so, the following practices shall be adopted:

(1) Lighting systems with high lighting efficiency shall be used.

(2) A proper control method shall be adopted for lighting equipment.

(3) Lighting equipment shall be installed in a manner that facilitates easy maintenance and management.

(4) The arrangement of lighting equipment, the setting of illuminance, and the selection of room shapes and interior finishes shall be properly determined.

4-2. With regard to lighting equipment to be installed in buildings for the applications specified in column (a) of Table 1, the value calculated by dividing the quantity of energy to be consumed by the lighting equipment concerned (hereinafter called the "quantity of energy consumed for lighting") for a year, converted into a quantity of heat, by the virtual lighting consumption energy of the building concerned in the same period, converted into a quantity of heat, shall be equal to or smaller than the value specified for the item concerned in column (e) of the table. In this case, when converting the quantity of energy for the energy type shown in the left column of Table 3 into a quantity of heat, the corresponding value in the right column shall be used for the calculation (if a smaller value than the value given in the right column can be calculated by installing equipment or appliances that ensure the efficient use of energy, the smaller value shall be used), other energies shall depend on their actual states, such as composition, and the quantity of energy consumed for lighting and the virtual quantity of energy consumed for lighting shall be as specified in (1) and (2) below:

(1) The quantity of energy consumed for lighting shall be the total of the lighting electric power consumption calculated for each inside room or passage using the following expression:

$$E\gamma = W\gamma \times A \times T \times F / 1{,}000$$

Where, $E\gamma$, $W\gamma$, A, T, and F represent the values shown below:

$E\gamma$: Total lighting electric power consumption of each room or passage (unit: kWh)

$W\gamma$: Lighting power consumption of each room or passage (unit: W/m^2)

A: Floor area of each room or passage (unit: m^2)

T: Annual lighting time of each room or passage (unit: hours)

F: Coefficient specified in the table below for each lighting equipment control method (If there is an alternative coefficient calculated based on the result of special study or research, it may be used instead.)

Control method	Coefficient
In-room detection control, such as a card or sensor	0.80
Automatic flashing control by detection of brightness	
Proper illuminance adjustment	0.85
Time schedule control	0.90
Daylighting control	
Zoning control	
Local control	
Others	1.00

(2) The virtual quantity of energy consumed for lighting shall be the total of the virtual lighting electric power consumption calculated for each room or passage using the following expression:

$$Es = Ws \times A \times T \times Q_1 \times Q_2 / 1{,}000$$

Where, Es, Ws, A, T, Q_1, and Q_2 represent the values shown below:

Es: Total virtual lighting electric power consumption of each room or passage (unit: kWh)
Ws: Standard lighting power consumption of each room or passage (unit: W/m^2)
A: Floor area of each room or passage (unit: m^2)
T: Annual lighting time of each room or passage (unit: hours)
Q_1: Coefficient specified in the table below for each lighting equipment type If there is an alternative coefficient calculated based on the result of special study or research, it may be used instead.)

Lighting equipment type	Coefficient
Lighting equipment adopting a special measure to control glare, such as a louver or translucent cover	1.3
Others	1.0

Q_2: Coefficient specified in the table below for each application and illuminance of lighting equipment

Application	Coefficient
Office rooms for offices and shops selling goods	L/750
School classrooms	L/500
Others	1.0

In this table, L is design illuminance (unit: luxes).

5. Efficient Use of Energy by Hot Water Supply Equipment

5-1. Proper measures shall be taken to realize efficient use of energy by hot water supply equipment. In doing so, the following practices shall be adopted:

(1) Shorter piping routes, thermal insulation of piping, etc., shall be considered in planning proper piping.

(2) A proper control method shall be adopted for hot water supply equipment.

(3) A heat source system that consumes energy with high efficiency shall be adopted.

5-2. With regard to hot water supply equipment to be installed in buildings for the applications specified in column (a) of Table 1, the value calculated by dividing the quantity of energy to be consumed by the hot water supply equipment concerned (hereinafter called the "quantity of energy consumed for hot water supply") for a year, converted into a quantity of heat, by the virtual hot water supply load of the building concerned in the same period, converted into a quantity of heat, shall be equal to or smaller than the value specified for the item concerned in column (f) of the table. In this case, when converting the quantity of energy for the energy type shown in the left column of Table 3 into a quantity of heat, the corresponding value in the right column shall be used for the calculation (if a smaller value than the value given in the right column can be calculated by installing equipment or appliances that ensure the efficient use of energy, the smaller value shall be used), other energies shall depend on their actual states, such as composition, and the quantity of energy consumed for hot water supply and the virtual hot water supply consumption load shall be as specified in (1) and (2) below:

(1) The quantity of energy consumed for hot water supply shall be the total of energies consumed by the units listed in a to c below for a year:

a. Boiler or another heat source for hot water supply

b. Circulating pump

c. Other units required for the hot water supply equipment concerned

(2) The virtual hot water supply load shall be the total of the virtual hot water supply loads calculated for the locations where hot water is used, by the following expression:

$$L = V \times (T_1 - T_2)$$

Where, L, V, T_1, and T_2 represent the values shown below:

L: Virtual hot water supply load (unit: kilojoules)
V: Hot water quantity used (unit: liters)
T_1: Hot water temperature used (unit: degrees Centigrade)
T_2: Water supply temperature by area (unit: degrees Centigrade)

6. Efficient Use of Energy by Lifting Equipment

6-1. Proper measures shall be taken to realize efficient use of energy by lifting equipment. In doing so, the following practices shall be adopted:

(1) A proper control method shall be adopted for lifting equipment.

(2) A drive system of high efficiency of use of energy shall be adopted.

(3) A proper installation plan for the required transport capacity shall be defined.

6-2. With regard to elevators among lifting equipment to be installed in buildings for the applications specified in column (a) of Table 1, the value calculated by dividing the quantity of energy to be consumed by the elevators concerned (hereinafter called the "quantity of energy consumed for elevators") for a year, converted into a quantity of heat, by the virtual elevator consumption energy of the building concerned in the same period, converted into a quantity of heat, shall be equal to or smaller than the value specified for the item concerned in column (g) of the table. In this case, when converting the quantity of energy for the energy type shown in the left column of Table 3 into a quantity of heat, the corresponding value in the right column shall be used for the calculation (if a smaller value than the value given in the right column can be calculated by installing equipment or appliances that ensure the efficient use of energy, the smaller value shall be used), other energies shall depend on their actual states, such as composition, and the quantity of energy consumed for elevators and the virtual quantity of energy consumed for elevators shall be as specified in (1) and (2) below:

(1) The quantity of energy consumed for elevators shall be the total electric power consumed by all elevators, calculated using the following expression:

$$E\gamma = L \times V \times F\gamma \times T / 860$$

Where, $E\gamma$, L, V, $F\gamma$, and T represent the values shown below:

$E\gamma$: Elevator electric power consumption (unit: kWh)
L: Load mass (unit: kg) V: Rated velocity (unit: m/minute)
$F\gamma$: Coefficient specified in the table below for each velocity control method
If there is an alternative coefficient calculated based on the result of special study or research, it may be used instead.)

Velocity control method	Coefficient
Variable voltage variable frequency control method (with power regenerative control)	1/45
Variable voltage variable frequency control method (without power regenerative control)	1/40
Static Leonard method	1/35
Word Leonard method	1/30
AC feedback control method	1/20

T: Annual operation time (unit: hours)

(2) The virtual quantity of energy consumed for elevators shall be the total of the values calculated by multiplying the virtual quantity of electric power consumed by each elevator by the transport capacity coefficient. In this case, the virtual electric power consumption for elevators and the transport capacity coefficient shall be as specified in a and b below:

a. The virtual electric power consumption for elevators shall be calculated using the following expression:

$$Es = L \times V \times Fs \times T / 860$$

Where, Es, L, V, Fs, and T represent the values shown below:

Es: Virtual electric power consumption for elevators (unit: kWh)
L: Load mass (unit: kg) V: Rated velocity (unit: m/minute)
Fs: Coefficient by velocity control method (1/40)
T: Annual operation time (unit: hours)

b. The transport capacity coefficient shall be calculated using the following expression. However, when the building concerned is an office building with four or fewer floors or a total floor area of 4,000 m^2 or less, the value obtained by dividing the average operation interval (unit: seconds) by 30 may be used as the transport capacity coefficient; and when the building concerned is a Western or Japanese-style hotel equipped with one or two elevators, 1 may be used as the transport capacity coefficient.

$$M = A_1/A_2$$

Where, M, A_1, and A_2 represent the values shown below:

M: Transport capacity coefficient
A_1: Standard transport capacity specified in the table below for the application and actual state of the building concerned

Application of building concerned	Actual state of building concerned	Standard transport capacity
Office	When occupied by a single company	0.25
	Other cases	0.20
Western or Japanese-style hotel	—	0.15

A_2: Planned transport capacity calculated by dividing the number of people that can be transported by the elevator in five minutes by average number of people who use the elevator in a five-minute period

Supplementary provisions
Ministry of International Trade and Industry/Ministry of Construction Notice No. 1 issued in 1993 is abolished.

Table 1

(a)	Western or Japanese-style hotel	Hospital or clinic	Shop selling goods	Office/td>	School	Restaurant
(b)	420	340	380	300	320	550
(c)	2.5	2.5	1.7	1.5	1.5	2.2
(d)	1.0	1.0	0.9	1.0	0.8	1.5
(e)	1.0	1.0	1.0	1.0	1.0	1.0
(f)	1.5	1.7	1.7	—	—	—
(g)	1.0	—	—	1.0	—	—

Table 2

Average floor area / Number of floors, excluding basement	50 m^2 or less	100 m^2	200 m^2	300 m^2 or more
1	2.40	1.68	1.32	1.20
2 or more	2.00	1.40	1.10	1.00

As long as the average floor area is within the range of given in this table, the scale correction coefficient shall be the value obtained by linearly interpolating the neighborhood scale correction coefficients.

Table 3

Heavy oil	41,000 kilojoules per liter
Kerosene	37,000 kilojoules per liter
Liquefied natural gas	50,000 kilojoules per kg
Electricity	10,250 kilojoules per kWh (or 9,620 kilojoules for electric power consumption of overnight purchased excess power (supplied by general electric utilities (those stipulated in 2, Section 1, Article 2, the Electricity Utilities Industry Law (Law No. 170, 1966) between 22:00 and 8:00 the following day))

Appendix 3

Fundamentals of Air Conditioning

1. Air conditioning

Air conditioning refers to control of air conditions of rooms or plants to their optimal states fitting for its usage and purposes. As other indices for judging the quality of a room atmosphere, there are acoustic impression, visual impression and sense of freedom, but air conditioning has nothing to do with them unless the facility factors affect them adversely.

Air condition of rooms to be controlled include the following 4 factors.

(1) Temperature

The room air is either cooled or heated for control to the prescribed value of the dry-bulb thermometer.

(2) Humidity

The room air is controlled to the prescribed comfortable relative humidity.

(3) Cleanliness

The room air is removed of dusts below the allowable dust concentration, and at the same time it is maintained so that fume, CO_2, odor, toxic gases, etc. are kept below the allowable concentration.

(4) Distribution

To facilitate uniform distribution of conditioned air in the room, a proper air flow is produced and a constant temperature condition of the whole room is maintained.

Purposes of this air-conditioning can be classified largely into a) hygienic air-conditioning and b) process air-conditioning.

a) Hygienic air conditioning

Hygienic air-conditioning means to maintain the room air in a state which maintains the hygienic environment for the human body and gives a sense of comfort and amenity namely to maintain the room air to a state suited for people living or working there. The 2 major factors governing the optimal air condition are temperature and humidity. Figure 1 shows the comfortable zones during winter and summer in Japan.

Meanwhile, apart from this figure, it is considered desirable to keep the room temperature not so greatly different from the outdoor temperature and to keep the humidity at a minimum level. And, the difference room and outdoor temperatures is considered must suitable when it is 5° ~ 7°C.

