Si-18

Service Manual

Air Conditioning and Refrigeration Equipment

Preface

This textbook is complied with the purpose of using it in the institute classes for the junior and middle class service technicians.
Although the contents and expressions may be sometimes inadequate, the minimum necessary knowledge and concepts for service technicians are edited to make them understood easily. We hope you will use the textbook effectively.

Contents

Chapter 1 Fundamentals of refrigeration

1

Chapter 1 Fundamentals of refrigeration

When studying refrigeration and air conditioning, it is important to master the fundamental principles of physics and thermodynamics explained in this chapter.
For those who are already familiar with these fundamentals, this chapter will serve as review or reference materials. Units are important subjects in this chapter. Various units are used depending on applications and districts and they are not unified throughout the world for the time being. The yard-pound system is still being used in quite a number of countries, and the metric system is used in the Japan Refrigeration and Air Conditioning Industries.
Furthermore, there are many kinds of systems in the metric - system. In order to settle the confusion caused by diversity of units, the international unit system (SI: Le Systeme International d'Unites) has been introduced, and it has been supported widely. In this textbook, however, the units of the metric system which are customarily used are mainly explained because we think it is too early to adopt the S.I. metric system fully in this textbook, as the system is not used in gauges, product catalogues, and technical materials which service technicians use daily.
In order to make the persons who are familiar with the yard-pound system read this textbook easily, the conversion formulae from the units of the conventional metric system to those of the yard-pound system, and at the same time, the units of the S.I. metric system which will be necessary in near future are also explained.

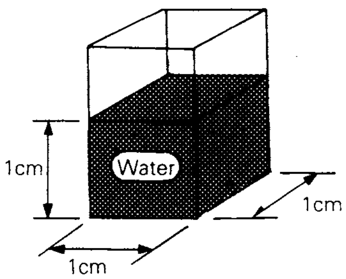
1.1 Pressure

1.1.1 Mass

Mass .... Mass is the amount of material in a substance measured in grams and kilograms.

1 gram [g] ..... A cubic centimeter [cm^3] of water at a temperature of greatest density has a mass of 1g (See Fig. 1-1.)

Fig.1-1



The relations among grams, kilograms and other units are shown in Table 1-1.

Table 1-1

Conventional metric system and S.I. metric system		Yard-pound system	
g	kg	oz	lb
1	0.001	0.03527	0.002205
1000	1	35.27	2.205
28.35	0.02835	1	0.0625
453.6	0.4536	16	1

* The conventional metric units and the S.I. metric units of mass are the same.

To convert one unit to another, use the following formuiae.

(1) g → kg To convert grams into kilograms
kg=0.001×g

(2) g → oz To convert grams into ounces
oz=0.03527×g

(3) kg → g To convert kilograms into grams
g=1000×kg

(4) kg → lb To convert kilograms into pounds
lb=2.205×kg

(5) oz → g To convert ounces into grams
g=28.35×oz

(6) oz → lb To convert ounces into pounds
lb=0.0625×oz

(7) lb → kg To convert pounds into kilograms
kg=0.4536×lb

(8) lb → oz To convert pounds into ounces
oz=16×lb

Example : Convert 200g into kg
Solution : 200g×0.001=0.2kg

Example : Convert 500g into oz
Solution : 500g×0.03527≒17.6oz

Example : Convert 4kg into g
Solution : 4kg×1000=4000g

Example : Convert 4kg into lb
Solution : 4kg×2.205≒8.8lb

Example : Convert 50oz into g
Solution : 50oz×28.35=1417.5g

Example : Convert 200oz into lb
Solution : 200oz×0.0625=12.5lb

Example : Convert 80lb into kg
Solution : 80lb×0.4536≒36.3kg

Example : Convert 5lb into oz
Solution : 5lb×16=80oz

1.1.2 Force and weight

Force... A force is defined as a push or pull. It is anything that has a tendency to set a body in motion, to bring a moving body to rest, or to change the direction of motion. A force may also change the size or shape of a body.

