Final Summary Report by Air Conditioner Evaluation Standard Subcommittee, Energy Efficiency Standards Subcommittee of the Advisory Committee for Natural Resources and Energy

The Air Conditioner Evaluation Standards Subcommittee conducted deliberations on judgment standards for the manufacturers or importers (hereinafter referred to as "manufacturers") concerning performance improvement of air conditioners, and prepared a final summary report as below.

1. Evaluation of Current Standards

The weighted harmonic mean of energy consumption efficiency by the volume of shipments of air conditioners (limited to those of wall-hung type among non-ducted types whose cooling capacity is 4.0 kW or lower out of air conditioners used for both cooling and heating) whose the target fiscal year finished in the 2004 freezing year was 5.05 (for products shipped in the 2004 freezing year). It corresponds to improvement by 67.8%, when compared with the weighted harmonic mean of the energy consumption efficiency by shipments prior to introduction of the Top Runner Standard (i.e., products shipped in the 1997 freezing year), which was 3.01. This means that improvements surpassing the energy consumption efficiency (5.00) and the assumed improvement rate (66.1%), which was then assumed in case that Top Runner standards were achieved.

In view of the above, energy-saving efforts in air conditioners (limited to those of wall-hung type among non-ducted types whose cooling capacity is 4.0 kW or lower out of air conditioners used for both cooling and heating) have been progressing well as a result of efforts by the manufacturers for energy conservation, and thus we can evaluate that the current standards based on the Top Runner Program are functioning effectively.

2. Target Scope [See Attachment 1]

This review shall cover air conditioners for household use (limited to those of wall-hung type among non-ducted types whose cooling capacity is 4.0 kW or lower, out of air conditioners used for both cooling and heating) whose the target year finished in the 2004 freezing year.

Air conditioners that use any energy other than electricity as a heat source for heating, highly gas-tight/heat-insulating housing duct air-conditioning systems, and multi-functional heat pump system air conditioners shall be excluded.

3. Items to be judgment standards for manufacturers

(1) Target fiscal year [See Attachment 2]

It shall be the fiscal year 2010.

(2) Target standard values [See Attachments 3 to 4]

With regard to air conditioners that manufacturers ship within Japan for the target fiscal year, the weighted harmonic mean of the energy consumption efficiency (Annual Performance Factor (APF)) calculated in (3) by the volume of shipments for each manufacturer per category shown in the table below shall not exceed the target standard value.

Category	Unit Form	Cooling Capacity	Dimension Type of Indoor Unit	Target Standard Value (APF)
A	Air Conditioners of wall-hung type among the non-duct types (excluding multi-type that control operation of indoor unit separately)	3.2 kW or lower	Dimension-defined type	5.8
B			Free–dimension type	6.6
C		Over 3.2 kW and 4.0 kW or lower	Dimension-defined type	4.9
D			Free–dimension type	6.0

Remarks: "Dimension Type of Indoor Unit" means that, with a standard Japanese wooden house as a model, air conditioner models whose indoor unit has horizontal width of 800 mm or less and height of 295 mm or less shall be defined as a dimension-defined type. Air conditioners other than those of dimension-defined type shall be free-dimension type.

In addition, note that we decided to categorize air conditioners by dimension of indoor unit, because it was feared that only those of free-dimension type might remain on the market otherwise, resulting in a collision with household equipment.

(3) Energy consumption efficiency measurement method [See Attachment 5]

As an index of the energy consumption efficiency of air conditioners, Annual Performance Factor (APF) shall be used. The measurement method shall be a calculation method specified in Japanese Industrial Standards C9612: 2005 Room Air Conditioner.

(4) Display items and others

Items to be displayed shall follow the provisions in the Household Good Quality Labeling Law. The items concerning energy saving shall be as follows:

1) Display items:

a) Category
b) Cooling capacity
c) Cooling power consumption
d) Cooling energy consumption efficiency
e) Heating capacity
f) Heating power consumption
g) Heating energy consumption efficiency
h) Cooling/heating average energy consumption efficiency
i) Annual Performance Factor
j) Manufacturer's name

(Note) Regarding the display of a) and i) in the above, revision of the Electric Machinery and

Appliance Quality Labeling Regulations is required.

2) Compliance items

a) The cooling capacity shall be displayed in kilowatts measured by the method specified in the cooling capacity test in Japanese Industrial Standards B8615-1. In this case, the allowable range shall be up to minus 5% of the displayed value.

b) The heating capacity shall be displayed in kilowatts measured by the method specified in the heating capacity test in Japanese Industrial Standard B8615-1. In this case, the allowable range shall be up to minus 5% of the displayed value.

c) The cooling power consumption shall be in watts or kilowatts measured by the method specified in the cooling power consumption test in Japanese Industrial Standard B8615-1. In this case, the allowable range shall be up to plus 10% of the displayed value.

d) The heating power consumption shall be in watts or kilowatts measured by the method specified in the heating power consumption test in Japanese Industrial Standard B8615-1. In this case, the allowable range shall be up to plus 10% of the displayed value.

e) The cooling energy consumption efficiency or heating energy consumption efficiency shall be a numeric value obtained by dividing the cooling capacity in kilowatts measured by the method specified in a) above by the cooling power consumption in kilowatts measured by the method specified in c) above. The obtained value shall be displayed to two places of decimals.

f) The heating energy consumption efficiency shall be a numeric value obtained by dividing the heating capacity in kilowatts measured by the method specified in b) above by the heating power consumption in kilowatts measured by the method specified in d) above. The obtained value shall be displayed to two places of decimals.

g) The cooling/heating average energy consumption shall be obtained by summing the cooling energy consumption efficiency and the heating energy consumption efficiency and then dividing it by 2. The obtained value shall be displayed to two places of decimals.

h) Annual Performance Factor shall be obtained by dividing the sum of heat quantity to be removed from indoor air and that to be added to indoor air throughout cooling period and heating period by total energy consumption to be consumed during the same period; these heat quantities are obtained by the test and calculating method for seasonal energy efficiency specified in Japanese Industrial Standards C9612: 2005. The obtained APF shall be displayed to one place of decimal.

i) Should any difference arise in measurements specified in a) to h) above due to different rated frequencies, measured values would be displayed for every rated frequency.

j) The display items listed in 1) above shall be clearly placed on prominent positions in catalogues or instruction manuals so that consumers can refer to them when selecting equipment.

4. Proposals for energy saving

(1) Actions of users

1) Through effective use of information such as “energy-saving labels”, etc, users are encouraged to make an attempt to not only select an air conditioner with excellent energy consumption efficiency but also reduce energy by using it appropriately and efficiently.
2) Users shall attempt to select an air conditioner while considering the setting or size of a room to install it in, in order to make full use of its capacity.

(2) Actions of retailers

1) Retailers shall attempt to not only distribute air conditioners with excellent energy consumption efficiency but also provide appropriate information for users to select them through use of “energy-saving labels”, etc. When using the energy-saving labels, as air conditioners vary in performance depending on areas where to be used, retailers shall carefully display labels in a manner that users can easily understand and get no false impression by means of, for example, showing conditions for calculating energy consumption efficiency.

(3) Actions of manufacturers

1) Manufactures shall promote technological development toward energy saving of air conditioners and attempt to develop products with excellent energy consumption efficiency.
2) From viewpoint of promoting the spread of air conditioners with excellent energy consumption efficiency, manufacturers shall attempt to provide appropriate information to encourage users to select air conditioners with excellent energy consumption efficiency, by displaying “energy-saving labels” in a catalogue, etc. As air conditioners vary in performance depending on areas where to be used, in implementing the energy-saving labels, manufacturers shall carefully display them in a manner that users can easily understand and get no false impression, by means of, for example, showing conditions for calculating energy consumption efficiency.
3) To respond to improved energy-saving performances such as insulation performance of buildings, etc. in recent years, manufacturers shall review guideline for applicable room sizes according to cooling capacity and heating capacity.
4) Since Annual Performance Factor (APF) adopted in this report is based on numeric values computed under certain conditions, manufacturers shall attempt to improve the measurement

method in the future as well, so that evaluation can be carried out in a condition closer to actual use.

(4) Actions of Government

1) From viewpoint of promoting the spread of air conditioners with excellent energy consumption efficiency, the government shall attempt to take necessary action such as the spread and enlightenment activities, in order to promote actions of users and manufacturers.
2) The government shall periodically and continuously monitor the implementation status of the display items by manufacturers and attempt at appropriate operation of the law so that information on energy consumption efficiency can be provided to users in a correct and easily understandable manner.
3) The energy-saving standard based on the Top Runner Program is a very effective approach for energy saving of products. Therefore, the government shall make efforts to spread it internationally by catching appropriate opportunities.

Attachment 1

Target Scope

This review shall cover air conditioners for household use (limited to those of wall-hung type among non-ducted types whose cooling capacity is 4.0 kW or lower, out of air conditioners used for both cooling and heating) whose the target year finished in the 2004 freezing year.

Note, however, that air conditioners that meet under the following requirements shall be excluded.

1) Air conditioners that use any energy other than electricity as a heat source for heating

Air conditioners being composite products that use electricity for cooling and use combustion heat of gas, oil, etc, as a heat source for heating. They are in limited use in cold region where heating by heat pumps cannot accommodate heating load.

Presently no international standard regarding the measurement method for these products exists, and no national standard has been established, either.

* Transition in shipments (2004 freezing year): Approximately 10,000 units

2) Ducted air-conditioning systems for highly gas-tight/heat-insulating housing

Air conditioners being dedicated for highly gas-tight/heat-insulating housing and with heat exchange capability between exhaust air and intake air, etc., for which no evaluation method has been established yet.

* Transition in shipments (2004 freezing year): Approximately 3,500 units

3) Multi-functional heat pump system air conditioners

Air conditioners being capable of floor heating and/or hot-water supply through the use of heated water produced through their heat pump systems. Their shipment number is still small although they are expected to spread in future.

* Transition in shipments (2004 freezing year): Approximately 2,000 units

Attachment 2

Target Year, etc, of Air Conditioners

1. In general, a considerable improvement in energy consumption efficiency is made when a model change takes place, and a typical development period of these new products is approximately 2 to 3 years. For this reason, consideration should be given so that manufacturers can take 1 to 2 opportunities of bringing out new models before the next target fiscal year.
   With the above in mind, it is appropriate to set the target year of air conditioners to fiscal year 2010 (Heisei 22), which is five years after establishment of the standard values.

2. In addition, it is expected that improvement rate of energy consumption efficiency in the target fiscal year will be approximately 22.4% based on an assumption that there will be no change from current volume of shipments (results of fiscal year 2005) as well as model composition of each category.

<Overview of Estimation>

(1) Energy consumption efficiency estimated from values of actual achievements of air conditioners shipped in fiscal year 2005: 4.9

(2) Energy consumption efficiency estimated from the target standard values of air conditioners to be shipped in the target fiscal year: 6.0

(3) Improvement rate of energy consumption efficiency

$$\frac{(6.0-4.9)}{4.9}\times 100 = \text{Approximately } 22.4\%$$

Attachment 3

Classification of Air Conditioners

1 Basic Idea

Idea of classification for overall air conditioners under the current standard is based on the following:

1) Classification by basic function
2) Classification by unit form
3) Classification by cooling capacity

In the scope of this review, air conditioners are classified as shown below:

Unit Form	Cooling Capacity
Air conditioners of wall-hung type among the non-duct types (excluding multi-type air conditioners that control operation of indoor unit separately)	2.5 kW or lower
	Over 2.5kW, 3.2 kW or lower
	Over 3.2kW, 4.0 kW or lower

Table 1: Current classification in the scope of this review

Air conditioners shall be classified, taking into consideration the fact that heat exchangers recently have been growing in size in order to improve energy-saving performance.