For general office work, design conditions are set at 18° ~ 22°C and 30% ~ 50% (R.H) during heating, and 25° ~ 28°C and 50% ~ 60% during cooling. When energy conservation is given priority, values near the lower limit of the given values, namely 18°C and 40% during winter, and 28°C and 50% during summer are adopted.

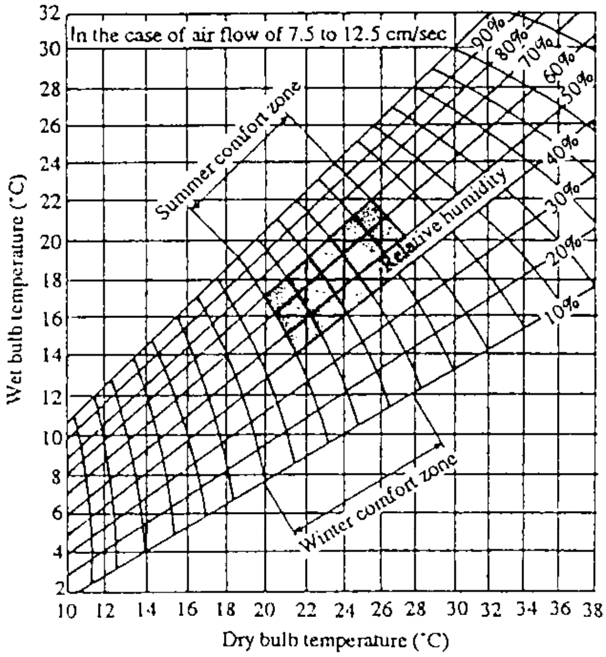


Figure 1 Comfort zone

b) Process air conditioning

Of processes of industrial production, many processes including from raw materials to completion and storage of products require independent conditions for retaining the facility and quality. As processes often require coexistence of operators workers there, process air conditioning should take factors of hygienic air conditioning into consideration. Generally, process air conditioning precedes, and for the human body hygienic performance is assured by local air conditioning and other means.

Table 1 shows typical design air conditioning states of various industrial processes. However, the table shows mere guidelines, and individual design should be determined by thorough study.

Table 1 Example of process air conditioning

Classification	Process	Temperature (°C)	Relative humidity (%)
Color printing	Bronze plating room	24–27	45–50
	Plate preparation	24	45–50
	Printing room	24–27	45–50
Printing	Book binding	21–24	45
	Form	24–27	45–50
	Printing room	24–27	45–50
	Web press	24–27	50–55
	Paper storage	20–23	50–60
	Photographic printing	21–23	40–50
Optict	Melting room	24	45
	Abrading room	27	80
Plywood	Manufacture	–	55–60
	Gluing	–	55–60
Rubber	Storage	14–24	40–50
	Cementing	27	25–30
	Dipping	24–27	25–30
	Manufacture	32	-
	Sulfurization	26–28	25–30
Laboratory	Animal laboratory	24–27	40
	Central analysia room	23	50
Photograph	Manufacture of ordinary film	23–24	24–40
	Printing	23–24	65–70
	Finished product storage	16–27	45–50
	Developing	21–24	60
Bakery	Base mixing	24–27	45–55
	Base fermentation	27	70–80
	Bread cooling	21	70–80
	Bread wrapping	18–24	50–65
	Powder storage	21–27	50–60
	Cake frezing	21–27	45–50
Precision machinery	Gear cutting	24–27	45–55
	Precision parts	24	45–55
	Precision assembly	20–24	40–50
	Precision test room	24	45–50
Pharmacy	Capsuling	24–27	25–40
	Colloid	21	30–50
	Deliquceene salt	27–32	15–40
	Gelatin capasule	26	40–50
	Powder product	24–27	5–35
	Tablet forming	21–27	35–40
	Tablet furish coating	24–27	35–40
	Serum	23–26	45–50
	Powder material drying	24–71	20
	General pharmacyh room	21–27	10–50
Electricity	Manufacture of thermostat	24	50–55
	Manufacture of insulating material	24	65–70
	Assembly of electron tubes	20	40
	Cable insulation	40	5
	Transformer coil winding	16–24	15–35
Food	Manufacture of butter	16	60
	Coffee substitute	24–27	40–45
	Milling	—	60
	Macaroni	21–27	38
	Mayonnaise	24	40–50
	Mushroom prowing room	14–27	75
Brewing	Storage of grains	16	35–40
	General manufacture	16–24	45–65
	Aging room	18–22	50–60
	Beer fermentation room	3–4	50–70
	Beer malthouse	10–15	80–85
Confectionery	Chewing gum Cooling	22	50
	Drying	49–60	50
	Wrapping and storage	21–24	45–60
	Candy Manufacture	18–27	35–50
	Cooling	24–27	40–45
	Product storage	16–24	45–55
	Dry fruits storage	10–13	50
	Chocolate Bar manufacture	18	45–50
	Center cream manufacture	24–29	50
	Nougats	18	50
	Starch room	24–29	50
	Wrapping	18	50
	Product storage	16–24	40–50
Tobacco	Cigarette Raw material storage	27	75–78
	Cutting	24–27	80
	Cut tobacco storage	27–29	60–65
	Manufacturing room	21–27	55–65
	Wrapping room	27–29	50
	Truck removing room	27	70–75
	Sweating	49	80
Cotton spinning	Roving	21–24	50–55
	Spinning	21–24	55–65
	Drawing	21–24	55
	Picker	21–24	45–50
	Roving	21–24	50–60
	Warp spinning	24–27	50–65
	Weft spinning	24–27	50–65
	Cotton reel	24–27	60–70
	Twister	21–24	65
	Woven textile	24–27	70–85
	Fabric storage	24–27	65–75
Jute spinning	Fabric conditioning room	24–27	90–95
	Spinning	24–27	60
	Woven textile	26–27	80
	Preparation	18–20	80
	Roving and spinning	24–27	60
Match	Manufacture	22–27	45–50
	Storage	15	50

2. Composition of air conditioning system

The final means for performing air conditioning is the air, and generally air conditioning is performed by letting out the air with proper temperature, moisture and cleanliness from blowing outlets into rooms. And there are various devices for achieving this aim, of which a composition of a relatively large-scale air conditioning system is shown in Figure 2. Here descriptions are given mainly on cooling, based on this composition.

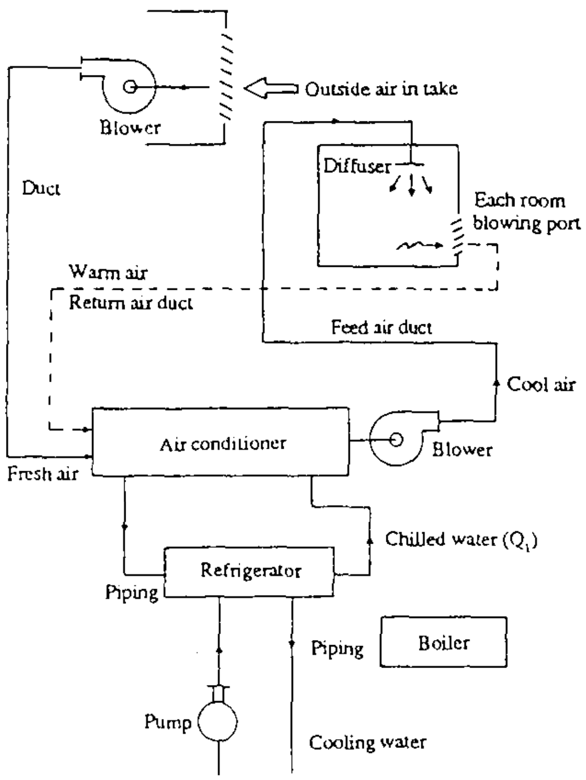


Figure 2 Composition example of large scale air conditioning system (during cooling)

During cooling, heat load flows from the outside into the room, which is transferred from air to chilled water within the air conditioner and carried to the heat source unit (refrigerator), and after pumped up by the refrigerator, is discharged through the cooling tower in to the atmosphere.

During heating, oil or gas is burnt by boiler, and this heat, after transferred to warm water, is carried to the air conditioner, and supplied into the room by means of air conditioner.

(1) Heat source unit

The heat source unit supplies warm water (heating medium) or chilled water (coolant) to the air conditioner. Heat source units for heating the heating medium include boiler, regenerator tank, heat pump, etc., and that for cooling the coolant include the refrigerator. Besides them are heat exchangers, pumps, blowers and pipings as auxiliary equipment.

(2) Air conditioner

A unit for preparing the blow air to a temperature, moisture and cleanliness suited for the required room conditions. If therefore is equipped with various equipment within for purifying, cooling, temperature reducing, heating, humidifying, blowing, etc.

(3) Supply unit

A unit for supplying fluid and gas composed of blower, pump, duct, piping, etc. That is, the air conditioned through the air conditioner is supplied by through the duct to a room to be cooled. And, the warm room air is absorbed by negative pressure of the blower and sent into the air-conditioner.

(4) Diffuser

Installed at the outlet or inlet of the duct, composed of blower outlet, suction port, muffler, damper, etc.

(5) Switch board, control panel, monitor panel

These are electric facilities for operating, controlling and monitoring the air conditioning system.

The above-mentioned units are not necessarily installed separately, and there are systems which combine several units in one or those in which all of them form a single unit, like a package-type air-conditioner, depending on the scale of air-conditioners.

3. Heat load of air conditioning system and its calculation

Figure 3 shows the inflow sections of heat load to a room.

Table 2 lists the type and composition of heat load, and calculation formulas corresponding to Figure 3. Additionally, accumulated heat load is generated during ordinary intermittent operation, which is accumulated in the building framework by invasion of external heat during the night when the air conditioner is stopped and is gradually flown away as load after resuming operation. Both Heating load and cooling load are largely affected when operation is stopped during the night and during the day respectively by heat accumulation.

Figure 4 shows a cooling load example at a plant office. Construction of the building is as shown in Figure 5.

According to Figure 4, load due to heat transfer is the largest, followed by lighting, external air, solar radiation and human body in that order.

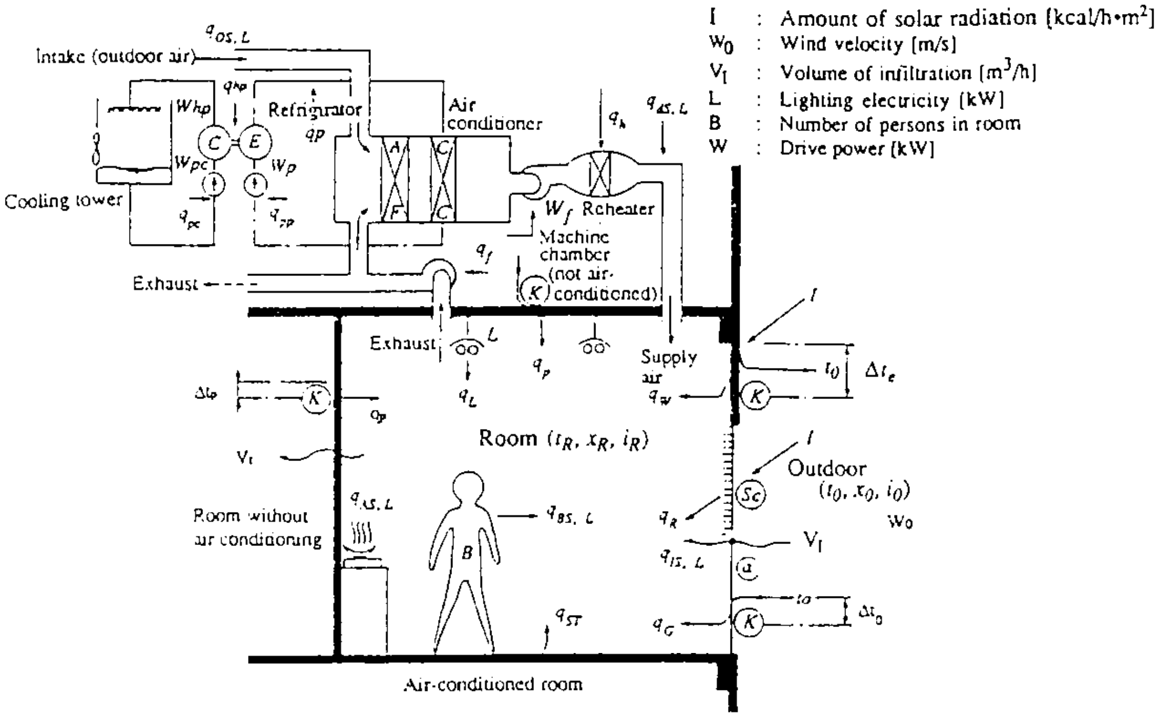


Figure 3 Type of heat load and inflow sections (cooling)