Weight... Weight is the most familiar force. The weight of a body is a measure of the force exerted on the body by the gravitational pull of the earth. (See Fig. 1-2.)

The units of force are the kilogram force [kgf] in the conventional metric system, the newton [N] in the S.I. metric system and the pound force [lbf] in the yard-pound system.

Kilogram force [kgf] ...A kilogram force is the force of gravity of an object having a mass of 1kg. The force of gravity gives an acceleration of 9.807 meter per second per second to the object. [See Fig. 1-3 (a).]

Newton [N]...A newton is that force which, when applied to a body having a mass of 1kg, gives it an acceleration of one meter per second per second. [See Fig. 1-3(b).]

The relations among kilogram force, newton and pound force are shown in Table 1-2.

Fig.1-2

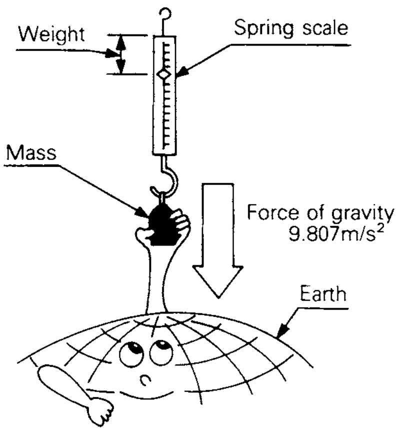


Fig.1-3

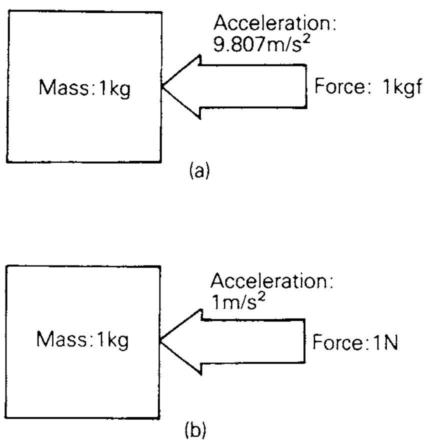
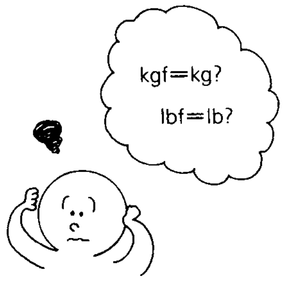


Table 1-2

Conventional metric system	S.I. metric system	Yard-pound system
kgf	N	lbf
1	9.807	2.205
0.1020	1	0.2248
0.4536	4.448	1

Fig.1-4



* There is a custom to abbreviate kilogram force as kilogram or pound force as pound and, even their symbols, "kgf" as "kg" or "lbf" as "lb". Almost all weighing apparatus indicate the units of mass. In this chapter, grab the differences between weight and mass clearly.

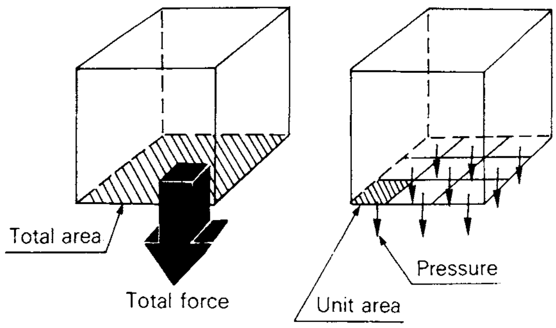
1.1.3 What is "Pressure"?

Pressure... Pressure is the force per unit area. It may be described as a measure of the intensity of force at any given point on the contact surface. Whenever force is evenly distributed on a given area, pressure at any point on the contact surface is the same and can be calculated by dividing the total force exerted by the total area on which the force is applied. Such relationship is expressed by the following equation. (See Fig. 1-5.)

$$P = \frac{F}{A}$$

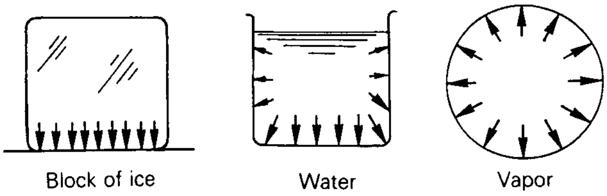
Where P = Pressure
F = Total force
A = Total area

Fig.1-5



A block of ice (a solid) exerts pressure on its support.
Water (liquid) exerts pressure on the sides and bottom of its container. Vapor (gas) exerts pressure on all surface of its container. (See Fig. 1-6.)