2. Specific Classification Method

(1) Classification by design concept accompanying increased size of heat exchangers

The growing size of heat exchangers shall be a major factor in improvement of energy consumption efficiency. Thus, current products (products that have satisfied the current standard) are roughly divided based on the design concept, as shown below:

1) Models that meet the current standard values in terms of energy saving while considering installation space and/or resource saving as well
2) Models that pursue energy-saving performance with no limit being imposed in terms of installation space and/or resource saving

If this classification was not made in this review, it was feared that only air conditioners categorized in 2) having excellent energy saving performance might remain on the market, possibly leading to a disharmony with housing setup. Thus, with a standard Japanese wooden house as a model, air conditioners shall be classified as follows: (See Figure 1)

1) Dimension-defined type: Models whose indoor unit is 800 mm or less in horizontal width and 295 mm or less in height.
2) Free-dimension type: Models other than those mentioned above

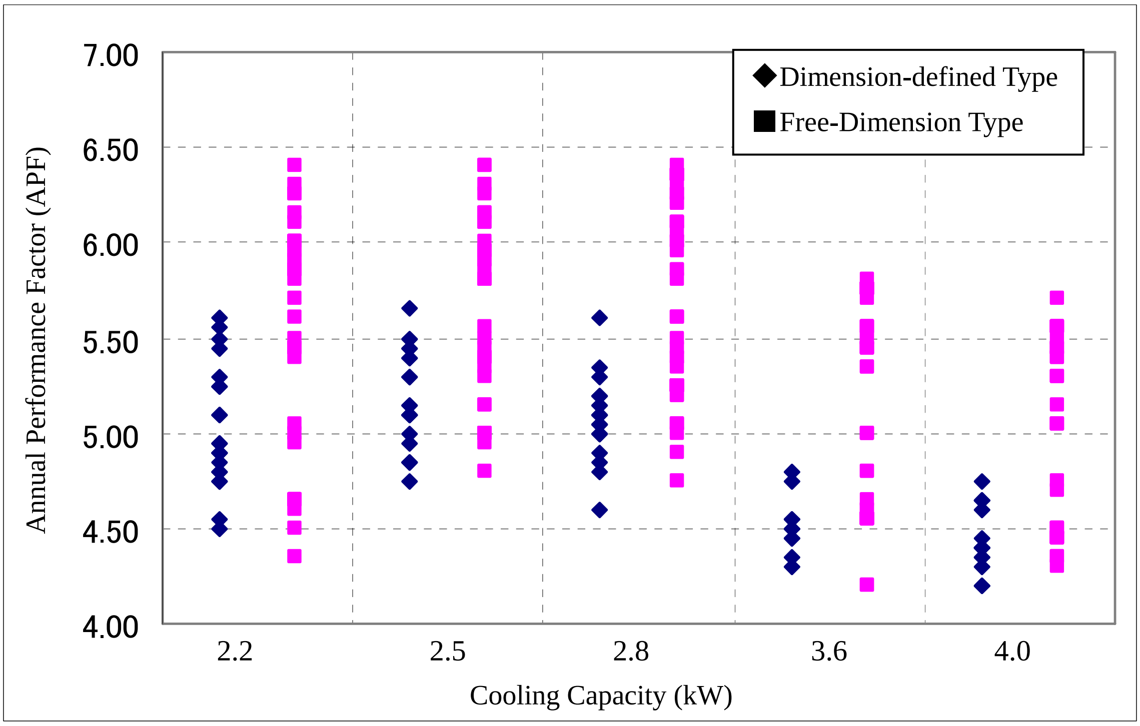


Figure 1: Cooling Capacity – Annual Performance Factor (APF) (Products in FY 2005)

(Reference: Basis for thresholds in dimension categories of indoor units)

Given a standard Japanese wooden house as a model, the thresholds of indoor units are 800 mm or less in horizontal width and 295 mm or less in height. The rationale for them is as follows:

1. Basis for height being 295 mm or less
   1) Building Standards Law, Enforcement Ordinance, Article 21 (Ceiling height of a living room)

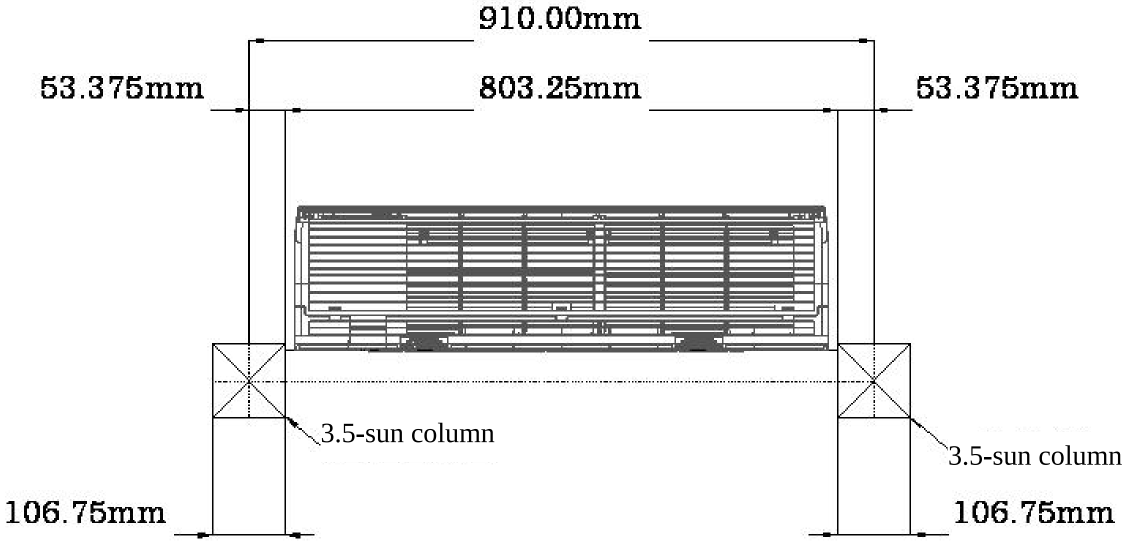
      The ceiling height should be 2.1 m or more.
   2) Standard window height is 1.8 m.
   3) Approximately 5 mm is needed as a clearance for preventing an air conditioner from interfering with ceiling.

   With the above in mind,

2,100mm－1,800mm－5mm＝295mm

2. Basis for horizontal width being 800 mm or less
   1) Inter-column module dimension according to the old Japanese measuring system (Shaku-Kan system) is 910 mm.
   2) Dimension of a 3.5-sun (sun: one of the units in Shaku-Kan system) column is 106.75 mm.
   3) Approximately 5 mm is needed as a clearance for preventing an air conditioner from interfering with ceiling.

   With the above in mind, 910mm－106.75mm－5mm≒800mm



3. <u>Setting of Basic Classification Proposal</u>

   With the above in mind, we shall define a basic classification proposal, as shown in the following table:

Temporary Category	Unit form	Cooling Capacity	Dimension Type of Indoor Unit
A	Air conditioners of wall-hung type among the non-duct types (excluding multi-type air conditioners that control operation of indoor unit separately)	2.5 kW or lower	Dimension-defined type
B			Free-dimension type
C		Over 2.5kW, 3.2 kW or lower	Dimension-defined type
D			Free–dimension type
E		Over 3.2 kW, 4.0 kW or lower	Dimension-defined type
F			Free-dimension type

Attachment 4

Target Standard Values of Air Conditioners

1. Idea on Establishment of Target Standard Values

(1) Basic idea

We shall set target standard values based on the idea of Top Runner Method. The specific policy shall be as follows:

1) Target standard values shall be set for every category that has been defined appropriately.
2) As for categories where future technological advances are expected to improve efficiency, the target standard value shall allow for as much improvement as possible.
3) Target standard values shall not conflict among categories.

(2) Target fiscal year

In general, a considerable improvement in energy consumption efficiency is made when a model change takes place, and a typical development period of these new products is approximately 2 to 3 years. For this reason, consideration should be given so that manufacturers can take 1 to 2 opportunities of bringing out new models before the next target fiscal year.

With the above in mind, it is appropriate to set the target year of air conditioners to fiscal year 2010 (Heisei 22), which is five years after establishment of the standards.

(3) Room for improvement of energy consumption efficiency by future technology advances

Technology development of air conditioners has been undertaken primarily for establishment of a comfortable living environment. Although technology development related to improvement of energy-saving performance has been implemented to accomplish the current target standards, development of each elemental technology has almost reached its limit and thus innovative technology development is hardly expected.

[Main examples of technologies for improving efficiency of air conditioners] (See reference 2)

・ Compressors: High-efficient compression technology, neodymium magnet, improvement of motor winding, low-iron-loss magnetic steel sheet, reduction of mechanical loss, reduction of pressure drop in suction/discharge, sine-wave drive control

・Fan motor: Introduction of DC brushless motor, increased number of poles/introduction of slots, optimization of core shape, reduction of circuit loss, optimal energization
・Electronically controlled valve
・Heat exchanger: Three-row arrangement of an indoor unit, multi-stage bending, improvement of fin shape, improvement of piping process

Although these technologies have been introduced into the current Top Runner equipment, it can be said that there still remains room for efficiency improvement in individual technologies, considering the fact that these introduced technologies differ depending on manufacturers and that each manufacturer is taking its own approach for further improvement of efficiency.
Taking into consideration the fact in comprehensive manner that these factors might contribute to higher efficiency, we set the target standard value by 3% up from the current Top Runner Value for the dimension-defined type and by 4% for the free dimension type.

2. Specific Target Standard Values

Target standard values of air conditioners shall be represented in real numbers.
To be specific, for each category the best value of energy consumption efficiency shall be a Top Runner Value, and a value obtained by adding improved efficiency to the Top Runner value shall be a target standard value.

In both the dimension-defined type and free dimension type, the category for cooling capacity of 2.5 kW or lower and the category for cooling capacity of over 2.5kW and 3.2 kW or lower shall be integrated, because their Top Runner Values are at almost same level.

Table 1: Top Runner Values of Air Conditioner

Temporary Category	Unit Form	Cooling Capacity	Dimension Type of Indoor Unit	Top Runner Value(APF)
A	Air Conditioners of wall-hung type among the non-duct types (excluding multi-type air conditioners that controls operation of indoor unit separately)	2.5 kW or lower	Dimension-defined type	5.65
B			Free–dimension type	6.40
C		Over 2.5kW,3.2 kW or lower	Dimension-defined type	5.60
D			Free–dimension type	6.40
E		Over 3.2kW, 4.0kW or lower	Dimension-defined type	4.80
F			Free–dimension type	5.80

Table 2: Target Standard Value of Air Conditioner

Category	Unit Form	Cooling Capacity	Dimension Type of Indoor Unit	Top Runner Value (APF)	Improved Efficiency (%)	Target Standard Value (APF)
A	Air conditioners of wall-hung type among the non-duct types (excluding multi-type air conditioners that control operation of indoor unit separately)	3.2kW or lower	Dimension-defined type	5.65	3.0	5.8
B			Free–dimension type	6.40	4.0	6.6
C		Over 3.2kW, 4.0kW or lower	Dimension-defined type	4.80	3.0	4.9
D			Free–dimension type	5.80	4.0	6.0

(Reference 1)

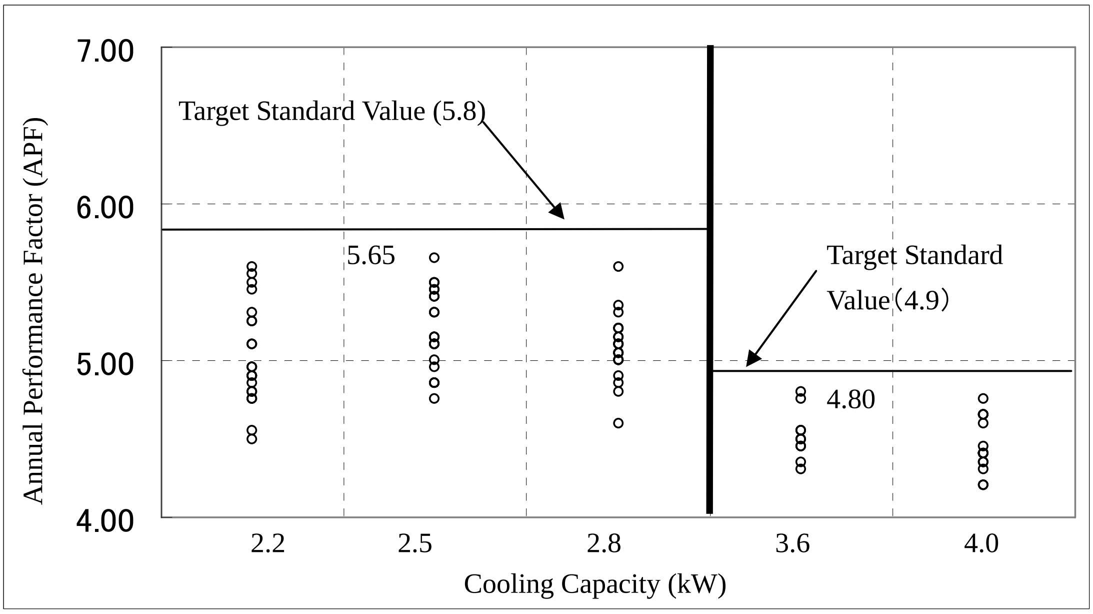


Figure 1: Top Runner Values and Target Standard Values in Categories A and C (for Dimension-defined Type)