Load due to humanbody	11%	
Load due to sunlight	15%	
Load due to external air	15%	
Load due to lighting	16%	
Load due to heat transfer	43%	Total 17,045 kcal/h

Figure 4 Example of air conditioning load in factory office (during cooling)

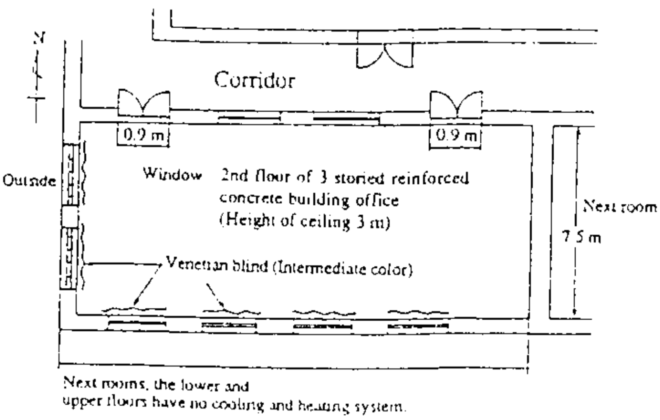


Figure 5 Example of office

Table 2 Types and composition of air conditioning heat loads, and calculation formulas

Heat source and heat sink load	Heat source unit load	Air conditioner load / System load	Load group	Sub-group	Type of load	Symbol	Calculation formula: Sensible heat load	Calculation formula: Latent heat load	Remarks
Heat source (oil, etc.) and heat sink (cooling tower–atmospheric air) load	Heat source unit (boiler, refrigerator, etc.) load HACL	Air conditioner load ACL	Room load RL	Outdoor load	Glass-transmitted solar radiation	q_R	$S_c \cdot A \cdot I$		S_c: Shield modulus, A: Area, I: Standard solar radiation gain
					Transfer through external wall and roof	q_W	$K \cdot A \cdot \Delta t_e$		K Heat transfer coefficient $\frac{1}{K} = \frac{1}{\alpha_i} + \Sigma \frac{d_j}{\lambda_j} + \frac{1}{\alpha_0}$
					Transfer through external wall glass	q_G	$K \cdot A \cdot \Delta t_0$		αi: Indoor heat transfer rate 8kcal/h·m²·°C α0: Outdoor heat transfer rate = 20 (summer), 30(winter) [kcal/h·m²·°C]
					Infiltration	$q_{IS,\ L}$	$0.28V_I \cdot \Delta t_0$	$715V_I \cdot \Delta x_0$	d_j: Thickness of j-layer of component member, λ_j: Thermal conductivity[kcal/m·h·°C]
					Accumulated heat load	q_{ST}			For all-day air conditioning qST=0 / Δte: Effective temperature difference (°C)
				Internal load	Lighting	q_L	$860\ b \cdot L$		b: Ballast coefficient, incandescent lamp b=1.0, fluorescent lamp b=1.2, L: Lighting electricity [kW]
					Human body	$q_{BS,\ L}$	$h_s \cdot B$	$h_L \cdot B$	h_s, h_L: Sensible heat and latent heat generated from a human body, B: Number of persons
					Equipment	$q_{AS,\ L}$	q_{AS}	q_{AL}	Use measured value (facility capacity × load factor)
			External air load		External air load	$q_{OS,\ L}$	$0.28V_0 \cdot \Delta t_0$	$715V_0 \cdot \Delta x_0$	Vo: Amount of air intake $\Delta t_0 = t_0 - t_R$ $\Delta x_0 = x_0 - x_R$
		System load	Duct system load		Duct heat reception and leakage	$q_{DS,\ L}$	$(K \cdot A \cdot \Delta t)$ $(0.28V_D \cdot \Delta t_0)$	$(715V_0 \cdot \Delta x_0)$	VD: Amount of leaked air / 5—20% of RL
					Fan heat	q_f	$860W_f$		Wf: Fan drive power [kW] / 5—20% of RL
					Reheat load	q_k	q_k		Use measured value of reheat quantity
			Piping system load		Piping heat reception	q_p	$(K \cdot A \cdot Dt)$		Δt: Difference between water temperature and ambient temperature / 2—5% of ACL
					Pump heat	q_{pp}	$860W_p$		Wp: Pump drive power / 2—5% of ACL
					Accumulator tank loss	q_{hr}	$(K \cdot A \cdot \Delta t)$		5—15% of HACL (Total 1-day value)
			Heat source system load		Refrigerator drive power	q_{hp}	$860W_{hp}$		For heat pump, it is included as part of heat source (during heating)
					Cooling water pump heat	q_{pc}	$860W_{pc}$		Wp: Pump drive power [kW]
					Boiler waste heat	q_c	$\left(\frac{1}{\eta} - 1\right)$ HACL		h: Boiler efficiency

4. Wet air and wet-air diagram

(1) Wet air

As air contains vapor, it is called wet air, and is handled as a mixture of dry air and vapor. Contents of dry air near the the ground surface is N_2 : Q_2 : Ar : CO_2=78.09 : 20.95 : 0.93 : 0.03, equivalent molecular weight 28.966, gas constant 29.27 kg/m/kg.°K, specific gravity 1.293 kg/m³N, and specific volume 0.77 m³N/kg. As vapor causes evaporation and condensation near the normal temperature, behavior of water content is very important in air conditioning.

- Dry-bulb temperature (DB)

  Temperature of the air measured under the state in which the temperature sensing element of the thermometer is dried, namely measured under an ordinary state of the thermometer, is called the dry-bulb temperature, and is expressed with °C.

- Wet-bulb temperature (WB)

  This refers to an indicated value measured with the temperature sensing element of a thermometer covered with wet gauze. The output and input of heat are balanced at the point where heat value which gauze lose by evaporation and heat value which the gauze receives from its circumference are equal, and the thermometer indicate the temperature of the wet gauge at the time. This temperature is the wet-bulb temperature, and it is determined by the air temperature and water content in the air.

- Dew-point temperature (DP)

  The lowest temperature at which the water content in the atmosphere can exist in a vapor state is called the dew-point temperature against the volume of vapor. When an object is cooled below the dew-point temperature, the air temperature which came in contact with it drops below the dew-point temperature to make part of the vapor in the air into a mist, adhere to the surface of the object and condense. Such a phenomenon is called dew formation.

- Absolute humidity

  The weight of vapor per 1 kg of dry air contained in wet air is called the absolute humidity. The absolute humidity does not vary even when temperature of wet air is varied, unless humidified or dehumidified, when the dewing temperature is reached or exceeded.

- Relative humidity (RH)

  Wet air of a certain temperature has a limit volume of water which it can contain in vapor state and the air containing the limit volume of vapor is called air in the saturated state or saturated air. The partial pressure of vapor at this moment is called the saturated vapor pressure.

The relative humidity refers to the ratio of the partial pressure of vapor contained in the air to the saturated vapor pressure at a certain temperature.

The partial pressure of vapor means the pressure which the vapor indicates when it is supposed that the vapor in wet air in a certain volume occupies the whole volume itself, and is obtained by the following formula.

$$Pv = \frac{x \cdot P}{0.622 + x} \quad \cdots\cdots (1)$$

Pv : Partial pressure of vapor (kg/cm^2 or mmHg)

p : Atmospheric pressure (kg/cm^2 or mmHg)

x : Absolute humidity (kg/kg')

- Specific volume

The volume of wet air containing 1kg of dry air is called the specific volume. When the absolute humidity of the air is x kg/kg', the weight of wet air contained in this specific volume is 1 + x kg. The specific volume V m^3/kg' is obtained by the following formals.

$$V = 0.00455\,(x + 0.622) \cdot T \quad \cdots\cdots (2)$$

T : Absolute temperature °K of wet air

- Specific enthalpy

The total heat value possessed by wet air containing dry air 1 kg is called the specific enthalpy. When temperature of the air with absolute humidity x kg/kg' is t°C, the specific enthalpy i kcal/kg' is obtained by the following formula.

$$i = 0.24t + x\,(597.1 + 0.441t) \text{ kcal/kg'} \quad \cdots\cdots (3)$$

(2) Wet air diagram (Air diagram)

It is easy to express the status value of wet air at 1 atmospheric pressure and at temperatures around the ordinary temperature on a graph using a wet air diagram. A general wet air diagram, as shown in Figure 6, uses oblique coordinates composed of enthalpy i and absolute humidity x, and it is also called the i-x diagram. When one status point is fixed, the dry-bulb temperature t, wet-bulb temperature t', dewing temperature t'', absolute humidity x, relative humidity ø and enthalpy i of the air at the state can be obtained immediately on the diagram. When two of these status values are fixed, the state of wet air is specified, and other status values are also fixed.

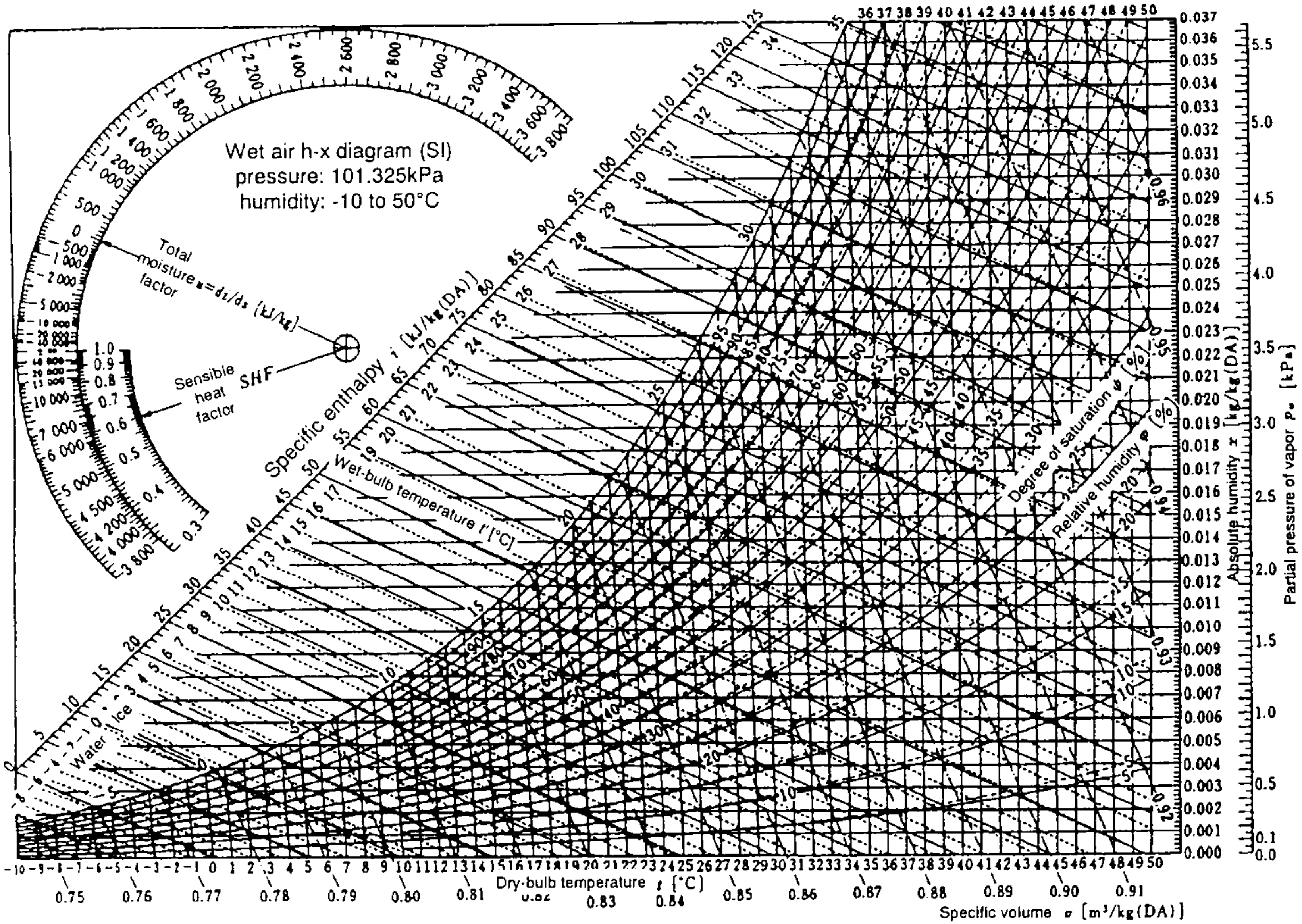


Figure 6 Wet air diagram

a. Heat balance and material balance

As shown in Figure 7, q_{SH} kcal of sensible heat is added to Gkg' of air ①, of which the specific enthalpy is i_1 kcal/kg' and absolute humidity is x_1 kg/kg', and at the same time moisture content L kg with specific enthalpy i_V kcal/kg is added as well making the state of the air i_2 kcal/kg' and x_2 kg/kg' ②, establishing the formula (4) from the heat balance;