Fig.1-6



1.1.4 Units of pressure

Units of pressure are the kilogram force per square centimeter [kgf/cm^2] in the conventional metric system, the pascal [Pa], the kilopascal [kPa] in the S.I metric system and the pound per square inch [psi] in the yard-pound system.

Kilogram force per square centimeter [kgf/cm^2]...A solid weight of 1kgf with a bottom surface area of 1cm^2 would exert a pressure of 1kgf/cm^2 upon a flat surface. [See Fig. 1-7 (a).]

Pascal [Pa]...A pascal is a newton per square meter. [See Fig. 1-7(b).]
1 kilopascal [kPa]=1000Pa

Pounds per square inch [psi]...A solid weight of 1 lb with a bottom surface area of 1 in^2 would exert a pressure of 1 psi upon a flat surface. [See Fig. 1-7(c).]

Fig.1-7

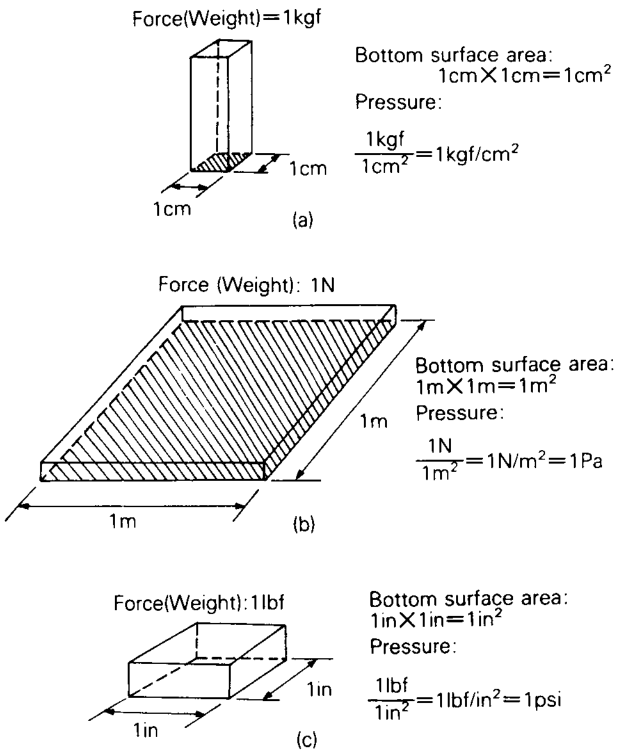


Fig.1-8

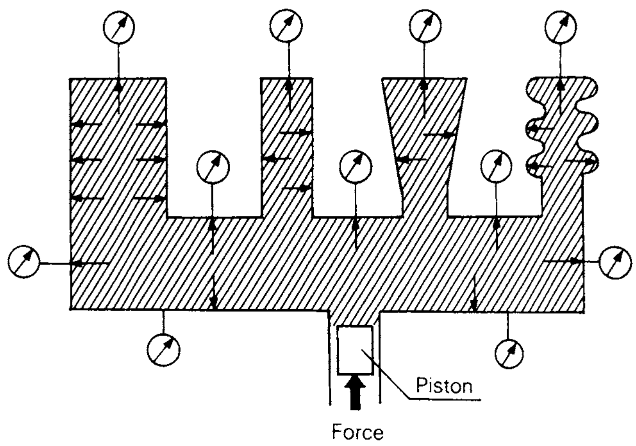
* Like the units of weight, the units of pressure are also abbreviated such as kilogram force per square centimeter as kilogram per square centimeter or pound force per square inch as pound per square inch and their symbols such as kgf/cm^2 as kg/cm^2 or lbf/in^2 as lb/in^2. On the gauges that servicemen normally use, only kg/cm^2 or lb/in^2 is indicated. There is no problem to think that kg/cm^2 or lb/in^2 is equal to kgf/cm^2 or lbf/in^2 respectively.