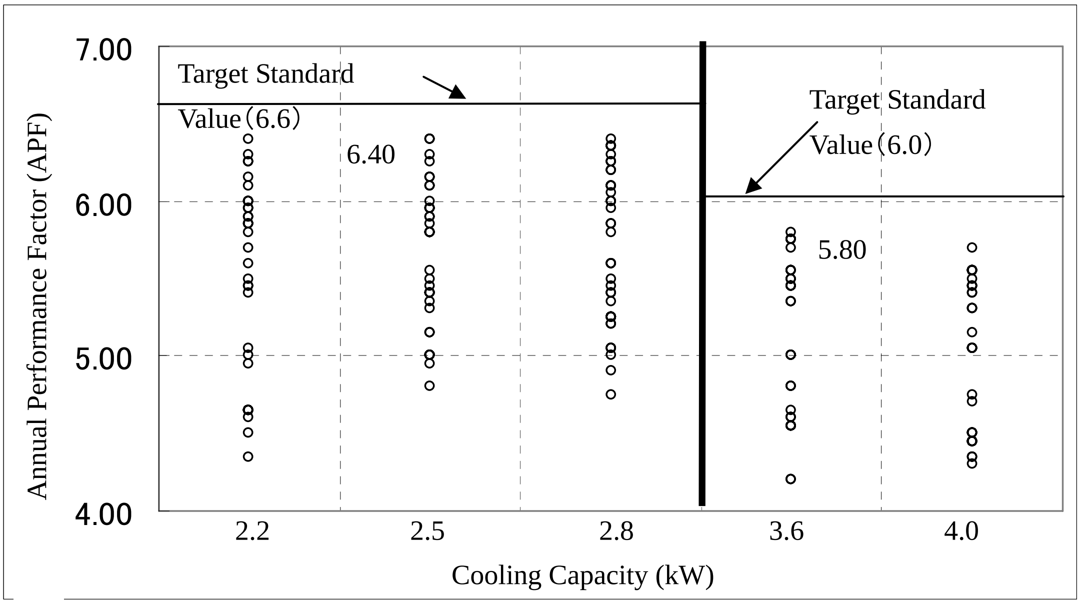


Figure 2: Top Runner Values and Target Standard Values in Categories B and D (for Free-Dimension Type)

(Reference 2)

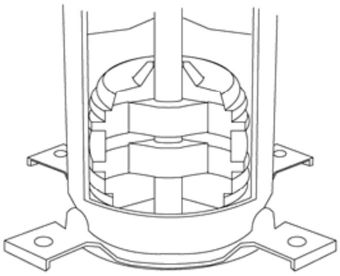
Examples of Main Technologies for Improving Efficiency of Air Conditioners

(1) Compressor

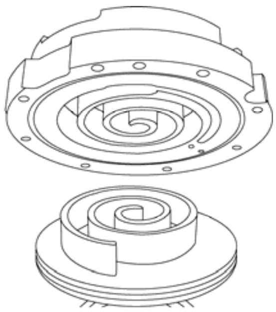
1) High-efficient compression technology

The compressor is the heart of an air conditioner and requires high-precise processing technology.

Although a rotary compressor with rotary method was widely adopted before, a twin rotary method or scroll method with better compression efficiency has now been developed and adopted.



Twin Rotary Compressor



Scroll Compressor

[Reduction of mechanical loss]

Sliding loss is reduced by improving precision in process of a sliding unit. In a scroll compressor, swirling scroll and fixed scroll are made to stick together, thereby reducing leak. When the sticking force is strong, sliding loss between these scrolls increases. On the other hand, when the sticking force is weak, a gat appears and causes increasing leak. Thus, in order to maintain the minimum sticking force to reduce sliding loss, there is provided a control valve for controlling pressure on the back of the swirling scroll so that there will be appropriate back pressure according to operating state.

[Reduction of pressure loss in suction/discharge]

An attempt to reduce a pressure loss is being made by improving a shape of passage. For instance, a suction passage is made to be tapered for a suction opening, and a discharge opening is stepped to be expanded.

2) Compressor motor

[Neodymium magnet]

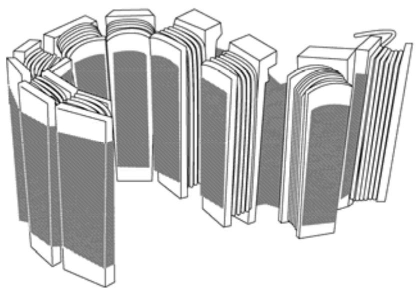
An attempt to improve motor efficiency is made by changing ferrite that has been conventionally used in a rotor to neodymium that has high magnetic flux density.

[Improvement of line area ratio of winding]

A proportion of total coil sectional area within the stator to a stator slot area is referred to a line-area ratio. If the line-area ratio could be increased, the coil sectional area could be expanded, thereby reducing copper loss.

In the past, as coil was threaded through a narrow space within a closed stator and winded, there remained a large dead space in the stator slot. However, development of a new manufacturing method allows for the high line-area ratio by winding the coil to the stator divided and spread out.

In addition, coil covering an end face of a stator core can be reduced by directly coiling the stator (intensive winding), thus also reducing copper loss.



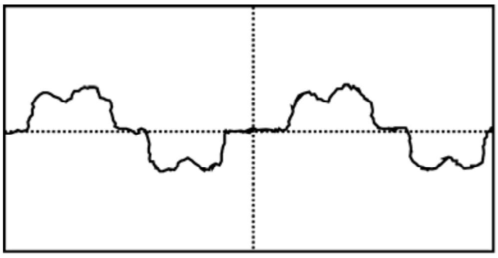
[Low-iron-loss magnetic steel sheet]

One of the factors of iron loss is eddy-current loss caused by eddy current generated in an iron core. Attempts have been made to prevent this current from flowing easily by means of, for example, adoption of silicon steel plates and/or thin laminated steel sheets.

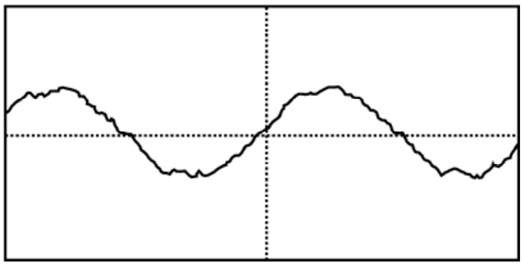
3) Sine-wave drive control of compressor motor

In the past, the square wave drive system, which switches current-conducting phases at every 60 degrees, was adopted as an operating method of a compressor for an inverter air conditioner. With this system, a position of a rotor could be sensed from induced voltage of the motor while motor current was not conducting, and thus the motor speed could be changed easily.

In this system, however, the square motor current caused reduced motor efficiency. To respond to this, recently, coupled with improved arithmetic performance of the microcomputer, the sine wave driving of motor current was made possible through development of the control technology to estimate a rotor position from motor current.



Waveform of Motor Current of Square-Wave Driving System



Waveform of Motor Current of Sine-Wave Driving System

(2) Blowers

1) Indoor blower

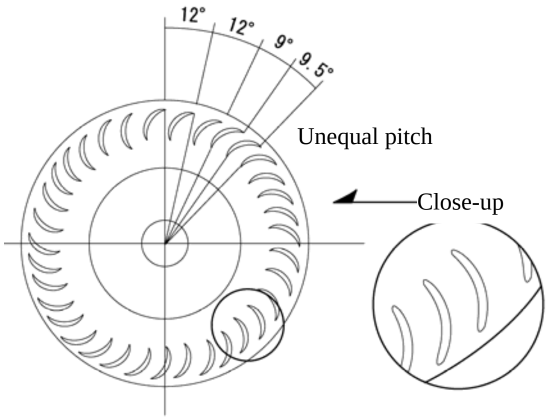
Various types of fans depending on unit form are used for blowers of indoor units. A "cross flow fan" is used for most of the wall-hung type air conditioners.

[Cross Flow Fan]

Although a cross flow fan was composed of blades that were processed metal sheets in the past, an attempt to increase air volume has been made through introduction of plastic blades having a wing-shaped section and growing size of fan diameter, while controlling noise.

The layout and molding of a fan and blades have also been improved, by having random spacing between blades, angling a fan shaft, etc.

Random Pitch



2) Outdoor blower

In general, a propeller fan is used for an outdoor unit of an air conditioner. Although it was made of processed metal sheets in the past, it is now made of plastics. An attempt to increase air volume has been made by improving a blade shape, while suppressing noise.

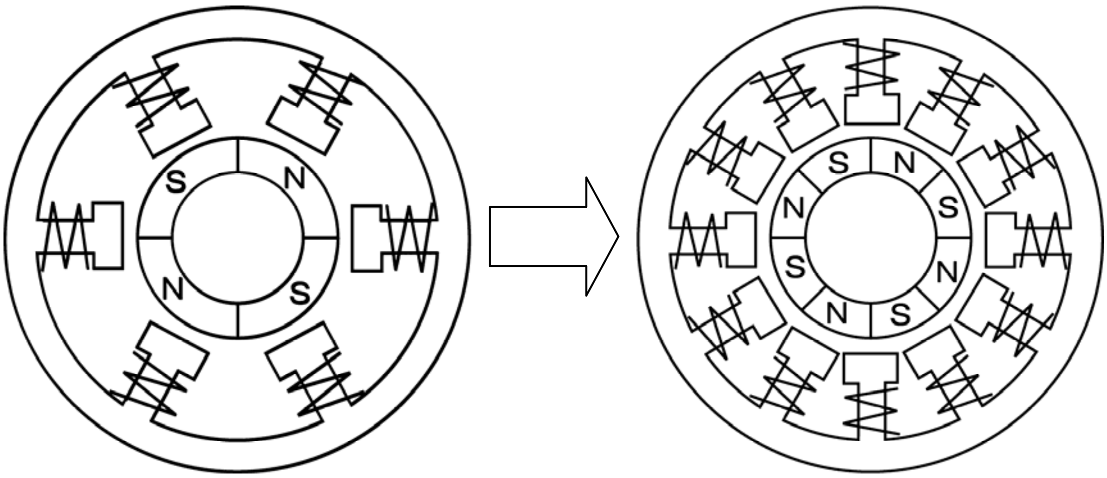
3) Fan motor

For fan motors for both indoor and outdoor units, an efficient DC brushless motor has replaced a conventional AC motor. In addition, to improve efficiency of a DC brushless motor, techniques that were developed for a compressor motor having high power consumption are incorporated, and optimization efforts have been made to achieve the most efficient combination of technologies, such as increased number of poles/slots, a devised core shape, reduction of circuit loss, optimal energization, etc.