$$G \cdot i_1 + q_{SH} + L \cdot i_V = G \cdot i_2 \quad \cdots\cdots (4)$$

Suppose q_{SH} and L are positive values in case of heating and humidifying, and negative values in case of cooling and dehumidifying.

Also, from the material balance of moisture content, formula (5) is established:

$$G \cdot x_1 + L = G \cdot x_2 \quad \cdots\cdots (5)$$

Suppose L takes positive values in case of humidifying, and negative values in case of dehumidifying.

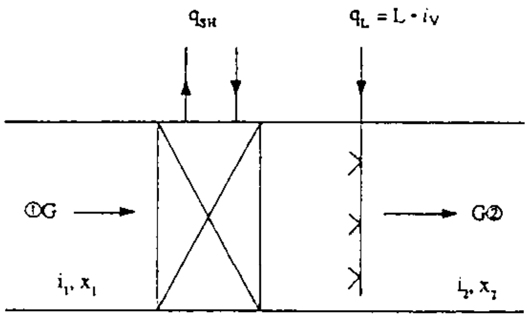


Figure 7

[Example]

A wet air 1,000kg'/h, of which the dry-bulb temperature is 30°C and the wet-bulb temperature 28°C, is cooled and dehumidified to a wet air with dry-bulb temperature 25°C and relative humidity 50%. The total heat volume removed by cooling and the amount of dehumidification are calculated using the air diagram.

From Figure 7 and from the volume G kg'/h of wet air at state ①, the removed total heat value between state ① and ②, Δi kcal/h, is

$$\Delta i = G(i_1 - i_2) \quad \cdots\cdots (6)$$

Also, moisture content Lkg/h removed between states (1) and (2) is obtained from the formula (5), as

$$L = G \cdot (x_1 - x_2) \quad \cdots\cdots (7)$$

From the air diagram, the specific enthalpy and absolute temperature of states (1) and (2) are obtained respectively, as

i_1 = 21.4 kcal/kg'　　　　　i_2 = 12.0 kcal/kg'

x_1 = 0.0233 kg/kg'　　　　　x_2 = 0.0098 kg/kg'

Therefore, from formulas (6) and (7), the removed heat value and removed moisture value are

$$\Delta_i = 1{,}000\,(21.4 - 12.0) = 9{,}400 \text{ kcal/h}$$

$$L = 1{,}000\,(0.0233 - 0.0098) = 13.5 \text{ kg/h}$$

To show the results on an air diagram, Figure 8, take a point ① where the dry-bulb temperature is 30°C and the wet-bulb temperature is 28°C, and a point ② where the dry-bulb temperature is 25°C and the relative humidity is 50%. The connect points ① and ②, and the obtained line ① ~ ② illustrates the results.

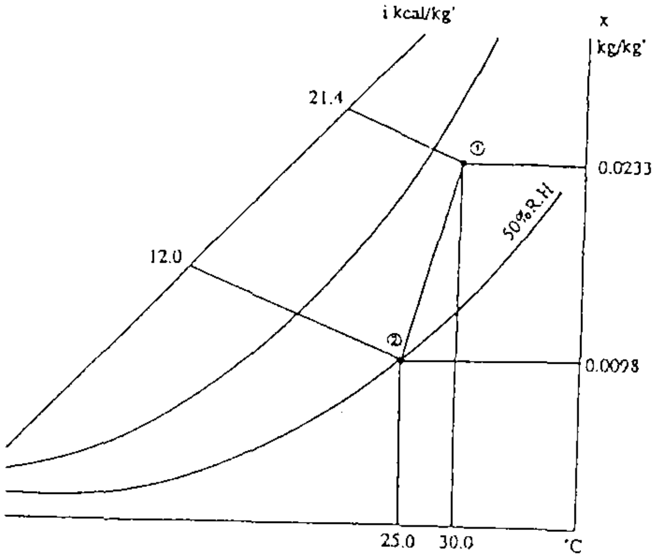


Figure 8　Wet air diagram

b. Mixing of air

In Figure 9, the volume of air, dry-bulb temperature, absolute humidity and specific enthalpy of status points ① and ② before mixing are G_1, G_2 kg/h, t_1, t_2°C, x_1, x_2 kg/kg', and i_1, i_2 kcal/kg' respectively. When both of these volumes of air are mixed at a rate of K : 1—K and form an air of G_3 kg/h, and the state values of the mixed air are t_3°C, $x_3$kg/kg' and i_3 kcal/kg', the following formulas are established.

$$i_3 = K \cdot i_1 + (1 - K) \cdot i_2 \quad \text{......(8)}$$

$$t_3 = K \cdot t_1 + (1 - K) \cdot t_2 \quad \text{......(9)}$$

$$x_3 = K \cdot x_1 + (1 - K) \cdot x_2 \quad \text{......(10)}$$

If each state value before mixing and the mix ratio are given, state values after mixing can be obtained from these formulas.

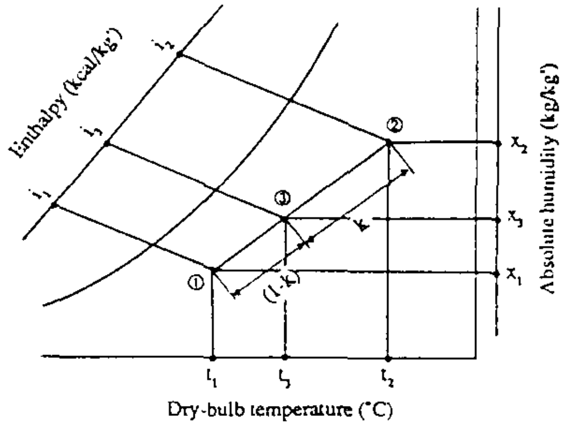


Figure 9 Wet air diagram

c. Calculation of sensible heat factor and flow rate

From Table 2, the room load RL can be summed up to a total heat load which is a sum of the sensible heat load q_{SH} and latent heat load q_{LH}. Here the SHF (sensible heat factor) is defined as follows.

$$SHF = q_{SH}/q_{TH} \quad \text{......(11)}$$

$$q_{TH} = q_{SH}+q_{LH} \quad \text{......(12)}$$

Suppose that the latent heat of evaporation of water as r and the generated water content as W, which causes the latent heat load q_{LH};

$$q_{LH} = r \cdot W \quad \text{......(13)}$$

Therefore, the following formula is lead by formulas (11) ~ (13), and the heat/water content ratio (or water content ratio) u is defined.

$$u = \frac{r}{1 - SHF} \quad \text{......(14)}$$

By air conditioned for temperature and humidity by air-conditioner blowing off into a room having loads for formulas (11) and (12), these loads are absorbed and the room is maintained to the design condition. The absorption rate of sensible heat and latent heat at this moment should satisfy a relationship given by formulas

(11) or (14), or otherwise the room would not meet the design condition, and either the temperature, humidity or both would deviate from the target.

In Figure 6, a line connecting a value of SHF obtained by formula (11), on the SHF scale provided at the bottom left of the figure, with the reference point (x mark) is called the line of sensible heat ratio or the SHF line. When the sensible heat factor of the room air is fixed, the state of the air is varied accordingly, and expressed by the status point which moves parallelly along the SHF line.

Suppose the specific heat of the air is cp, specific gravity ρ_a, and the blown volume of air G (weight) or V (volume);

$$q_{SH} = cp \cdot G \cdot (t_R - t_D) \quad \text{......(15)}$$

$$= cp \cdot \rho_a \cdot V \cdot (t_R - t_D)$$

$$= 0.29V \cdot (t_R - t_D) \quad \text{......(16)}$$

$$\therefore V = \frac{q_{SH}}{0.29(t_R - t_D)} \quad \text{......(17)}$$

The necessary blow volume of air can be obtained from the formula (17). Here t_D is temperature of the blown air and t_R is set room temperature. For heating, the denominator of the formula (17) may be replaced as $t_D - t_R$, or q_{SH} may be given in the negative form.

Wind volume of the air conditioner can be calculated by determining the necessary flow rate from the formula (17) in relation to the maximum load of each room to be air-conditioned, and by summing up the results for each of the respective air conditioning systems.

Since load varies all year round in the actual air conditioning system, it is necessary to change the heat volume which should be supplied by formula (16) according to such load variations. To do this, a method for varying the flow rate V on the right side of the formula (16) (varying flow rate system), and a method for varying the temperature difference of blown air ($t_R - t_D$), which actually varies the temperature of blown air t_D (fixed flow rate system) can be considered. The varying wind volume system is preferable in terms of energy conservation, however, as the mix pattern in the room of the blown air is varied when flow rate is varied, care should be taken for the location and selection of blower outlets.