1.1.5 Pascal's Law

Pascal's Law... Pressure applied on a confined fluid is transmitted equally in all directions.

Fig. 1-9 illustrates Pascal's Law. It shows a fluid-filled cylinder with different shapes of chambers.
A piston is fitted into a small cylinder which is connected to the larger cylinder. A force is applied to the piston in the small cylinder. The pressure gauges show the pressure transmitted equally in all directions and chambers regardless of the size and shape of chambers.

Fig.1-9



1.1.6 Atmospheric pressure

Atmospheric pressure... The earth is surrounded by an envelope of atmosphere or air. Air has weight and exerts a pressure on the surface of the earth. The pressure exerted by the atmosphere is known as atmospheric pressure.

The weight of a column of air having a cross section of 1 square cm and extending from the surface of the earth at the sea level to the upper limits of the atmosphere is 1.033kgf (14.70lbf). Therefore, the pressure on the surface of the earth at the sea level resulting from the weight of the atmosphere is 1.033kgf/cm^2 (14.70lbf/cm^2) (See Fig. 1-10.)

Barometers... To measure the atmospheric pressure experimentally, a barometer is used. A simple barometer consists of glass tube sealed at one end and opens at the other end. Fill the tube with mercury, then, seal the open end with a finger, and invert it in a container of mercury. When the finger is removed, mercury will drop to the level corresponding with the atmospheric pressure. The height of mercury column will be 760mm (29.92 in.) at the sea level under the standard conditions. (See Fig. 1-11.)

Fig.1-10

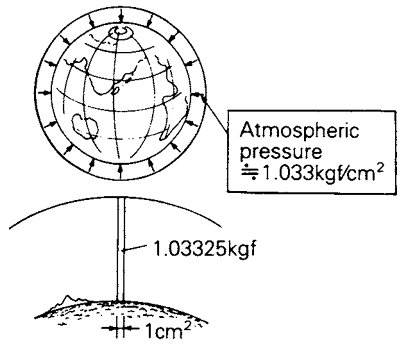
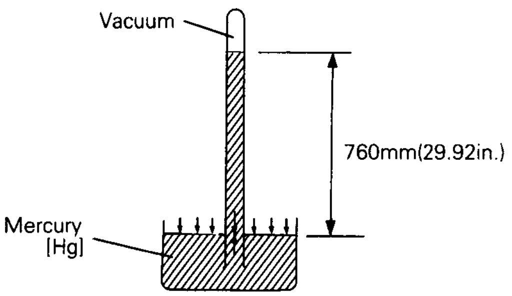


Fig.1-11



Atmospheric pressure is expressed in many ways as shown below.

Atmospheric pressure =1.033kgf/cm^2
=1atm
=760mmHg
=101.3kPa
=14.70lbf/in^2 [psi]
=29.92in.Hg

1.1.7 Vacuum

Vacuum... Pressures lower than atmospheric pressure are called vacuum.

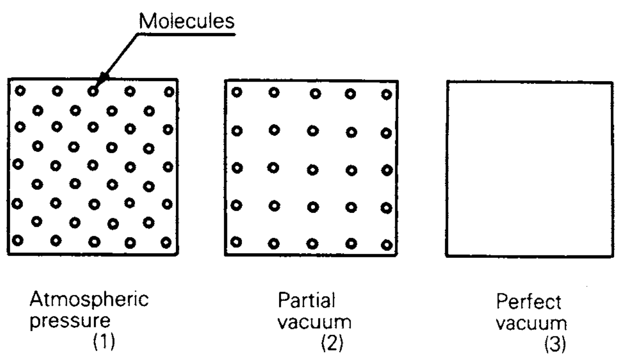
Perfect vacuum...A pressure which cannot be reduced any further is called perfect vacuum. (Absolute vacuum)

Partial vacuum...A pressure lower than atmospheric pressure, but not a perfect vacuum, is called partial vacuum.