Example of Increased Number of Poles/Slots

4-pole 6-Slot

8-pole 12-Slot



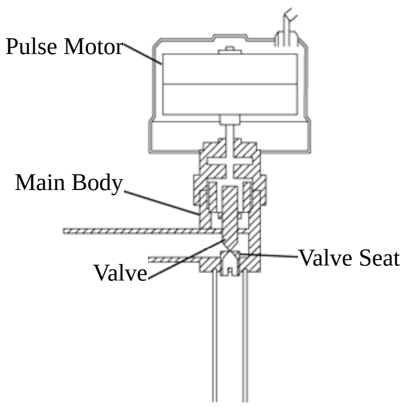
(3) Electronically controlled expansion valve

A decompressor is a component to create high-pressure and low-pressure states in a refrigerant circuit. Until now a capillary tube has been used primarily. A capillary tube refers to a thin and long copper pipe being about 0.2 to 2 m long and having an inside diameter of 1 mm to 2mm. This pipe generates pipe resistance and achieves throttling action (decompression).

A capillary tube has been widely used for a room-air conditioner as it can be implemented with a simple structure. However, adjustment of appropriate degree of throttling according to number of revolutions is not possible because the degree of throttling is constant even when the number of revolutions of a compressor varies.

Thus, an electronically controlled expansion valve has become used, which enables appropriate degree of throttling based on an electronic signal from a microcomputer determining the operating state of an air conditioner. The valve is such structured that a pulse motor rotates based on an electronic signal, and a gap between the valve and a valve seat is adjusted by converting the rotation into up-and-down motion, thereby controlling the degree of throttling.

This could achieve efficient control of the refrigerant flow, depending on the operating state, such as the changing number of revolutions of a compressor used in an inverter air conditioner. Thus, the electronically controlled expansion valve has become mainstream.



(4) Heat exchanger

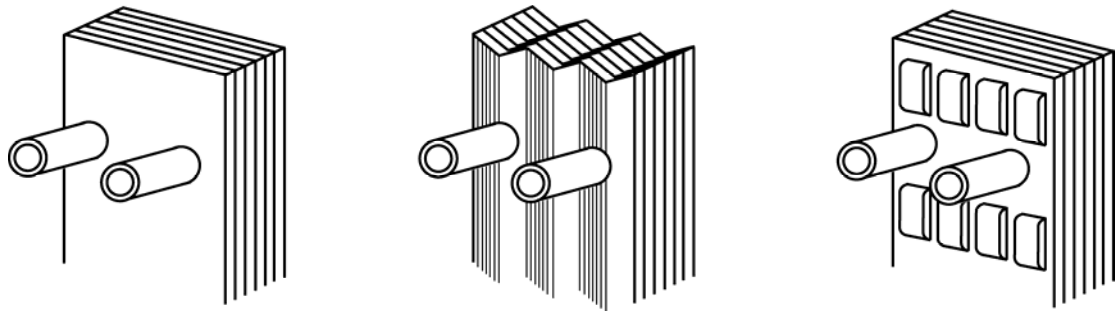
A heat exchanger is one of the important components of an air conditioner. It exchanges heat between indoor air and a refrigerant in an indoor unit, and between outdoor air and a refrigerant in an outdoor unit.

A fin-tube-type heat exchanger in which a copper tube for the refrigerant penetrates a plate-like aluminum fin for air is used as the heat exchanger.

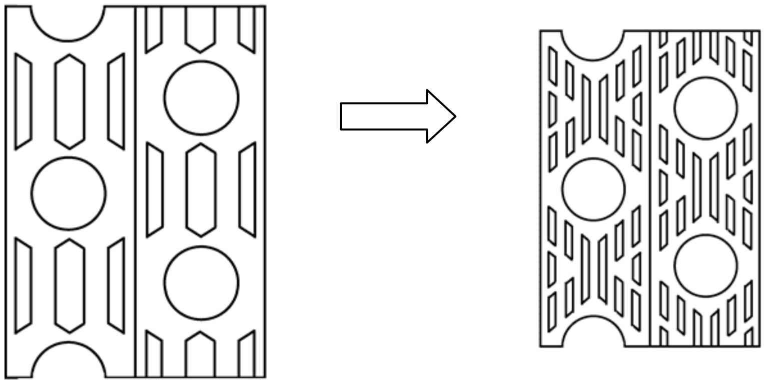
1) Fin for heat exchange

Initially, a flat aluminum plate (plate fin) was used for a fin of a heat exchanger. Then, a corrugated fin and a slit fin with cutouts were adopted, and improvement of the slit shape has been made. In addition, in case that wind speed of air passing through a heat exchanger is nonuniformly distributed, improvement has been carried out to increase the overall heat exchange capacity by equalization of the wind speed distribution, such as increasing the height of a fin facing faster wind speed and lowering the height of a fin facing slower wind speed.

Plate Fin | Corrugated Fin | Slit Fin



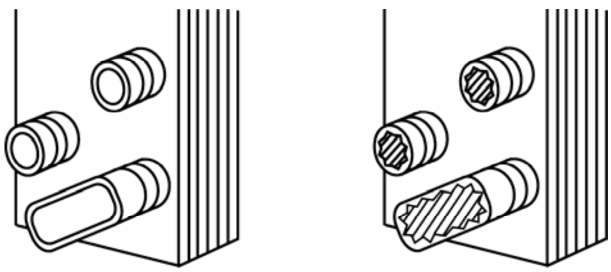
Improvement of Slit Shape



2) Copper tube for heat exchange

Initially, a smooth tube, inner surface of which was not processed like a copper tube, in general, was used for a heat exchanger. For saving energy, a tube with internal groove was developed and optimization of a groove shape has been pushed forward.

Smooth Tube | Tube with Internal Groove



Optimization of a Groove Shape

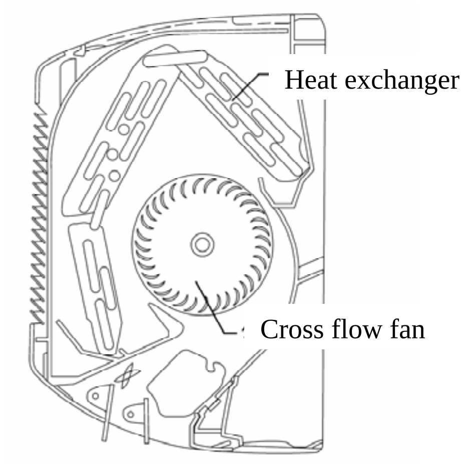
In addition, in order to improve heat conduction with a refrigerant and a copper pipe, reduction of a pipe diameter has been implemented.

[Example] Pipe Diameter 9.5mm → 7.0mm → 6.3mm

Improvement has also been made to reduce pressure loss, and thereby increase the total heat exchange capacity, by reducing a pipe diameter for a part of liquid state and increasing it for a part of gas state, depending on the condition of refrigerant liquid and gas passing through the piping.

3) Form of heat exchanger

In separate wall-hung type indoor units that account for most of the room-air conditioners, a cross section of the conventional heat exchanger was molded like a plate. However, in order to expand heat exchange area in a limited space, bent one and one molded like a curved surface have been developed.



In addition, the heat exchanger in the initial indoor unit was arranged in two columns. However, improvement has been made to increase a heat transmission area and augment the heat exchange capacity by partially arranging it in three columns, if an indoor unit structure can afford enough space for it.

Attachment 5

Energy Consumption Efficiency of Air Conditioners and Measurement Method

1. Basic Idea

When air conditioners were designated as equipment for the Top Runner Standard in 1998 (Heisei 10), "COP (Coefficient of Performance)" was adopted as an index related to energy consumption efficiency. The COP is represented by either a numeric value obtained by dividing cooling capacity (kW) by cooling power consumption (kW) (hereinafter referred to as "cooling COP") or a numeric value obtained by dividing heating capacity (kW) by heating power consumption (kW) (hereinafter referred to as "heating COP"). The COP of a cooling-cum-heating air condition is a mean of the cooling COP and the heating COP.

However, said index is an evaluation approach principally featuring constant-speed models. Thus, in recent years when inverter models have become a mainstream, it is pointed out that the index is no longer necessarily an appropriate evaluation approach. Thus, it is considered reasonable to newly adopt the Annual Performance Factor (APF) that is an energy saving evaluation standard better representing the reality.

2. Specific Energy Consumption Efficiency and Measurement Method

An index related to energy consumption efficiency of air conditioners shall be "Annual Performance Factor (APF)", and a measurement method thereof shall be in accordance with the calculation method specified in Japanese Industrial Standards C9612: 2005 Room Air Conditioners.

3. Annual Performance Factor (APF)

A performance index in the current Energy Saving Law uses COP of rated conditions of cooling and heating.

However, the capacity of air conditioners changes according to ambient air and also to the number of revolutions of a compressor in case of inverter models, which are the current mainstream (room-air conditioners of capacity variable type); therefore, evaluation in a manner closely reflecting actual use is difficult to be achieved only with the rated conditions.

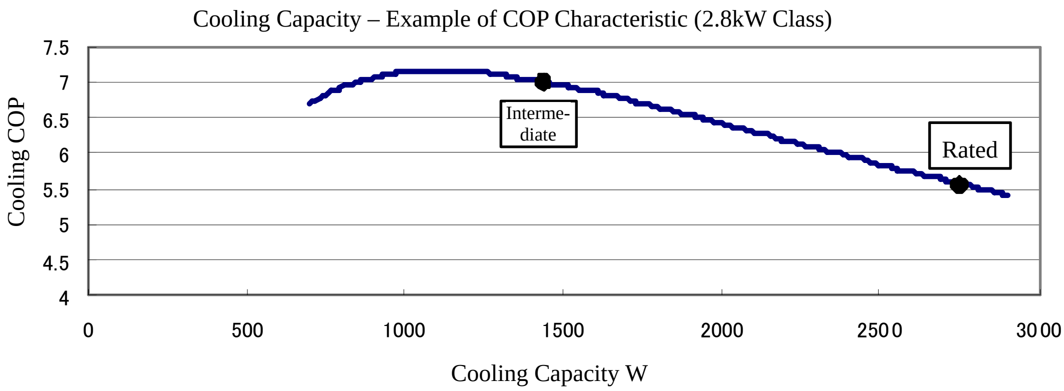


Figure 1: Cooling Capacity – COP Characteristic (2.8 kW Class)

Thus, Annual Performance Factor (APF) was provided to enable evaluation of energy consumption efficiency that is well representing actual use, by means of considering occurrence time of outside air temperature during cooling/heating period and efficiency of air conditioners according to capacity change that is a characteristic of inverter models.

Shown below is a comparison between COP and APF:

	Cooling/Heating Average COP	Annual Performance Factor (APF)
Calculation Method	Cooling/heating average COP = (cooling rated COP + heating rated COP)/2 where a rated COP refers to a value obtained by dividing capacity (W) at a rated point by then power consumption (W). (Evaluation in both cooling and heating conditions)	A proportion of summation (Wh) of heat quantity to be subtracted from and added to indoor air throughout cooling and heating periods to total electric energy to be consumed during the same periods.
Measurement Points	Two points Cooling rated Heating rated	Five points Cooling rated Cooling intermediate Heating rated Heating intermediate Heating low temperature
Features	▪ Measurements points are only a few, i.e., 2 points and the measurement is simple to conduct. ▪ They are efficiencies of fixed points and hardly representing actual use at all.	▪ Measurements points are many, i.e., 5 points and thus measurement takes time. ▪ Since the method calculates efficiency considering intermediate performance that frequently occurs in actual use, it is possible to calculate efficiency closer to reality.