The cooling capacity q_c of the air conditioner can be given by the following formula, by supposing the specific enthalpy of the air conditioner of its intake air and outlet air respectively as i_3 and i_4.

$$q_c = \rho_a \cdot V \cdot (i_3 - i_4) \quad \text{......(18)}$$

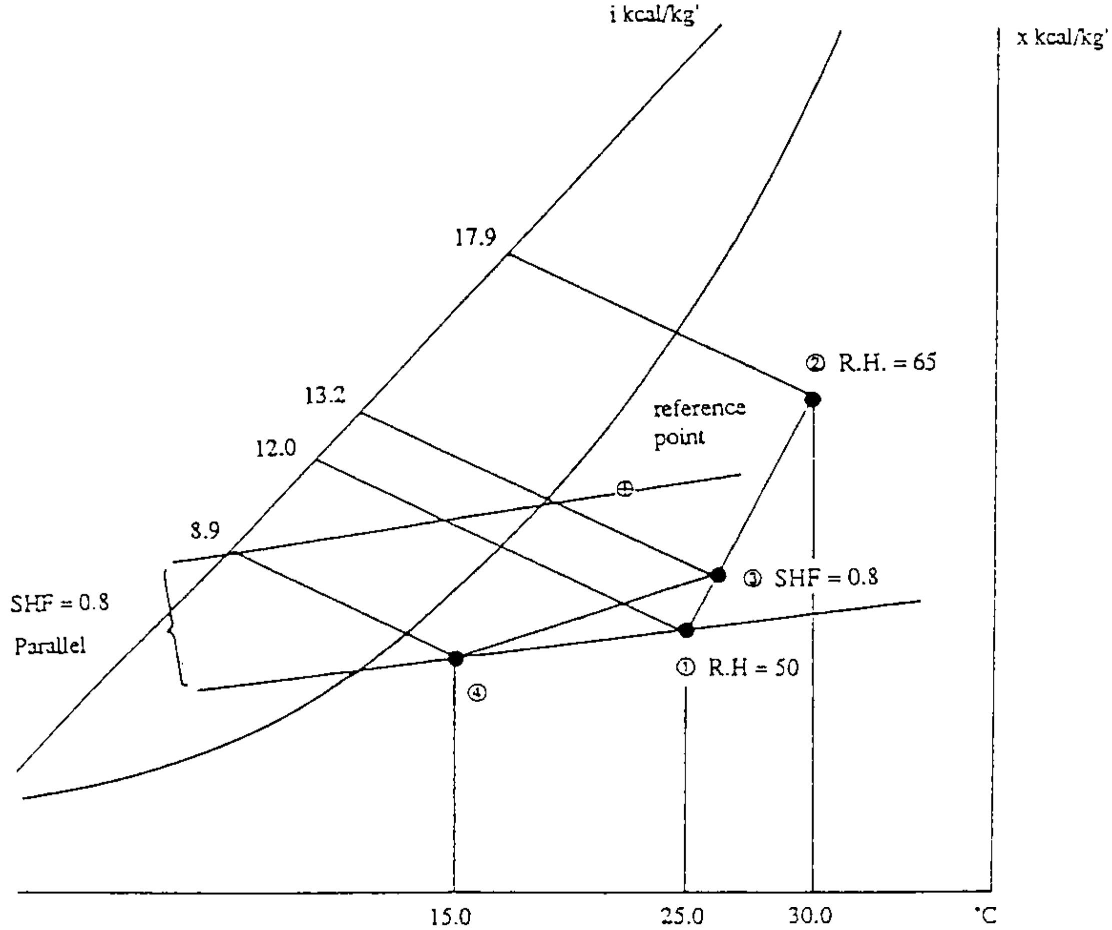


Figure 10 Wet air diagram

Meanwhile, the driving electric power P kW of the cooling facility which is necessary for attaining this refrigerating capacity q_c is given by the following formula by supposing the coefficient of performance of the refrigerating facility ε as

$$P = \frac{q_c}{860 \cdot \varepsilon} \quad \text{.......(19)}$$

When air conditioning is performed, the air blown off into the room of the dry-bulb temperature, absolute humidity and specific enthalpy are varied by addition or removal of sensible heat and latent heat. The status point of the varied state can be determined on the air diagram by means of the added or reduced sensible heat value and latent heat value. This is explained in the calculation of the following example.

[Example]

When the generated heat values are 40,000 kcal/h for sensible heat q_{SH}, and 10,000 kcal/h for latent heat q_{LH}. Supposing the set room conditions to be t_R = 25°C and relative humidity 50%, the conditions of external air 30°C by dry-bulb temperature and relative humidity 65%, and the intake volume 20% of the total supplied air volume we can determine, the total supplied air volume, external air intake volume, cooling coil load, and driving electric power of the refrigerating facility. Provided, the blown volume of air t_D is 15°C, and the coefficient of performance of the refrigerating facility is 3.0.

The total supplied air volume V m^3/h is calculated from the formula (17), supposing the air is 1.2 kg/cm^3 in specific gravity ρ_a, and 0.24 kcal/kg°C in specific heat c_p;

$$V = \frac{40{,}000}{0.29 \times (25 - 15)}$$

$$= 13{,}900$$

The external air intake volume Q_2 m^3/h is given as,

$$Q_2 = 0.2 \times 13{,}900 = 2{,}780$$

Next, SHF is determined from formulas (11) and (12),

$$SHF = \frac{40{,}000}{40{,}000 + 10{,}000} = 0.8$$

In Figure 6, the point of intersection of a line which is parallel to the SHP line (SHF = o.8), extended from the set status point ① of the room and the dry-bulb temperature line 15°C is to ④, the status point of external air ②, and the status point of mixed external air and ventilation ③. (Figure 10)

From this, the specific enthalpy i_2 of external air 17.9 kcal/kg' specific enthalpy i_1 of room air 12.0 kcal/kg', and specific enthalpy after mixing i_3 13.2 kcal/kg' can be obtained.

As the status point ④ indicates the state of the air after passing the cooling coil, where the specific enthalpy i_4 is 8.9 kcal/kg', the cooling coil load q_c kcal/h is determined from the formula (18), as;

$$q_c = 1.2 \times V \bullet (i_3 - i_4)$$

$$= 1.2 \times 13{,}900 \times (13.2 - 8.9)$$

$$= 71{,}700$$

And, the driving power for refrigerating facility P kW is determined from the formula (19), as;

$$P = \frac{71{,}700}{860 \times 3.0} = 27.7$$

5. Energy conservation of air conditioning facility

For air conditioners, the load to be air conditioned is determined first, and secondly a suitable air conditioning system for this load is selected. Therefore, in considering energy conservation of an air conditioning facility, reducing the cooling load (1st step), and selecting an energy-saving air conditioner or system for the remaining cooling load (2nd step) are very important. Here, measures are considered mainly in relation to existing buildings.

(1) Heat insulation

The transfer heat load is expressed by $K \bullet A \bullet \Delta t_e$ (Table 2). The area A and effective temperature difference Δt_e are determined by the shape of building, weather condition and heat capacity, so when these cannot be changed, it is easiest to insulate the heat, that is vary the heat transfer coefficient K. As methods of heat insulation, there are the following 3 methods.

a. Heat insulation of walls and windows

While external heat insulation has an advantage of being able to cut off heat without obstacles from the outside, internal heat insulation has disadvantages such as restrictions due to furniture or reduction of the room area.

b. Heat insulation of roofs and floors

c. Heat insulation of window glass

Heat insulation of window glass is done by doubling of window glass or doubling of window sashes. For the heat transfer coefficient, there is not so much difference as far as the number of window glasses is the same.

(2) Light shielding

The glass transmitted solar radiation load is expressed by $S_C \bullet A \bullet I$ (Table 2). The standard solar radiation gain is decided by weather condition and layout of the building, and methods is adopted for varying the shielding factor and window area.

a. Fitting blinds and curtains

It should be noted that the shielding effect is available only under the condition that sure open/close operations of blinds are carried out. Also, since the shield effect is related with the use of day light, it is essential to obtain a method which makes the sum of cooling/heating energy and lighting energy at a minimum.

b. Fitting louvers and hoods

Provide fixed hoods louvers, etc. outside windows with considerations made so as to shield solar radiation during the summer and not shield it during the winter.

c. Repairing window glass

Window glass is replaced with heat ray absorbing glass or reflecting glass, without having to change sashes, and the amount of transmitted solar radiation through window glass is reduced by bonding solar radiation adjusting film, to reduce cooling load.

(3) Preventing infiltration

Load q_i kcal/h due to infiltration is caused by natural ventilation, namely entrance of external air through crevices of windows and doors and the open and close operations, and it is expressed by the following formula.

$$q_i = 0.28V_1 \cdot \Delta t_0 + 715V_1 \cdot \Delta x_0$$
$$= 0.28n \cdot V \cdot \Delta t_0 + 715n \cdot V \cdot \Delta x_0$$

n : number of times for natural ventilation (see Table 3)

V : Room capacity (m^3)

Table 3 Number of times for natural ventilation (N)

Class of room	n
1 wall surface facing outside air and having window or door	1
2 walls surface facing outside air and having window or door	1.5
3 walls surface facing outside air and having window or door	2
4 walls surface facing outside air and having window or door	2
Room without window facing the outside air or door	1/2 — 3/4

For air-tight window, 1/2 of this table shall be used. However, n shall be more than 1/2 in any case.

To reduce infiltration load, windows and doors may be sealed, and the number of (open/close) operations may be reduced, as practicable, much as possible by automatic doors. However, since Δt_0 will become negative when the outdoor temperature is below the room temperature during the nighttime, and it means more reduction of cooling load, and cooling effect is obtained by opening windows and doors to introduce external air.

(4) Reducing heat values generated by equipment in the room

It is preferable not to place any equipment which generated heat inside the air-conditioned room. For lighting as well, adoption of local lighting and high-efficiency lamps and improvement of lighting appliances for more efficiency of lighting, or adoption of a ventilation system for disposing generated heat by lighting equipment separately, are desirable.

(5) External air load

The external air load qo is produced by forced ventilation and is expressed by the following formula.

$q_0 = 0.28V_0 \bullet \Delta t_0 + 715V_0 \bullet \Delta x_0$

The ventilation volume V_0 is regulated mainly from the safety and hygiene for man. Suppose the allowable CO_2 concentration is 0.1%, the required volume of external air is approx. 30 m^3/h/person.

At any rate, in order to reduce external air load, it is important to minimize the volume of ventilation within a range in which CO_2 concentration is below 0.1%.

Where there is a circulation system as shown in Figure 11, introduction of external air should be reduced, as much as possible, by recirculating within the system. The damper of the circulation system is increased in size to increase return air, and at the same time opening of the damper at the external air intake system is reduced in size to cut down on the intake volume of external air.

What should be noted in the system (Figure 11) is that the room pressure becomes negative against the outdoors when return air is made excessive, resulting in a state which readily allows invasion of air and dusts from outside. Therefore, it is desirable to maintain the room pressure in the positive state at 0.1 mmAq ~ 1 mmAq against the outdoors.

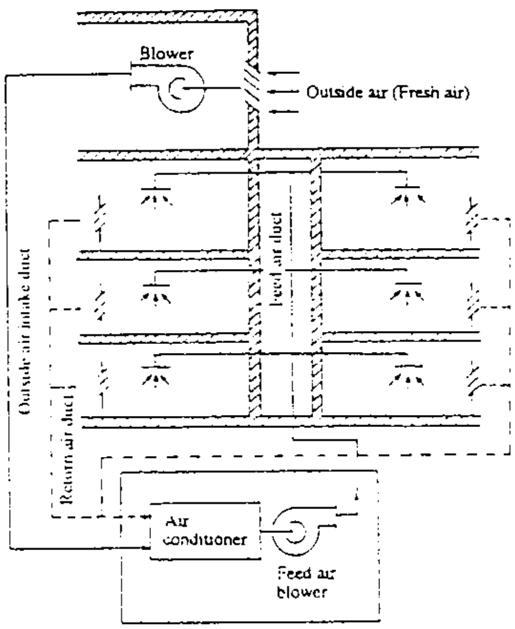


Figure 11 Air conditioning system when return air is available

(6) Alleviating the set room temperature

By raising the set temperature during cooling, cooling load by heat transfer from wall surfaces, which is proportionate to difference between temperatures inside and outside the room, is greatly reduced. In the case shown in Figure 4, for example, raising set temperature from 26°C to 27°C reduced cooling load by approx. 100kcal/h. It also reduces q_{SH} and increases t_R in the formula (17), the supply air volume can be reduced by fixing t_D, and thereby axial power of the blower can be reduced. It will also lead to reduction of drive power for compressor and so on.

(7) Review of room humidity

In the case of air conditioners having a dehumidifying function, alleviation of humidity condition is an effective measure forwards energy conservation. According to the example calculations, variations of air conditioning load by varying humidity and by varying temperatures are as shown in Figure 12.

While approx. 4.2 kcal/h of load reduction can be attained when humidity is alleviated from 40%RH to 60% RH at 23°C, load reduction is approx. 0.7 kcal/h only when temperature is alleviated from 21°C to 25°C at relative humidity 50%RH — alleviation of humidity is about 6 times more effective as energy conservation. However, it should be noted that excessively high humidity would give uncomfortableness to man and affect on products quality adversely.