A perfect vacuum is expressed in many ways as shown below.

Perfect vacuum =0kgf/cm^2
=0mmHg
=0Pa
=0psi
=0in.Hg

Fig.1-12



1.1.8 Conversion of pressure units

The relations among kgf/cm^2, kPa, psi and other units are shown in Table 1-3.

Table 1-3

Conventional metric systems			S.I metric system	Yard-pound system	
kgf/cm^2	atm	mmHg	kPa	psi	in.Hg
1	0.9678	735.6	98.07	14.22	28.96
1.033	1	760	101.3	14.70	29.92
0.001360	0.001316	1	0.1333	0.01934	0.03937
0.01020	0.009869	7.501	1	0.1450	0.2953
0.07031	0.06805	51.71	6.895	1	2.036
0.03453	0.03342	25.40	3.386	0.4912	1

To convert one unit to another, use the following formulae.

(1) kgf/cm^2 → atm — To convert kgf/cm^2 into atm
atm=0.9678×kgf/cm^2
Example : Convert 20kgf/cm^2 into atm
Solution : 20kgf/cm^2×0.9678≒19.36atm

(2) atm → kgf/cm^2 — To convert atm into kgf/cm^2
kgf/cm^2=1.033×atm
Example : Convert 2atm into kgf/cm^2
Solution : 2atm×1.033=2.066kgf/cm^2

(3) kgf/cm^2 → mmHg — To convert kgf/cm^2 into mmHg
mmHg=735.6×kgf/cm^2
Example : Convert 1.5kgf/cm^2 into mmHg
Solution : 1.5kgf/cm^2×735.6≒1103mmHg

(4) mmHg → kgf/cm^2 — To convert mmHg into kgf/cm^2
kgf/cm^2=0.001360×mmHg
Example : Convert 745mmHg into kgf/cm^2
Solution : 745mmHg×0.001360≒1.013kgf/cm^2

(5) kgf/cm^2 → MPa — To convert kgf/cm^2 into MPa
MPa=0.098×kgf/cm^2
Example : Convert 12kgf/cm^2 into MPa
Solution : 12kgf/cm^2×0.098≒1.176MPa

(6) MPa → kgf/cm^2 — To convert MPa into kgf/cm^2
kgf/cm^2=10.2×MPa
Example : Convert 105 MPa into kgf/cm^2
Solution : 105MPa×10.2=1071kgf/cm^2

(7) kgf/cm^2 → psi — To convert kgf/cm^2 into psi
psi=14.22×kgf/cm^2
Example : Convert 20kgf/cm^2 into psi
Solution : 20kgf/cm^2×14.22=284.4psi

(8) psi → kgf/cm^2 — To convert psi into kgf/cm^2
kgf/cm^2=0.07031×psi
Example : Convert 300psi into kgf/cm^2
Solution : 300psi×0.07031≒21.09kgf/cm^2

(9) MPa → psi — To convert MPa into psi
psi=145.0×MPa
Example : Convert 15 MPa into psi
Solution : 15MPa×145.0=2175psi

(10) psi → MPa — To convert psi into MPa
MPa=0.00689×psi
Example : Convert 40psi into MPa
Solution : 40psi×0.00689= 0.275MPa

(11) psi → in.Hg — To convert psi into in.Hg
in.Hg=2.036×psi
Example : Convert 28psi into in.Hg
Solution : 28psi×2.036≒57in.Hg

(12) in.Hg → psi — To convert in.Hg into psi
psi=0.4912×in.Hg
Example : Convert 62in.Hg into psi
Solution : 62in.Hg×0.4912≒30.45psi