Table 1: Comparison of COP and APF

(1) Calculation conditions for Annual Performance Factor (APF)

The prerequisite for calculation of Annual Performance Factor (APF) shall be as follows:

・Outside air temperature: setting Tokyo's as a model

・Indoor set temperature: 27℃ when cooling/20℃ when heating

・Period: Cooling period: 3.6 months (June 2 to September 21)

Heating period: 5.5 months (October 28 to April 14)

・Operating Time: 18 hours, from 6:00 to 24:00

・Housing: An average wooden house according to Japanese Industrial Standards C9612 (face south)

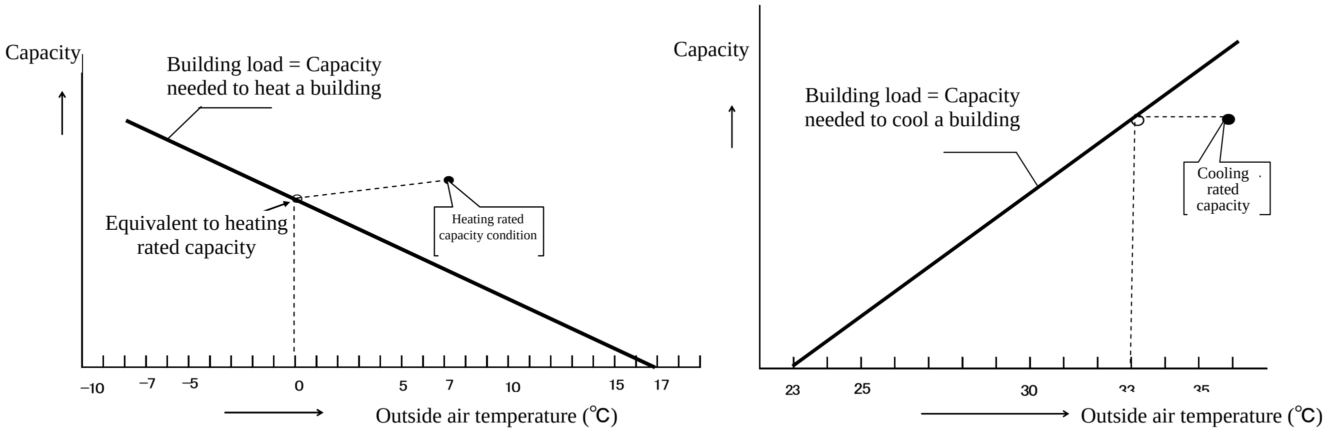


Figure 2: Characteristics of Heating/Cooling Capacity Needed for Air-conditioning a Building, According to Outside Air Temperature

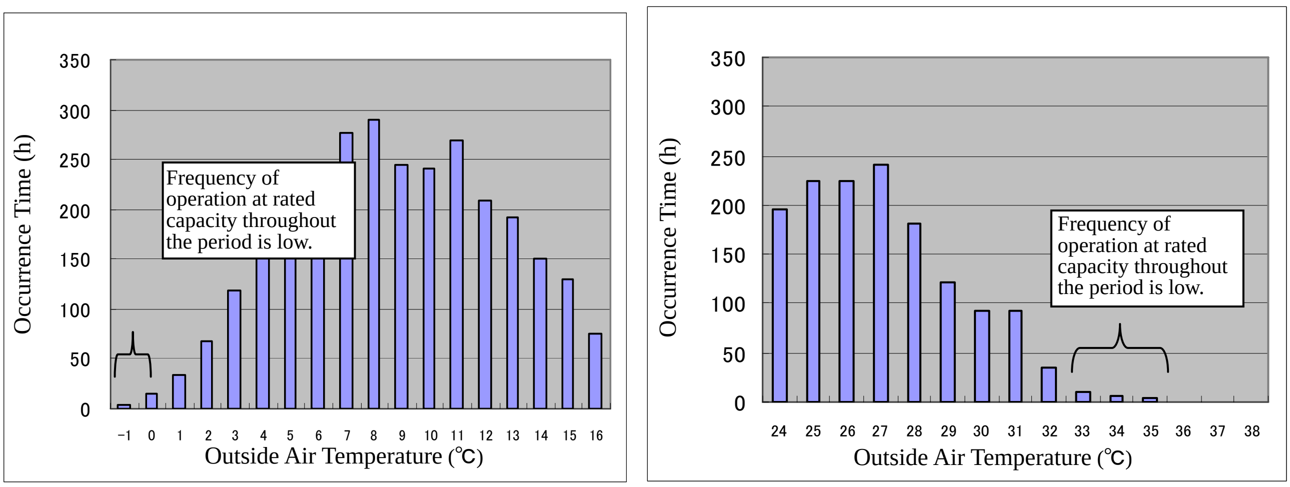


Figure 3: Relationship of Outside Air Temperature and its Occurrence Time in Tokyo

By adding intermediate performance evaluation points that are the most frequent, energy consumption efficiency throughout a period can be calculated simply and accurately.

(2) Calculation of energy consumption efficiency during cooling period

1) The capacity of an air conditioner for every outside air temperature associated with building load is calculated, considering a change in capacity according to outside air temperature, which is determined from capacities at a rated and an intermediate capacity evaluation points.

2) Similarly, power consumption of an air conditioner for every outside air temperature associated with building load is calculated, considering a change in power consumption according to outside air temperature, which is determined from power consumptions at a rated and an intermediate capacity evaluation points.

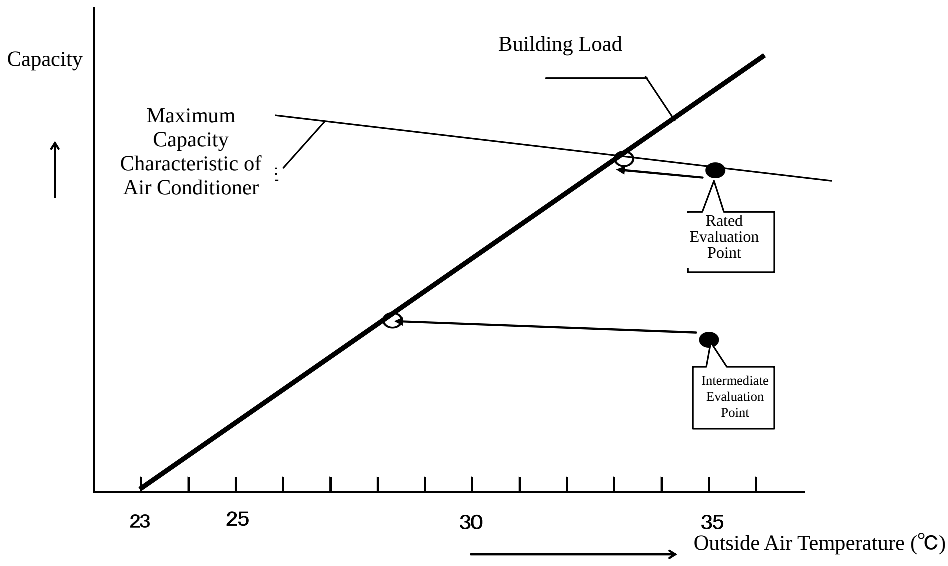


Figure 4: Outside Air Temperature – Capacity When Cooling

3) The heat quantity (kWh) when an air conditioner cools a building is calculated for every outside air temperature from capacities an air conditioner shows per outside air temperature and their occurrence time. Then, the sum total of heat quantities needed for cooling a building at each outside air temperature (Cooling Seasonal Total Load (kWh)) is determined.

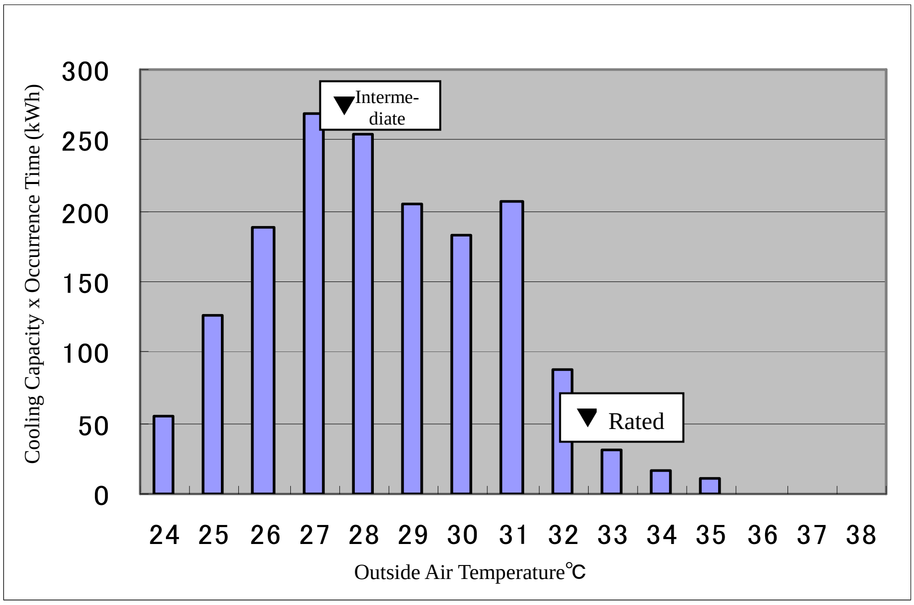


Figure 5: Heat Quantity which Air Conditioner Needed to Cool a Building (Example)

4) The consumed energy (kWh) for cooling a building is calculated for every outside air temperature from power consumptions of an air conditioner and their occurrence time at building load points. Then, the total sum of energy consumed by cooling operation at every outside air temperature (Cooling Seasonal Energy Consumption (kWh)) is determined.

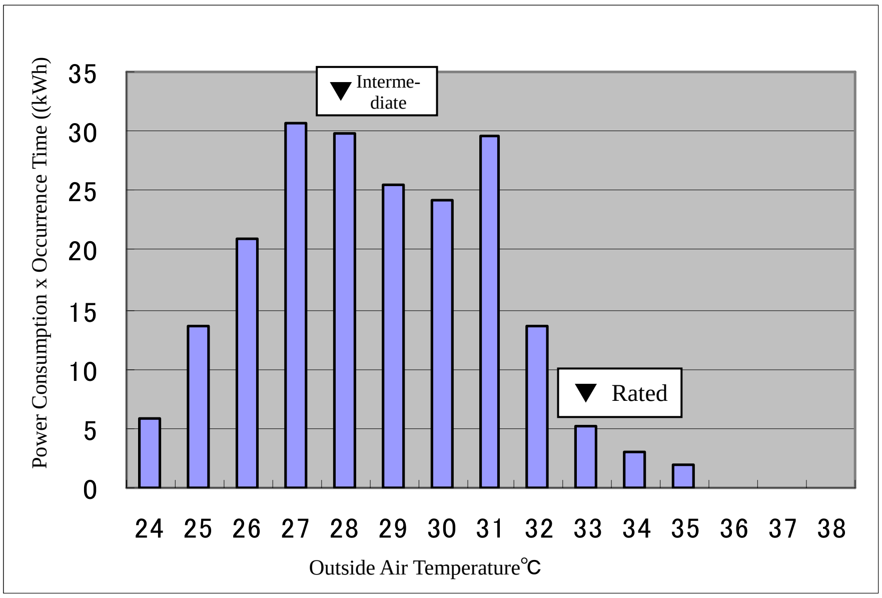


Figure 6: Energy Consumed by Cooling Operation (Example)

5) Cooling Seasonal Performance Factor (CSPF: commonly known as Cooling APF) is determined from Cooling Seasonal Total Load and Cooling Seasonal Energy Consumption.

$$\text{CSPF} = \frac{\text{Cooling Seasonal Total Load (CSTL)}}{\text{Cooling Seasonal Energy Consumption (CSEC)}}$$

(3) Calculation of energy consumption efficiency during heating period

1) The capacity of an air conditioner and its power consumption at each outside air temperature associated with building load is calculated from values at a rated and an intermediate capacity evaluation points.

Similar to the idea for the cooling period, the capacity an air conditioner shows and its power consumption are calculated for every outside air temperature. They will additionally be calculated at a low temperature evaluation point, which is one of the capacity evaluation points. In addition, as for heating operation, when outside air temperature is low, an air conditioner’s capacity and power consumption shall be calculated by adding performance loss due to defrosting a heat exchanger of an outdoor unit.