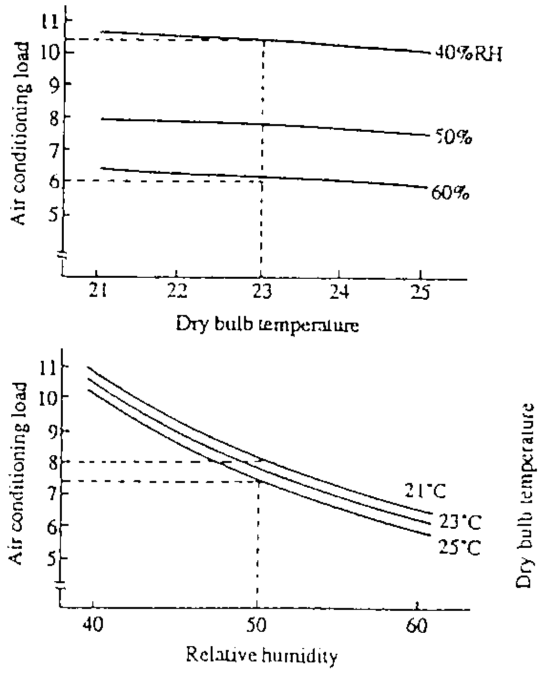


Figure 12 Energies required for temperature and humidity changes

(8) Improving control method

As mentioned before, control of heat load is available by method which varies flow rate, and by method which varies set temperature with flow rate set constant. Reduction effect of drive power for the fan and pump is larger in the former, and it results in energy saving.

As control methods for flow rate, there are control of dampers and vanes, and various rotating speed controls. Power consumption is ranked as discharge damper control > inlet vane control > rotating speed control. As rotating speed control by VVVF is easily available for existing motor facilities with considerable effects, it should be studied first among other possibilities.

(9) Regular maintenance

a. Cooling water piping

Accumulation of scale and sludge in piping will increase resistance and require more pump output for the same flow rate. If the water quality is poor, it will naturally accelerate accumulation of scale and sludge. Therefore, control of water quality is necessary. Reference values for the control criterion are shown in Table 4.

Table 4 Quality Standard of Cooling Water

(Japan Refrigeration and Air Conditioning Industrial Association Standard)

Item			Standard value for makeup water	Standard value for cooling water *1	Tendency*3	
					Corrosion	Scale
Standard item	PH (25°C)		6.0 ~ 8.0	6.0 ~ 8.0	o	o
	Conductivity	(μv/m)	200 or less	500 or less (1,000 or less)	o	
	Chlorine ion Cl	(ppm)	50 or less	200 or less	o	
	Sulfuric acid iron SO_4	(ppm)	50 or less	200 or less	o	
	Total iron Fe	(ppm)	0.3 or less	1.0 or less*2	o	o
	M Alkalinity $CaCO_3$	(ppm)	50 or less	100 or less		o
	Total hardness C_2CO_3	(ppm)	50 or less	200 or less		o
Reference item	Sulfur ion S	(ppm)	Not be detected	Not be detected	o	
	Ammonium iron NH_4	(ppm)		Not be detected	o	
	Silicon oxide SiO_2	(ppm)		50 or less		o

*1 Cooling water means water passing through condenser for both transient and circulation systems.

*2 Standard value for plastic piping shall be 0.5 ppm or below.

*3 Mark o in "Tendency" column indicates a factor concerning either corrosion or scale tendency.

b. Heat exchanger

When scale, sludge and microbes are generated in the evaporator and condenser by cooling water, they will be accumulated to drop the efficiency of heat exchange, and increase power consumption per refrigerated ton. Therefore, periodical cleaning is necessary.

c. Air duct

When filters are used for cleaning the air, periodical cleaning is inevitable. Clogging of filters increases pressure loss and reduce wind volume to degrade cooling capacity. As air conditioners are quickly contaminated when installed at places under poor atmospheric conditions, cleaning is required at least once a week.

d. Others

It is desirable to reduce air-conditioning load, as possible, by performing reviews of air-conditioning zones through studies on unbalanced supercooling/super heating of rooms, review of air-conditioning levels at corridors, etc. in each season.

Also, in installing any air conditioning systems, studies should be made carefully, including appropriateness of installing heat accumulation tanks, appropriateness of using waste heat, selection of the most efficient air conditioning duct system, etc., all of which are realized by placing emphasis on reduction of the running costs.

CASE STUDY OF ECCJ FACTORY

(Air Conditioning)

EQUATIONS FOR COOLING LOAD

Total Cooling Load :

Room cooling load

• Heat transmission through exterior walls and roof	(sensible heat load)
• Heat transmission through interior walls	(sensible heat load)
• Heat transmission through window glass	(sensible heat load)
• Solar heat gain through window glass	(sensible heat load)
• Heat generation by lighting equipments	(sensible heat load)
• Heat generation by other equipments	(sensible & latent heat load)
• Heat generation by human body	(sensible & latent heat load)
• Air infiltration	(sensible & latent heat load)

Fresh air cooling load

• Outside fresh air	(sensible & latent heat load)

1. Heat transmission through exterior walls and roof : Qwo [W]

$$Q_{wo} = K\ A_w \Delta\theta e$$

K	: Heat transmission coefficient	[W/m^2C]
Aw	: Area of Wall (or roof)	[m^2]
$\Delta\theta e$	: Equivalent temperature difference	[C]

2. Heat transmission through interior walls etc. : Qwi [W]

$$Q_{wi} = K\ A_w\ d\ \Delta\theta o$$

K	: Heat transmission coefficient	[W/m^2C]
Aw	: Area of Wall (or ceiling or floor)	[m^2]
d	: coefficient of temperature difference	[ND]
$\Delta\theta o$	: Air temperature difference	[C]

3. Heat transmission through window glass : Qgl [W]

$Qgl = K\ Ag\ \Delta\theta o$

K : Heat transmission coefficient [W/m^2C]
Ag : Area of window glass [m^2]
$\Delta\theta o$: Air temperature difference [C]

4. Solar heat gain through window glass : Qg2 [W]

$Qg2 = SC\ Sn\ Ag$

SC : Shading coefficient of window glass [ND]
Sn : Solar heat gain through standard glass [W/m^2]
Ag : Area of window glass [m^2]

5. Heat generation by lighting equipments : QL [W]

$QL = qL\ Af$

qL : Lighting power per unit floor area [W/m^2]
Af : Floor area [m^2]

6. Heat generation by other equipments : Qes, Qel [W]

$Qes = qes\ Af$ (sensible heat)
$Qel = qel\ Af$ (latent heat)

qes : Sensible heat from equipments per unit floor area [W/m^2]
qel : Latent heat from equipments per unit floor area [W/m^2]
Af : Floor area [m^2]

7. Heat generation by human body : Qhs, Qhl [W]

$Qhs = P\ qhs\ Af$ (sensible heat)
$Qhl = P\ qhl\ Af$ (latent heat)

qhs : Sensible heat from human body [W/person]
qhl : Latent heat from human body [W/person]
P : Number of person per unit floor area [person $/m^2$]
Af : Floor area [m^2]

8. Air infiltration : Qis, Qil [W/m²]

$Qis = 0.335\ Vi\ \Delta\theta o$ (sensible heat)

$Qil = 831\ Vi\ \Delta Xo$ (latent heat)

Vi	: Rate of air infiltration	[m^3/h]
$\Delta\theta o$	: Air temperature difference	[C]
ΔXo	: Absolute humidity difference	[kg/kg']

9. Outside fresh air : Qos, Qol [W/m²]

$Qis = 0.335\ Vo\ \Delta\theta o$ (sensible heat)

$Qil = 831\ Vo\ \Delta Xo$ (latent heat)

Vi	: Intake rate of outside fresh air	[m^3/h]
$\Delta\theta o$	: Air temperature difference	[C]
ΔXo	: Absolute humidity difference	[kg/kg']

COOLING LOAD CALCULATION SHEET

FLOOR: 5F ROOM NAME:R5S Room air temp.:24[℃] Room air humidity:9.5[g/kg'](RH50[%])

Time				8	9	10	11	12	13	14	15	16	17	18
Δθo:Air temp. difference [deg C]														
ΔXO:Absolute humidity difference[g/kg']														
Δθe:Equivalent temperature difference [deg C]			roof											
			N											
			E											
			S											
			W											
Sn :Solar heat gain[W/m2] (standard glass)			N											
			S											
Exterior Walls or Roof														
	Aw[m2]	K[W/m2C]	Dir.											
Roof			roof											
Wall-1			N											
Wall-2			E											
Wall-3			S											
Wall-4			W											
TOTAL														
Interior Walls etc.														
	Aw[m2]	K[W/m2C]	d.											
Ceiling														
Floor														
Wall-1														
Wall-2														
Wall-3														
Wall-4														
TOTAL														
Window(heat transmission due to temp. difference)														
	Ag[m2]	K[W/m2C]												
Window-1														
Window-2														
TOTAL														
Window(Solar heat gain)														
	Ag[m2]	SC[ND]	Dir.											
Window-1			S											
Window-2			S											
TOTAL														
Lighting		Af[m2]	L[W/m2]											
Office equipments		Af[m2]	qs,ql[W/m2]											
(S)														
(L)														
Human	P[P/m2]	Af[m2]	qe,qs[W/P]											
(S)														
(L)														
Air infiltration			Vi[m3/h]											
		(S)												
		(L)												
Outside fresh air			Vo[m3/h]											
		(S)												
		(L)												
Room Cooling Load														
			(S)											
			(L)											
			TOTAL											
Fresh Air Cooling Load			(S)											
			(L)											
			TOTAL											
Total Cooling Load			(S)											
			(L)											
			TOTAL											

[E X A M P L E]

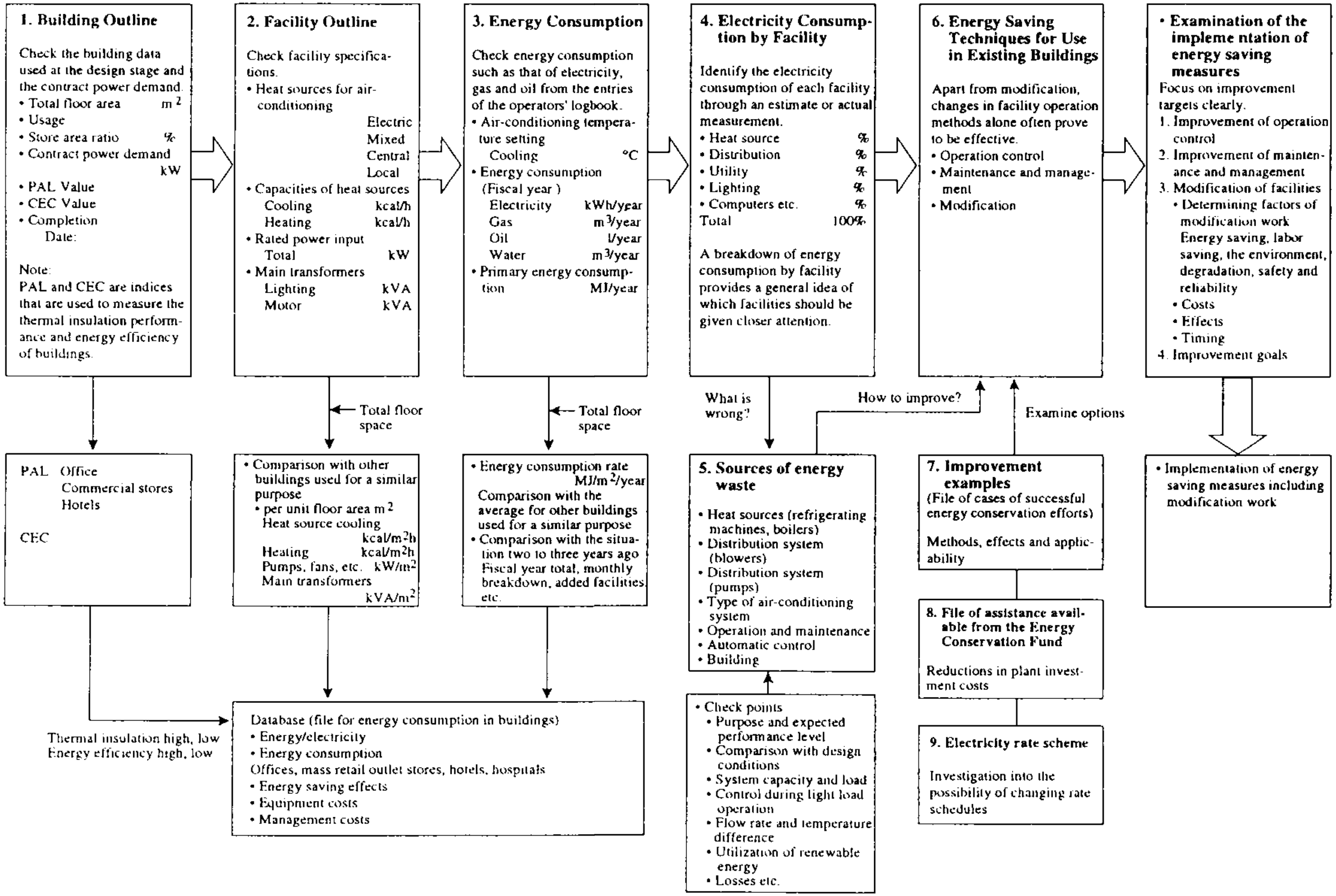
COOLING LOAD CALCULATION SHEET

FLOOR: 5F ROOM NAME:R5S Room air temp.:24[℃] Room air humidity:9.5[g/kg'](RH50[%])