1.1.9 Absolute pressure and gauge pressure

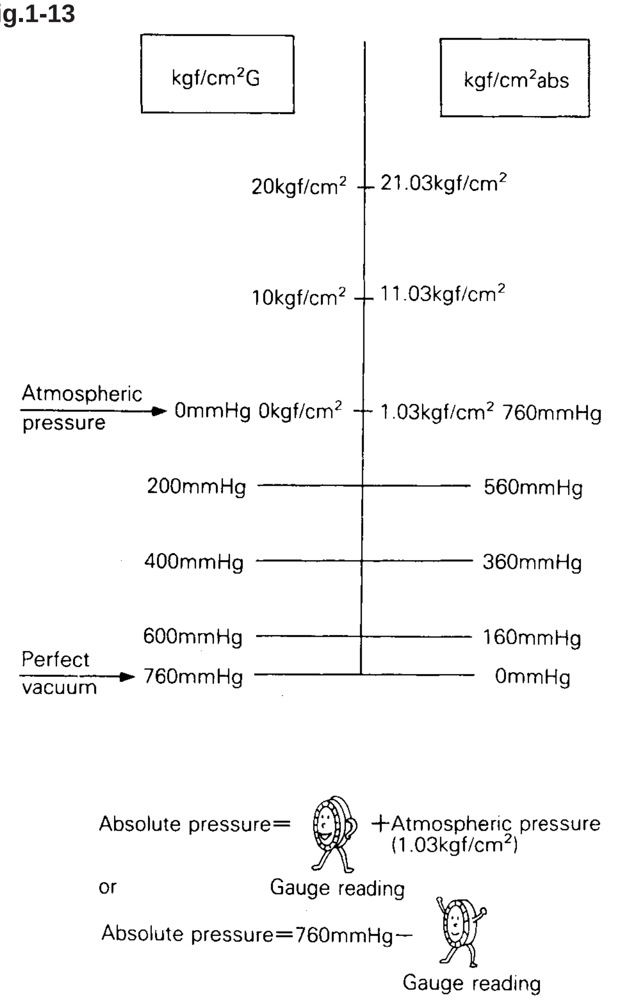
Gauge pressure... Gauge pressure is the pressure as indicated by a gauge. It is important to understand that gauges are calibrated to read zero at atmospheric pressure. Gauges measure only the difference in pressure between the total pressure of the fluid in the vessel and the atmospheric pressure.

Gauge pressures are expressed as "kgf/cm^{2}G", "psig" or "kPa(G)".

Absolute pressure... Absolute pressure is the "total" or "true" pressure of a fluid. When the fluid pressure is greater than the atmospheric pressure, the absolute pressure of the fluid is determined by adding the atmospheric pressure to the gauge pressure, and when the fluid pressure is less than the atmospheric pressure, the absolute pressure of the fluid is found by subtracting the gauge pressure from the atmospheric pressure.
In solving most pressure and volume problems or using the Mollier chart, it is necessary to use absolute pressures.

Absolute pressures are expressed as "kgf/cm^{2}abs", "psia" or "MPa".
However, it is normal to omit "G", "g", "abs" or "a" except when it is necessary to discriminate gauge pressure from absolute pressure.

Fig.1-13



Example : A pressure gauge reads 1.8MPa (18kgf/cm^2).
What is the absolute pressure in this case?

Solution : Absolute pressure=[1.8+0.1] MPa; (18+1.03) kgf/cm^2
=1.9MPa; (19.03kgf/cm^2)

Example : A compound gauge on the suction pipe reads 200mmHg.
What is the absolute pressure?

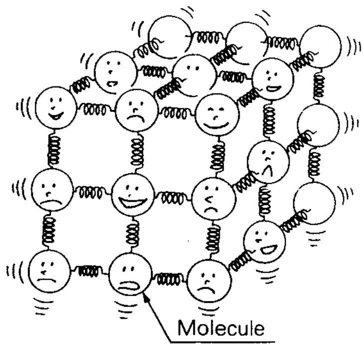
Solution : Absolute pressure=760-200=560mmHg

1.2 Heat and temperature

1.2.1 What is "Heat"?

Heat is a form of energy. It is related to the molecular motion or vibration. A molecule is the smallest particle in which any substance can be broken down and still retain its chemical identity. As a substance is warmed, molecules move more rapidly. As a substance is cooled, they slow down. If all heat is removed from a substance, all molecular motion stops. In other words, if a substance is warmed, heat is added, if cooled, heat is removed. (See Fig. 1-14.)