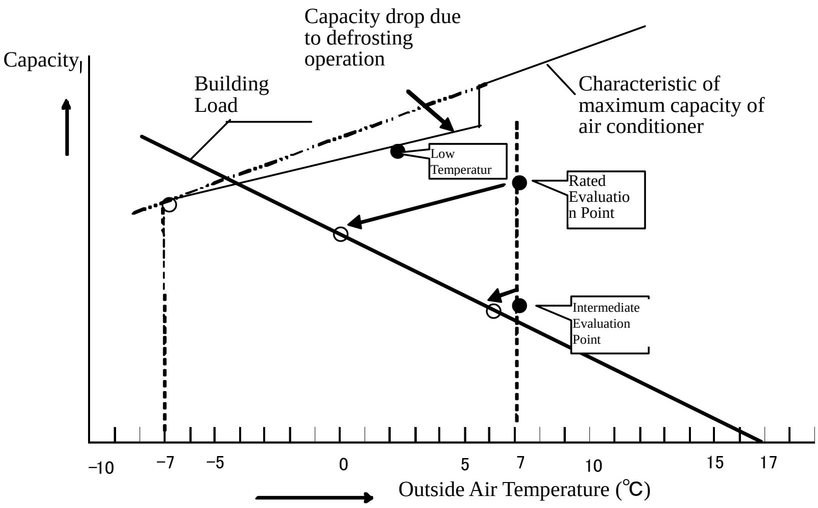


Figure 7: Outside Air Temperature – Capacity When Heating

2) The heat quantity (kWh) when an air conditioner heats a building is calculated for every outside air temperature from capacities an air conditioner shows per outside air temperature and their occurrence time. Then, the sum total of heat quantities needed for heating the building at every outside air temperature (Heating Seasonal Total Load (kWh)) is determined.

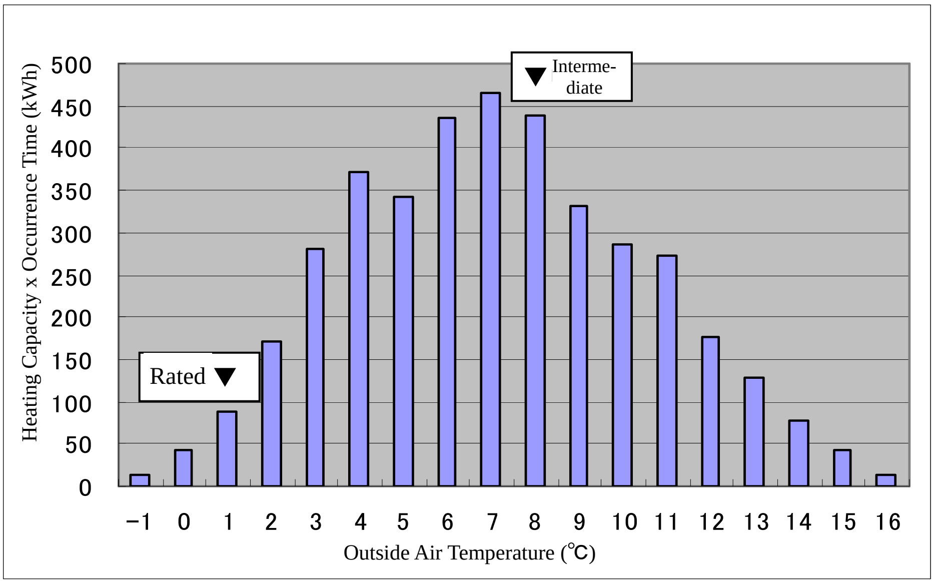


Figure 8: Heat Quantity an Air Conditioner Needed to Heat a Building (Example)

3) The consumed energy (kWh) for heating a building is calculated for every outside air temperature from power consumptions of an air conditioner and their occurrence time at building load points. The total sum of energy consumed by heating operation at every

outside air temperature (Heating Seasonal Energy Consumption (kWh)) shall be determined.

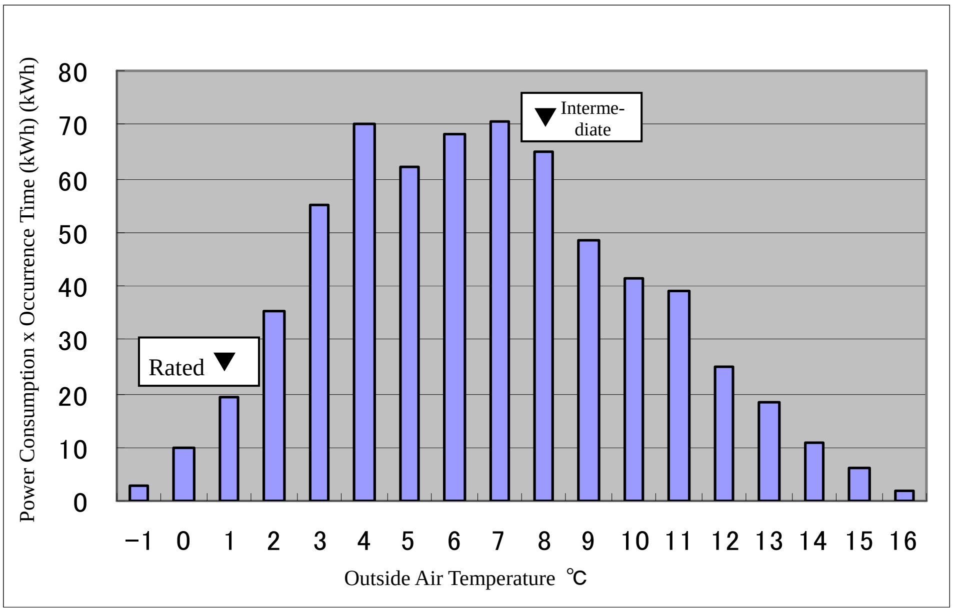


Figure 9: Energy Consumed by Heating Operation (Example)

4) Heating Seasonal Performance Factor (HSPF: commonly known as Heating APF) shall be determined from Heating Seasonal Total Load and Heating Seasonal Energy Consumption.

$$\mathrm{HSPF} = \frac{\text{Heating Seasonal Total Load (HSTL)}}{\text{Heating Seasonal Energy Consumption (HSEC)}}$$

(4) Annual Performance Factor (APF)

Annual Performance Factor shall be calculated from the total load and the seasonal energy consumption of cooling and heating operations.

$$\mathrm{APF} = \frac{\text{Cooling Seasonal Total Load + Heating Seasonal Total Load}}{\text{Cooling Seasonal Energy Consumption + Heating Seasonal Energy Consumption}}$$

Attachment 6

Air Conditioner Evaluation Standard Subcommittee
Energy Efficiency Standard Subcommittee of the Advisory Committee for Natural Resources and Energy
Background of Holding

First Subcommittee Meeting (August 8, 2005)

- Disclosure of the Air Conditioner Evaluation Standard Subcommittee
- Achieving status of air conditioners
- Current situation of air conditioners
- Scope of air conditioners to be covered
- Energy consumption efficiency and measurement method

Second Subcommittee Meeting (December 9, 2005)

- Categories for target setting of air conditioners
- Target standard values and target fiscal year of air conditioners

Third Subcommittee Meeting (January 31, 2006)

- Interim summary report

Attachment 7

Air Conditioner Evaluation Standard Subcommittee, Energy Efficiency Standards Subcommittee of the Advisory Committee on Natural Resources and Energy

List of Members

Chairman:	TAKANORI SAITO	Professor Emeritus, University of Tokyo
Members:	HIROSHI ASANO	Professor in Department of Mechanical Engineering, Graduate School of Engineering, University of Tokyo
	KAZUO UENO	Assistant Research Department Head, Energy Technology Research Department, National Institute of Advanced Industrial Science and Technology
	AKIRA OKAGAKI	Japan Building Mechanical and Electrical Engineers Association
	MAKOTO KAIBARA	PJ Leader, Domestic Air Conditioner Energy Saving PJ, Japan Refrigeration and Air Conditioning Industry Association
	MASAHIKO SASAKURA	Chairman, Package Air Conditioner Technology Ad Hoc Committee, Japan Refrigeration and Air Conditioning Industry Association
	HARUKI SATO	Professor, Department of System Design Engineering, Faculty of Science and Technology, Keio University
	KIKUKO TATSUMI	Managing Director of Nippon Association of Consumer Specialists
	EIJI TOBIHARA	Professor Specialized in Environmental Studies, Graduate School of Frontier Science, University of Tokyo
	YOICHI HORI	Professor, Institute of Industrial Science, University of Tokyo
	TOSHIHISA MASUDA	General Manager, Technology Dept, Energy Conservation Center, Japan
	CHIHARU MURAKOSHI	Director and General Manager of Laboratory, Jyukankyo Research Institute Inc.

Reference 1

Current Situation of Air Conditioners

1. Air Conditioner Market

1-1 Market Trend of Air Conditioners

(1) Scope of air conditioners

Air conditioners (AC) shall be roughly divided into those for buildings and those for transports.

Shown below are an overall view of air conditioners and an overview of shipment volume:

(Unit: Number of units, 2004 Freezing Year)

Air Conditioners	General Air Conditioners for Buildings	Electric Type	Residential Air Conditioners 6,723,072	Service Air Conditioners 731,795	
		Those Other than Electric Type	Gas Engine Heat Pump Air Conditioners 39,703		
	Air Conditioners for Transports		Air Conditioners for Automobiles 4,883,685	Air Conditioners for Buses 12,319	Air Conditioners for Railway Vehicles (Number of units unknown)

Source: Japan Refrigeration and Air Conditioning Industry Association

(2) Transition in the number of shipments of air conditioners

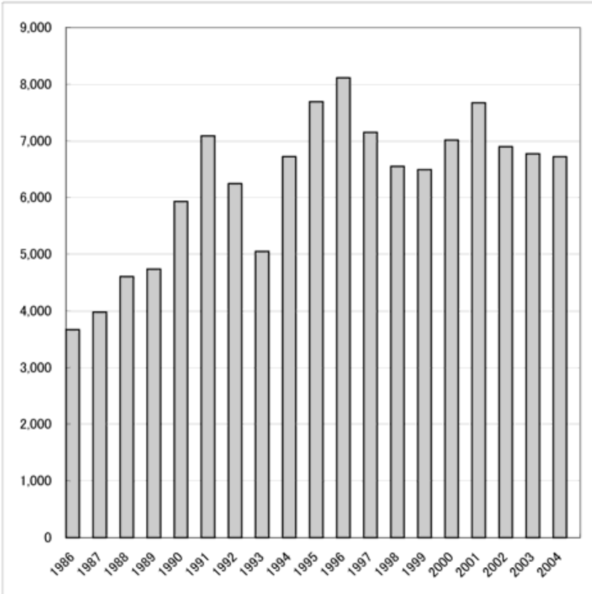
1) Residential air conditioners

Although shipments of residential air conditioners tend to be greatly affected by climate factors, they have been stabilized around 7.0 million units for the past ten years.

(Unit: 1,000 units)

Freezing Year	Total of Domestic Shipments
1986	3,673
1987	3,982
1988	4,605
1989	4,734
1990	5,932
1991	7,092
1992	6,249
1993	5,048
1994	6,724
1995	7,697
1996	8,116
1997	7,154
1998	6,551
1999	6,496
2000	7,019
2001	7,677
2002	6,902
2003	6,774
2004	6,723

(Unit: 1,000 units)



（Freezing Year）

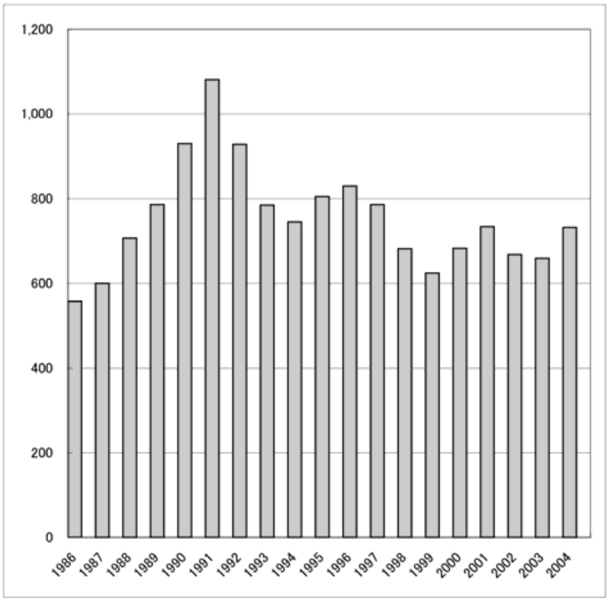
2) Service air conditioners

Although shipments of service air conditioners tend to be affected by economic trends, they have been stabilized around 700,000 units for the past 10 years.