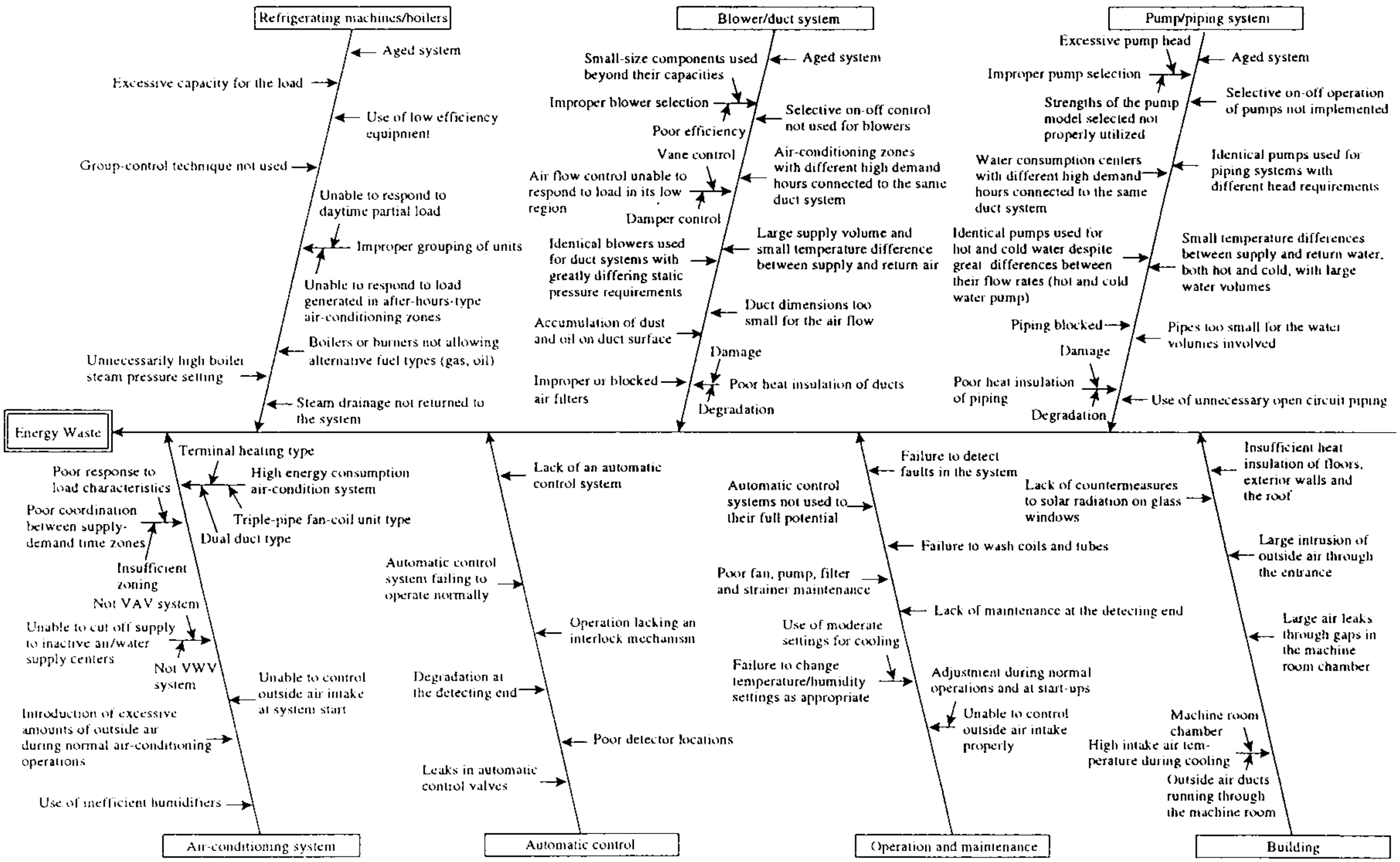
Time				8	9	10	11	12	13	14	15	16	17	18
Δ θo:Air temp. difference [deg C]				5	7	8	9	9	9	9	9	8	8	7
ΔXO:Absolute humidity difference[g/kg']				10	10	10	10	10	10	10	10	10	10	10
Δ θe:Equivalent temperature difference [deg C]			roof	11	16	21	27	31	34	35	34	32	28	23
			N	6	7	7	8	9	10	10	10	11	11	11
			E	16	20	21	21	18	16	14	13	12	11	10
			S	4	6	8	11	13	15	16	16	14	13	11
			W	4	5	7	8	9	11	14	18	22	25	25
Sn :Solar heat gain[W/m2] (standard glass)			N	38	42	43	43	43	43	43	40	38	76	99
			S	40	77	131	171	180	157	108	56	36	30	20
Exterior Walls or Roof														
	Aw[m2]	K[W/m2C]	Dir.											
Roof	0	0.00	roof	0	0	0	0	0	0	0	0	0	0	0
Wall-1	0	0.00	N	0	0	0	0	0	0	0	0	0	0	0
Wall-2	37	1.17	E	693	866	909	909	779	693	606	563	519	476	433
Wall-3	114	1.17	S	533	800	1066	1466	1733	1999	2133	2133	1866	1733	1466
Wall-4	37	1.17	W	173	216	303	346	390	476	606	779	952	1082	1082
TOTAL				1399	1882	2278	2722	2902	3168	3345	3475	3338	3291	2981
Interior Walls etc.														
	Aw[m2]	K[W/m2C]	d.											
Ceiling	576	1.49	0.25	1073	1502	1716	1931	1931	1931	1931	1931	1716	1716	1502
Floor	576	1.49	0.25	1073	1502	1716	1931	1931	1931	1931	1931	1716	1716	1502
Wall-1	213	0.84	0.25	224	313	358	403	403	403	403	403	358	358	313
Wall-2	0	0.00	0.25	0	0	0	0	0	0	0	0	0	0	0
Wall-3	0	0.00	0.25	0	0	0	0	0	0	0	0	0	0	0
Wall-4	0	0.00	0.25	0	0	0	0	0	0	0	0	0	0	0
TOTAL				2369	3317	3791	4265	4265	4265	4265	4265	3791	3791	3317
Window(heat transmission due to temp. difference)														
	Ag[m2]	K[W/m2C]												
Window-1	50	6.29		1560	2184	2496	2808	2808	2808	2808	2808	2496	2496	2184
Window-2	50	4.95		1228	1719	1964	2210	2210	2210	2210	2210	1964	1964	1719
TOTAL				2788	3903	4460	5018	5018	5018	5018	5018	4460	4460	3903
Window(Solar heat gain)														
	Ag[m2]	SC[ND]	Dir.											
Window-1	50	0.96	S	1905	3666	6238	8142	8571	7476	5143	2666	1714	1428	952
Window-2	50	0.53	S	1052	2024	3444	4495	4732	4127	2839	1472	946	789	526
TOTAL				2956	5691	9681	12638	13303	11603	7982	4139	2661	2217	1478
Lighting		Af[m2]	L[W/m2]											
		576	20	11520	11520	11520	11520	11520	11520	11520	11520	11520	11520	11520
Office equipments		Af[m2]	qs, ql[W/m2]											
(S)		576	10	5760	5760	5760	5760	5760	5760	5760	5760	5760	5760	5760
(L)		0	0	0	0	0	0	0	0	0	0	0	0	0
Human	P[P/m2]	Af[m2]	qe. qs[W/P]											
(S)	0	576	63	3617	3617	3617	3617	3617	3617	3617	3617	3617	3617	3617
(L)	0	576	56	3214	3214	3214	3214	3214	3214	3214	3214	3214	3214	3214
Air infiltration			Vi[m3/h]											
		(S)	311	521	729	833	937	937	937	937	937	833	833	729
		(L)	311	2586	2586	2586	2586	2586	2586	2586	2586	2586	2586	2586
Outside fresh air			Vo[m3/h]											
		(S)	1728	2893	4051	4629	5208	5208	5208	5208	5208	4629	4629	4051
		(L)	1728	14367	14367	14367	14367	14367	14367	14367	14367	14367	14367	14367
Room Cooling Load														
			(S)	30930	36419	41941	46476	47321	45888	42443	38730	35980	35490	33305
			(L)	5800	5800	5800	5800	5800	5800	5800	5800	5800	5800	5800
			TOTAL	36730	42219	47741	52276	53121	51688	48244	44530	41780	41290	39106
Fresh Air Cooling Load			(S)	2893	4051	4629	5208	5208	5208	5208	5208	4629	4629	4051
			(L)	14367	14367	14367	14367	14367	14367	14367	14367	14367	14367	14367
			TOTAL	17260	18417	18996	19575	19575	19575	19575	19575	18996	18996	18417
Total Cooling Load			(S)	33823	40469	46571	51684	52530	51096	47652	43938	40609	40119	37356
			(L)	20167	20167	20167	20167	20167	20167	20167	20167	20167	20167	20167
			TOTAL	53990	60636	66737	71851	72696	71263	67818	64105	60776	60286	57523

6. Energy-Saving Techniques for Equipment Operation and Control in Buildings

(1) Flowchart Energy Saving Checks in Buildings



(2) Schematic Diagram Showing Sources of Energy Waste



(3) Energy Saving Techniques for use in Existing Buildings

1) Techniques involving operation control

Item	Techniques to improve the effectiveness of energy saving efforts		Effects	Remarks
(1) Reducing the air intake volume	a. Reviewing the outside air intake requirements	• Find a minimum required outside air intake setting suitable for the building usage and number of people present.		Consideration should be given to malodor generation and an interior pressure balance, in addition to CO^2 concentration control. • Introduction of dampers for outside air intake control
	b. Controlling outside air intake	• Provide outside air intake control according to changes in the number of people in rooms. • Implement outside damper control using a CO^2 concentration detector or a timer based on forecast changes in the number of people present	Effective for buildings with large daily or hourly variations in the number of people present, e.g. department stores and theaters	
	c. Avoiding outside air intake during precooling	• Close dampers completely using a timer during time zones when there are few people present, e.g. at system start-ups	Reductions in air-conditioning load due to outside air and the required air-conditioning capacity	Attention should be given to achieving an interior pressure balance through outside air intake and exhaust operations.
(2) Changing temperature settings	a. Changing thermostat settings (rooms where people stay a long time)	• Generally adopt higher cooling temperature settings.	Summer room temperature: 26°C -> 28°C Reduction in cooling load by about 20%	Reductions in air-conditioning load due to outside air Consideration should be given to variations in the pleasant temperature level depending on each individual, as well as room-to-room temperature fluctuations.
	b. Changing thermostat settings (other rooms)	• Increase temperature settings for spaces where people do not stay long, e.g. corridors and entrance halls.		
	c. Changing temperature settings based on the outside air temperature	• Increase temperature settings as the outside temperature rises		
	d. Changing the temperature setting for the computer room	• Increase temperature settings as high as possible, provided it does not affect computer performance (consideration of 28°C).	Reduction in computer-related cooling load	Consultation with the computer maker Reheating heaters
(3) Preventing overcooling	a. Checking thermostat settings	• Provide frequent manual control where the automatic control system is inadequate.	Interior environment improvements, as well as energy savings, will result.	• Provide dampers at necessary locations if there is no means of air flow control.
	b. Adjusting air supply volumes and flow rates	• Prevent the overcooling of rooms by adjusting branch dampers, etc. • Provide frequent unit air flow and water flow control.		