(Unit: 1,000 units)

Freezing Year	Total of Domestic Shipments
1986	557
1987	600
1988	707
1989	786
1990	930
1991	1,081
1992	928
1993	785
1994	745
1995	805
1996	830
1997	786
1998	682
1999	624
2000	684
2001	734
2002	668
2003	659
2004	732

(Unit: 1,000 units)



（Freezing Year）

Source: Japan Refrigeration and Air Conditioning Industry Association

(3) Shipment volume of air conditioners by function/form/cooling capacity

[By Function]

1) Residential air conditioners

A cooling-cum-heating type accounts for 99% of the total shipments.

(Unit: Number of units 2004 freezing year)

Dedicated for Cooling	Cooling-cum-Heating	Total
90,458	6,632,614	6,723,072

Source: Japan Refrigeration and Air Conditioning Industry Association

2) Service air conditioners

A cooling-cum-heating type accounts for 92% of the total shipments.

(Unit: Number of units 2004 freezing year)

Dedicated for Cooling	Cooling-cum-Heating	Total
90,201	674,594	731,795

Source: Japan Refrigeration and Air Conditioning Industry Association

[By Form]

1) Residential air conditioners

Among air conditioners that have a one-to-one combination of indoor unit and outdoor unit, those having a wall-hung type indoor unit account for 98% of the total shipments.

(Unit: Number of units 2004 freezing year)

Single (one to one)		Multiple type	Total
Wall-hung type	Built-in type		
6,562,333 (98%)	90,754 (1%)	69,985 (1%)	6,723,072 (100%)

Source: Japan Refrigeration and Air Conditioning Industry Association

2) Service air conditioners

Air conditioners that have a cassette-type indoor unit account for 63% of the total shipments.

(Unit: Number of units 2004 freezing year)

Floor-installed type	Ceiling-suspended type	Wall-hung type	Cassette type	Built-in type	Duct type	Total
46,646 (4%)	152,373 (15%)	101,054 (10%)	660,168 (63%)	38,881 (4%)	42,653 (4%)	1,041,775 (100%)

Source: Japan Refrigeration and Air Conditioning Industry Association

[By Cooling Capacity]

1) Residential air conditioners

The residential air conditioners whose cooling capacity is in 2.2kW class (mainly for a six-tatami-mat room) has the largest shipment, accounting for 39.8% of the total shipments.

(Unit: Number of units 2004 freezing year)

Applicable Room Size in Terms of the Number of Tatami-Mats	Cooling Capacity (kW)	Total (Number of Units)
Less than 6	Less than 2.2	70,691(1.1 %)
6	2.2	2,675,862 (39.8 %)
8	2.5	1,071,935 (15.9 %)
10	2.8	1,489,616 (22.2 %)
11	3.2	7,907 (0.1 %)
12	3.6	280,523 (4.2 %)
14	4.0	670,664 (10.0 %)
Over 14	Over 4.0	455,874 (6.8 %)
Total		6,723,072 (100.0 %)

Source: Japan Refrigeration and Air Conditioning Industry Association

2) Service air conditioners

Depending on diversity of business buildings, cooling capacities widely range. However, air conditioners having cooling capacity up to 28 kW accounts for 94.1% of the total shipment.

(Unit: Number of units 2004 freezing year)

Cooling Capacity (kW)	Total
~ 4.5	59,668 (8.2 %)
~ 5.0	79,553 (10.9 %)
~ 6.3	44,520 (6.1 %)
~ 8.0	113,107 (15.5 %)
~ 11.2	88,398 (12.1 %)
~ 14.0	105,537 (14.4 %)
~ 16.0	63,329 (8.7 %)
~ 22.0	45,812 (6.3 %)
~ 28.0	88,773 (12.1 %)
~ 40.0	22,365 (3.1 %)
~ 56.0	17,365 (2.4 %)
~ 63.0	838 (0.1 %)
~ 80.0	1,198 (0.2 %)
~ 160	746 (0.1 %)
Over 160	586 (0.1 %)
Total	731,795 (100.0 %)

Source: Japan Refrigeration and Air Conditioning Industry Association

(4) Transition in the number of imported air conditioners

1) Residential air conditioners

The majority of imported air conditioners for household use are from overseas production bases of Japanese manufacturers. The percentage of residential air conditioners that are manufactured overseas and sold in Japan has been increasing, and it is expected to be approximately 40% in 2004.

Unit: Number of units

	Calendar Year	2000	2001	2002	2003	2004
Import	Total	450,354	1,030,780	2,045,781	2,211,207	2,682,811
	China	210,839	252,940	1,561,341	1,808,583	2,371,002
	Thailand	121,912	225,474	198,026	151,834	222,592
	Malaysia	50,853	190,100	152,202	112,181	9,250

Source: Ministry of Finance, Customs Statistics

(Reference)

Freezing Year	2000	2001	2002	2003	2004
Domestic Shipments	7,018,512	7,676,629	6,901,805	6,774,002	6,723,072

Source: Japan Refrigeration and Air Conditioning Industry Association

2) Service air conditioners

There has been almost no import.

(5) Penetration of residential air conditioners and number of air conditioners owned per household

It can be said that now air conditioners prevail among almost every household.

According to the statistic survey of housing/lands by the Ministry of Internal Affairs and Communications, the number of rooms per house is 4.77 rooms, and the number of owned air conditioners will possibly increase in the future. In 2004, the number of air conditioners owned per household has reached 2.8 units per household.

Year/Month	Ownership Rate (%)	Number of Owned Air Conditioners	Number of Owned Air Conditioners Per Household
1984/March	49.3	75.2	1.5
1989/March	63.3	110.7	1.7
1994/March	74.2	151.6	2.0
1999/March	84.4	200.7	2.4
2004/March	87.1	245.3	2.8

Number of Owned Air Conditioners: per 100 households

Source: Cabinet Office, Survey of Consumer Behavior

1-2 Main Domestic Manufacturers

1. Residential Air Conditioners

- Corona Corporation
- Sanyo Electric Air Conditioning Co., Ltd.
- Sharp Corporation
- Daikin Industries, Ltd.
- Chofu Seisakusho Co., Ltd.
- Toshiba Carrier Corporation
- Hitachi Appliance, Inc.
- Fujitsu General Co., Ltd.
- Matsushita Electric Industrial Co., Ltd.
- Mitsubishi Heavy Industries, Ltd. ,
- Mitsubishi Electric Corporation

(In the order of Japanese Syllabary)

2. Service Air Conditioners

- Sanyo Electric Co., Ltd.
- GAC Corporation
- Sharp Corporation
- Daikin Industries, Ltd.
- Toshiba Carrier Corporation
- Nippon PMAC Co., Ltd.
- Hitachi Appliance, Inc.
- Matsushita Electric Industrial Co., Ltd.
- Mitsubishi Heavy Industries, Ltd.
- Mitsubishi Electric Corporation

(In the order of Japanese Syllabary)

2. Energy Saving Efforts in Residential Air Conditioners until Now

2-1 Response to the Current Energy Saving Law

(1) Status of achieving target

At the end of March, 1998, new target values were set according to the Top Runner Program, and the 2004 freezing year was set to be the target year of residential air conditioners.

Although they were high target values requiring considerable improvement, because of efforts made by each of the industrial association member companies, all the member have achieved the target.

Cooling-cum-Heating Type (Heat Pump)

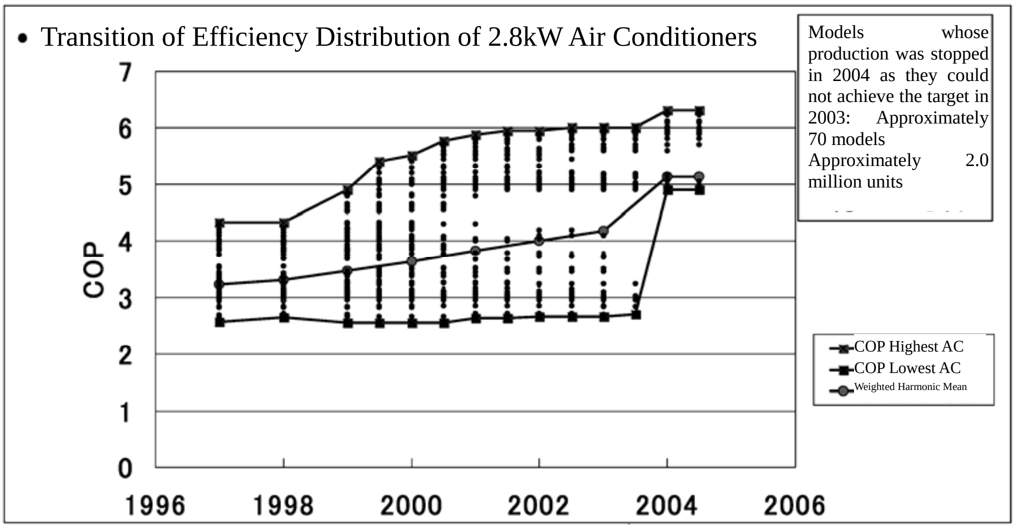
Category		Weighted Harmonic Mean of Cooling/Heating Average COP Achievements of the Industry						Target Values
Unit Form	Cooling Capacity	Fiscal Year 1999	Fiscal Year 2000	Fiscal Year 2001	Fiscal Year 2002	Fiscal Year 2003	Fiscal Year 2004	
Wall-hung Types Among Non-ducted Types	2.5 kW or lower	3.17	3.24	3.37	3.49	3.75	5.33	5.27
	Over 2.5kW, 3.2kW or lower	3.47	3.63	3.83	4.00	4.18	5.14	4.90
	Over 3.2kW, 4.0kW or lower	3.07	3.37	3.57	3.92	3.99	4.10	3.65

Category		Achievement Rate (%)					
Unit Form	Cooling Capacity	Fiscal Year 1999	Fiscal Year 2000	Fiscal Year 2001	Fiscal Year 2002	Fiscal Year 2003	Fiscal Year 2004
Wall-hung Types Among Non-ducted Types	2.5kW or lower	60.2	61.5	63.9	66.2	71.2	101.1
	Over 2.5kW, 3.2kW or lower	70.8	74.1	78.2	81.5	85.3	104.9
	Over 3.2kW, 4.0kW or lower	84.1	92.3	97.8	107.4	109.3	112.3

Source: Japan Refrigeration and Air Conditioning Industry Association

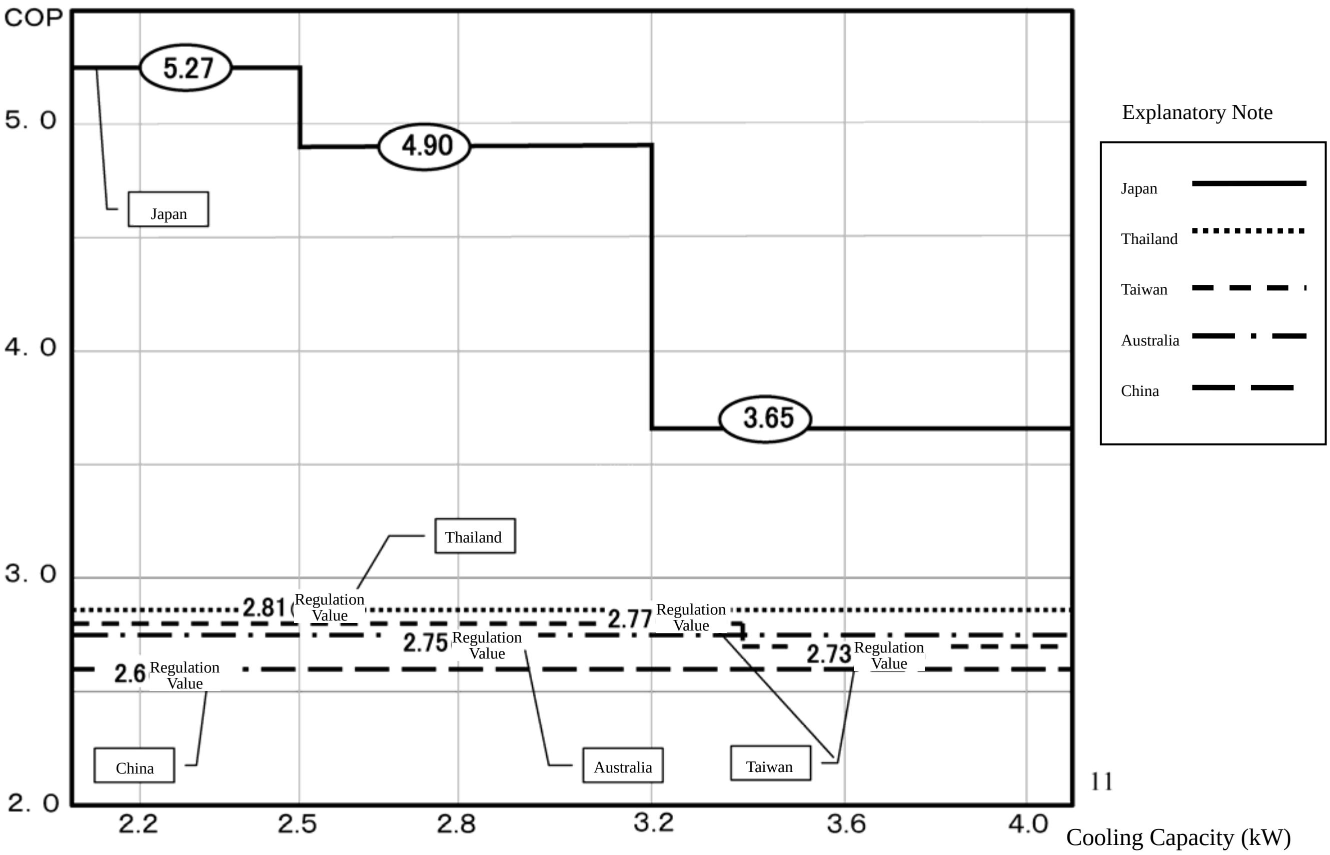
(2) Background to achievement of target

The demand for products that place higher priority on a price than on energy saving performance was strong in the market. Thus, before the target year, in order to ensure the achievement of standards of the Energy Conservation Law, the industry prepared a self-action plan to increase the share of shipments of models that satisfied the standard.



2-2 Comparison with Overseas Energy Saving Regulations

Because of the Top Runner Program implemented by the Energy Conservation Law, the energy saving performance of Japanese air conditioners is at substantially high level in the world. Shown below is a comparison with various overseas standards, for reference:

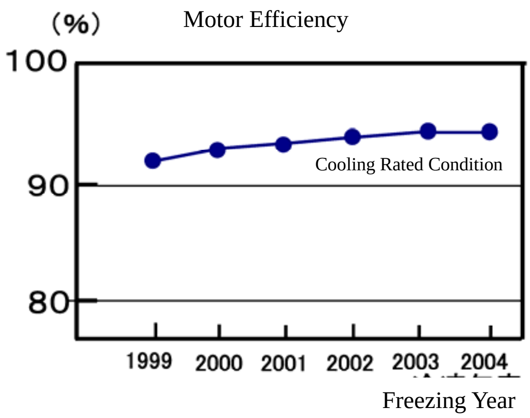


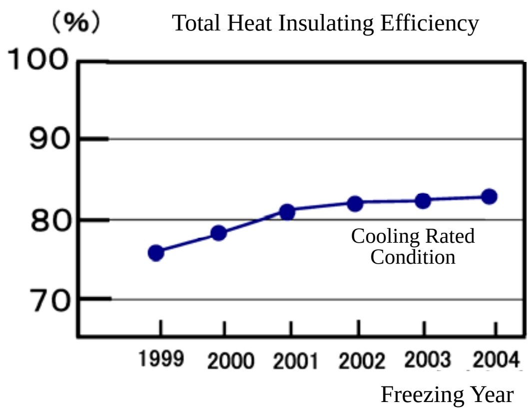
2-3 Technological Approach to Energy Saving of Residential Air Conditioners in the Future

(1) Technology for improving performance of compressor

The efficiency of a compressor is represented by “efficiency of motor” in a power output section and by “total heat-insulating efficiency” indicating how much compression actually takes place without loss using the obtained motive energy.

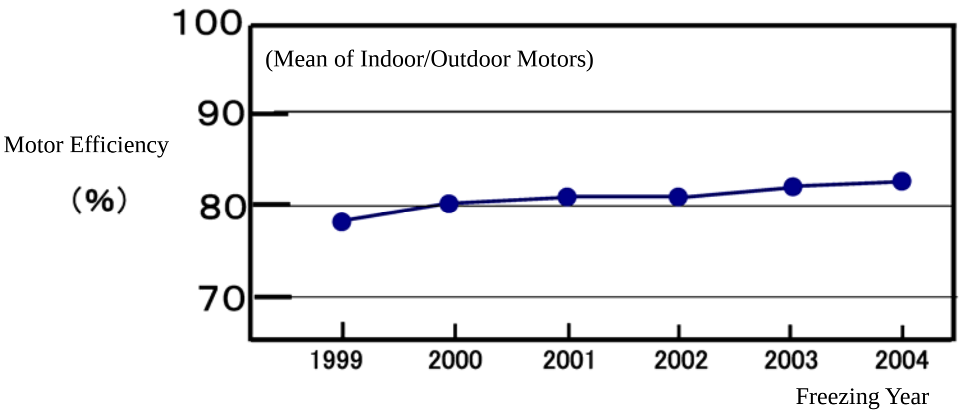
The “compressor motor efficiency” is approximately 95% and “total heat-insulating efficiency” is over 80%.





(2) Technology for improving performance of a fan motor

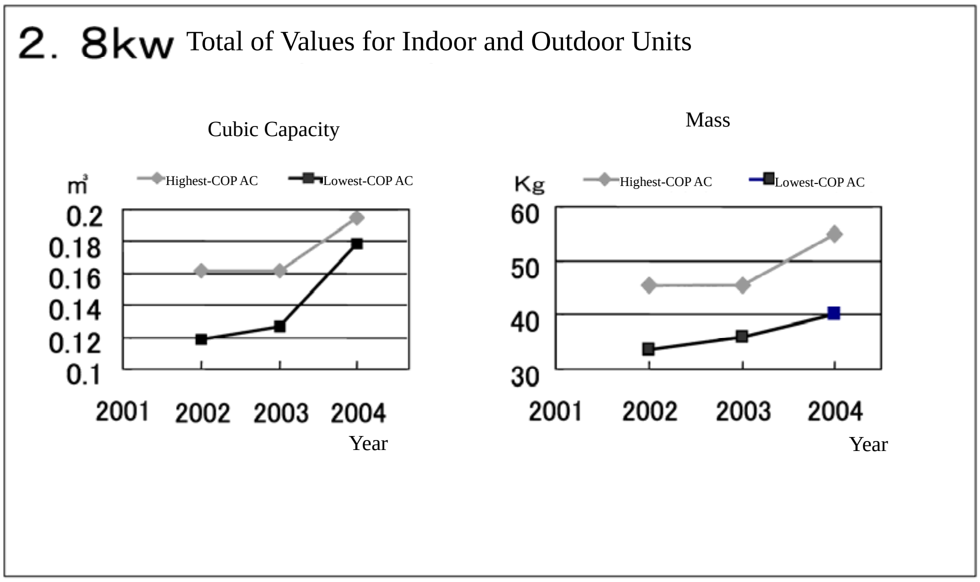
The efficiency improvement in “blower motor efficiency” is greater than 80%.



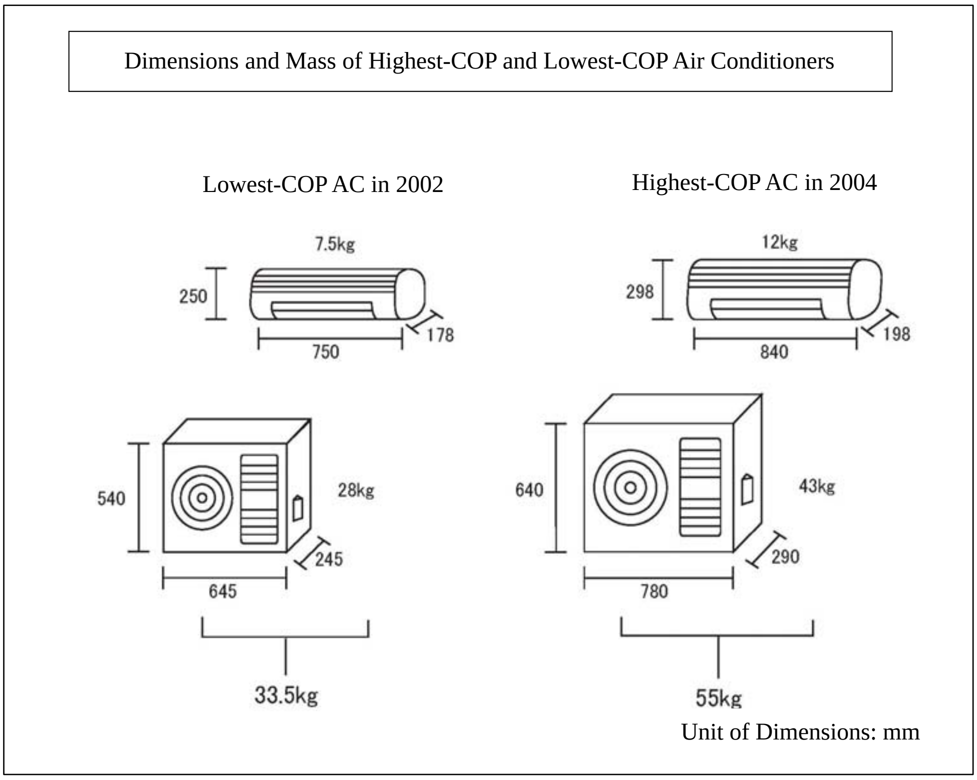
(3) Growing size of heat exchangers

An attempt to save energy has been made by increasing size of a heat exchanger and thus alleviating the compression ratio.

(Reference)



Source: Japan Refrigeration and Air Conditioning Industry Association



Source: Japan Refrigeration and Air Conditioning Industry Association

2-4 Approach to Reduction of Standby Power Consumption

(1) Independent declaration by the industry

In January 2001, Japan Electronics and Information Technology Industries Association, Japan Electrical Manufacturers' Association, and Japan Refrigeration and Air Conditioning Industry Association made an independent declaration for reducing standby power consumption. It stated that for anchor products of residential air conditioners, "they will make efforts toward the target which is to decrease the standby power consumption below 1W by 2004 freezing year".

(2) Status at the end of 2004 freezing year in response to the independent declaration of the industry

Targeted models	191 models
Achieved models	191 models
Achievement rate	100%
Mean of Standby power consumption	0.81W

3. Future Approach to Energy Saving and Challenges

As it now stands, improvement of energy saving by increasing size of a heat exchanger is a key factor.

3-1 Various Problems Accompanying Growing Size of Air Conditioners

(1) Installability

Considering the fact that intra-column dimension of half-ken width ("ken" is a unit in Shaku-kan method) of a Japanese house is 800 mm, it is concerned that an air conditioner will not be suitable for being used as household equipment if its width exceeds 800 mm.

(2) Comfort

It is concerned that the further growth in size of a "heat exchanger/blower" might damage the basic comfort; such as, "evaporation temperature rises and thus humidity in a room is difficult to be cleared" in the case of cooling operation.

(3) Resource saving

Increased size of equipment might also increase usage of copper and aluminum, in particular, which are materials for a heat exchanger. Thus, from the standpoint of resource saving, the problem still remains.

3-2 Relationship between Difference in Running Cost and Sales Price

In order to actualize the efficiency of an energy saving model for the next generation, it is essential to increase size of a heat exchanger, which leads to cost increase for material input. Hence, it is concerned that it will not be possible to offset a difference in the initial cost between energy saving models and others even with a difference in running cost for 10 years between them.