Item	Techniques to improve the effectiveness of energy saving efforts		Effects	Remarks
(4) Changing humidity setting and avoiding reheating	a. Changing humidistat setting	• Generally adopt higher humidity settings. • Increase the dew point temperature setting where dew point control is provided.	Energy saving effects achieved by changing the dew point temperature of primary air: Summer: 10°C -> 12°C Approx 17% reduction	Increasing humidity settings during cooling is effective for rooms with a small sensible-heat factor where people do not stay long, e.g. theaters, public halls and restaurants.
	b. Avoiding reheating for the purpose of dehumidifying, if there is no need for constant temperature.	• Stop using a reheating device.		
	c. Maintaining the room temperatures by reducing air supply volumes instead of providing reheating, in the case of a fall in sensible heat load during coolingChange from CAV to VAV	• Allow a rise in room humidity during low cooling load hours.		
(5) Adjusting system starting and stopping times and reducing operating hours	a. Optimizing the starting time b. Investigating the stopping time	• Adjust time schedules for starting and stopping according to days of the week and seasons. • Operate only minimum necessary equipment after hours (overtime hours).	Energy savings through the shortening of the duration of precooling Reductions in system operating hours	
	c. Shortening operating hours d. Reducing the size of the supply area	• Reduce the operating hours of ventilating fans for the machine room, parking space, etc. • Introduce local air-conditioning (concentrated air-conditioning within limited areas)	Reductions in blower operating hours Reductions in air-conditioner operating hours	
(6) Reducing air supply volumes	a. Adjusting air supply and exhaust volumes for the machine room, parking area, etc.	• Check the ventilation frequency, as well as the minimum air flow requirement according to the Parking Facilities Law, the Building Standards Law, etc. • Decrease air flow by modified the pulley instead of individually controlling duct system dampers, when dealing with excessive air supply by blowers.	Since blower power consumption increases proportionally with the cube of air flow rate, a 10% decrease in air flow rate will result in a 27% decrease in power consumption.	Investigation is necessary as to whether temperature and humidity conditions will deteriorate to such an extent as to be detrimental to office equipment, etc.

Item	Techniques to improve the effectiveness of energy saving efforts		Effects	Remarks
(7) Operating heat source equipment efficiently	a. Group-controlling boilers, refrigerating machines, etc.	• Reduce the number of active units during partial load operations.	Improvement in total efficiency Improvement in the coefficient of performance	Partial load operation characteristics and other data relating to equipment targeted for energy-saving efforts, including its associated equipment, must be thoroughly known. Care should be taken where there are strict temperature control requirements.
	b. Adjusting cold water outlet temperature settings for refrigerating machines			
	c. Adjusting the cooling water temperature setting	• Lower the cooling water temperature to the lowest tolerable level for refrigerating machines via cooling tower fan shutdown control. Apply the same technique to cooling tower by-pass valve.	Improvement in the coefficient of performance	The lower limit of cooling water temperature setting must be established. Turbo-refrigerating machines: 15°C Absorption refrigerating machines 25°C
(8) Heavy utilities	a. Operation and management of heavy utilities	• Reduce the number of elevators and escalators in operation. • Reduce the frequency of elevator stopping.	Reductions in power required to operate heavy utilities	Target a utilization factor of just below 50%.
(9) Hot-water supply and sanitary systems	a. Operation and management of hot-water supply system b. Sanitary system	• Reduce both hot-water supply hours and areas. • Lower hot-water supply temperatures depending on usage. • Provide flush valve fine adjustments.	Reduction in unnecessary energy consumption Reduction in heat losses relating to hot-water supply Reduction in boiler energy consumption Reduction in water consumption	
(10) Lighting facilities	a. On-off management of lights	• Keep illumination level to the allowable minimum • Turn off some lights in over-illuminated working spaces • Reduce lighting time before working hours begin. Illuminate floor by floor during early morning cleaning, etc., depending on actual work progress. • Turn off lights in rooms which are not in use. • Turn off lights near windows.	Reduction in lighting hours Reduction in cooling load	
(11) Electrical facilities	a. Operation and management of the electrical facilities	• Connect loads in such a way as to balance the phases of three-phase power feeders.		Check on the low load operation of electrical facilities.

3) Techniques involving modifications to equipment

Item	Techniques to improve the effectiveness of energy saving efforts		Effects	Remarks
(1) Building	a. Increasing the thermal insulation of external walls	• Modify walls and windows to improve their thermal insulation. • Modify the roof and floors to improve their thermal insulation. • Thermally insulate window panes.	Reductions in air-conditioning load due to heat transmission through the building structure	• Exterior thermally insulating construction method (aluminum panels etc.) • Wooden frames can be used in the interior of existing buildings.
	b. Avoiding solar radiation	• Provide blinds and curtains • Provide louvers and eaves • Modify window panes • Sprinkle the roof with water and provide water tank on it.	Reductions in air-conditioning load due to solar radiation	• Solar radiation control film • Use blow water for cooling etc.
	c. Preventing drafts	• Modify the entrance and provide a revolving door, an enclosed buffer area, etc.	Reductions in air-conditioning load due to intrusion of outside air	Automatic doors allow considerable drafts from outside.
	d. Improving lighting	• Provide reflective louvers and eaves. • Paint room interiors in light colors. • Finish walls with a surface coating.	Reflecting effects Maintenance of brightness	
	e. Improving ventilation	• Modify window frames and provide windows that can be opened.		
(2) Type of heat source	a. Heat recovery and reuse	• Use total enthalpy heat exchangers • Use heat recovery heat pumps • Recover heat from exhausts and drainages (boiler flue gas, drainage from the hot-water - system, steam drainage, etc.) • Recover heat from refrigerating machine cooling water • Recover heat from air-conditioning system return air	Reduction in air-conditioning load due to outside air (approx 70% recovered) Improvements in the coefficient of performance of heat pumps as a result of heat recovery For hot air supply and reheating during cooling Reductions in air supply and exhaust fan power consumption	• Installation of exhaust ducts and exhaust fans Ventilation of polluted rooms
	b. Modification of the heat source system	• Convert the system to a heat storage type. • Modify the heat storage tank and heat storage system. • Modify the heat source to convert it to a high efficiency one. • Change the type of heat source operation control system.	Reduction in contract power demand Improvement in the efficiency of the heat source	• Heat pumps etc.

2) Techniques involving maintenance and management

Item	Techniques to improve the effectiveness of energy saving efforts	Effects	Remarks
(1) Maintenance and cleaning of equipment	(a) Clean air-conditioning fan-coil units and filters. (b) Inspect and repair duct leaks. (c) Clean condensers and evaporators.	Improvements in heat exchange efficiency Reductions in energy consumption associated with heat distribution	Cleaning of interior air inlets and outlets
(2) Repair and replacement of equipment	(a) Repair equipment and devices exhibiting performance degradation due to corrosion, wear, tear, etc. (b) Carry out replacement in cases where performance degradation cannot be rectified even if repairs are provided.	Improvements in equipment and heat exchange efficiencies	
(3) Inspection of automatic control equipment	(a) Check the precision of sensors. (b) Check operation of valves, dampers, etc. (c) Above all, inspect the heat source control system.	Improvements in the interior environment, as well as energy saving effects	Air leaks from air piping
(4) Strengthening the supervision of equipment	(a) Increase meters and other measuring instruments to help monitor energy consumption and interior environment conditions, etc. (b) Check management items.	Labor saving as well as energy saving effects	
Others	(a) Place OA equipment with the same temperature and humidity condition in the same space. (b) Remove objects near air outlets, etc. that interfere with air flow, such as other equipment and decorations. (c) Keep shut doors leading to the outside or rooms without air-conditioning, providing "Do not open" signs on them. (d) Provide ventilation in toilets only when they are used by linking its operation to that of lighting. (e) Place a wind cover at outside air inlets so as to prevent excessive outside air intake. (f) Keep blinds shut if there is solar radiation while cooling is being provided. (g) Do not wear too many clothes while cooling is provided. (h) Broadcast messages appealing for energy saving efforts at the beginning and end of working hours within the building. (i) Create an energy conservation promotion organization.		Blinds should be drawn down at the end of work (to avoid morning solar radiation).

Item	Techniques to improve the effectiveness of energy saving efforts		Effects	Remarks
(3) Distribution system	a. Modification of hot and cold water piping systems	• Change to variable water flow type. • Increase differences between water utilization temperatures. • Reduce piping resistance and water velocity. • Change to selective on-off control. (VWV system) • Increase the heat insulation of piping.	Reductions in power consumption by pumps [Three-way valve control -> Two-way valve control Changes in the size of elbows, tees and pipes Dividing pumps into groups (collective pump capacity control)]	• Selective on-off control It is necessary to check the number of coil rows in connection with change in water volume.
	b. Modification of duct systems	• Change to a variable air flow duct system. • Increase differences between - air outlet and room temperatures. • Reduce air velocity inside the duct. • Increase the heat insulation of ducts.	Reductions in power consumption by fans [CAV -> VAV High velocity ducts -> Low velocity ducts]	Necessary check points include ventilation frequency in connection with change in air flow rates and air flow distribution in connection with change in air outlet temperatures.
	c. Modification of the type of air-conditioning system	• Review the air-conditioning zoning strategy and control each zone individually after increasing the number of zones. • Introduce an outside air intake control system. • Change the type of air conditioning system: from all-air to water-air type: from constant air flow to variable air flow type. • Switch from reheating to VAV type. Change the air supply volume according to changes in sensible heat load.	Energy savings and improvements in the interior environment Reductions in energy consumption accompanying heat distribution and outside air cooling Single duct system -> FCU system CAV system -> VAV system	Zoning and control equipment locations • Introduction of new exhaust fans Carbon dioxide concentration control
	d. Others	• Introduction of air curtains • Introduction of local exhaust outlets	Load reduction as a result of preventing outside air from leaking in Reduction of heat generation in the rooms	
(4) Heavy utilities	a. Heavy utilities	• Implement group-control for elevators.		

Item	Techniques to improve the effectiveness of energy saving efforts		Effects	Remarks
(5) Hot-water supply and sanitary systems	a. Hot-water supply system b. Sanitary system	• Strengthen the thermal insulation of the hot-water supply system • Improve the hot-water supply system. Through a change from the central to local type • Introduce water saving devices. • Wash urinals using a sensor. • Finish floors with coating. • Utilize rain water.	Reductions in heat losses Savings in water consumption No more need for washing with a brush	• Utilization of running steel pipes (to reduce head loss)
(6) Lighting facilities	a. Limiting lighting areas	• Split the power distribution circuit for lighting. • Provide an individual switch for every lighting fixture. • Implement the automatic control of lighting using timer switches. • Implement local lighting. • Introduce outdoor lighting timers and automatic on-off switches.		• Canopy switches • Timers and photoelectric sensors
	b. Increasing lighting efficiency	• Change to high efficiency lamps. • Modify or replace lighting fixtures.	Improvements in lighting efficiency	• Electronic ballast type high frequency lamps • Bulb-shaped fluorescent lamps
(7) Power receiving facilities		• Introduce power condensers to improve power factor. • Introduce demand supervisory control. • Improve the power factor of transformer secondary circuits.	Power factor improvements Reductions in the maximum power demand	• Automatic power factor control device • Power demand controller • Placement of power condensers on the load side of transformers