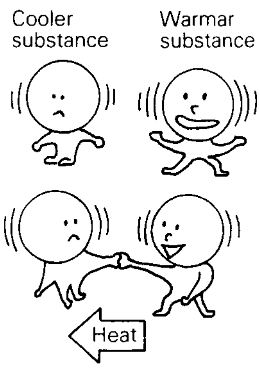
Fig.1-14



1.2.2 Heat flow

Heat always flows from a warmer substance to a cooler one. What happens is that the faster moving molecules give out some of their energy to slower moving molecules. Therefore, the faster molecules slow down a little and the slower ones move a little faster. (See Fig. 1-15.)

Fig.1-15



1.2.3 Heat transfer

Heat may be transferred from one body to another by one of the following methods.

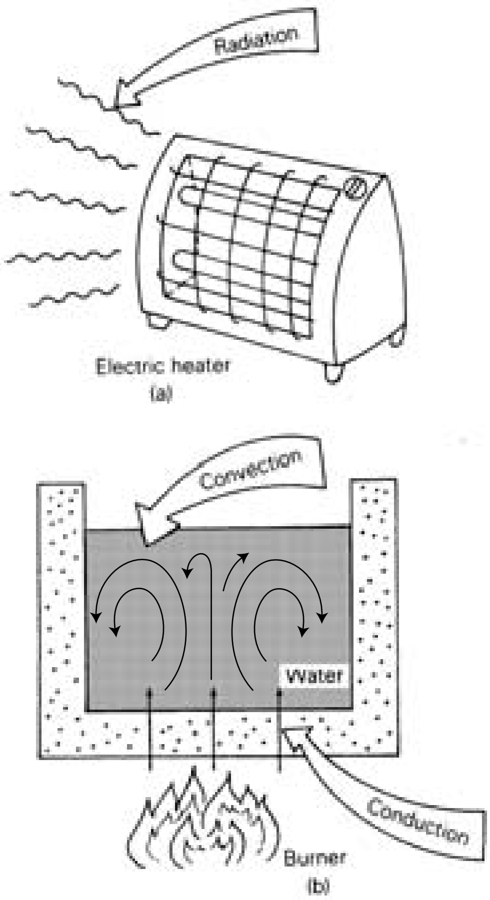
Radiation... The heat transfer in the form of a wave motion similar to light waves in which the energy is transmitted from one body to another without the need for intervening matter. [See Fig. 1-16(a).]

Conduction... The flow of heat among parts of a substance. The flow can also be from one substance to another substance in direct contact. [See Fig. 1-16(b).]

Convection... The moving of heat from one place to another by way of fluid or air. [See Fig. 1-16(b).]

Some systems of heat transfer use a combination of these three methods.

Fig.1-16

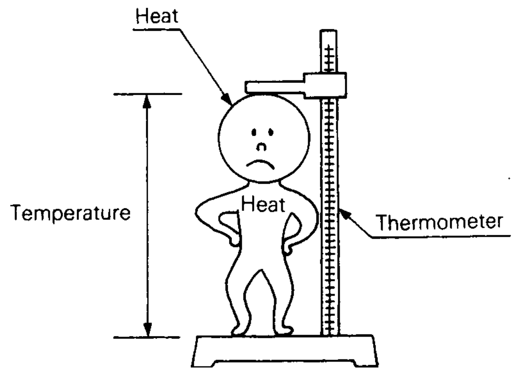


1.2.4 What is "Temperature"?

Temperature... Temperature measures the heat intensity or heat level of a substance. Temperature alone does not give the amount of heat in a substance. It indicates the degree of warmth or how hot or cold a substance or body is.

It is important not to use the words "heat" and "temperature" carelessly.

Fig.1-17



1.2.5 Thermometric scales

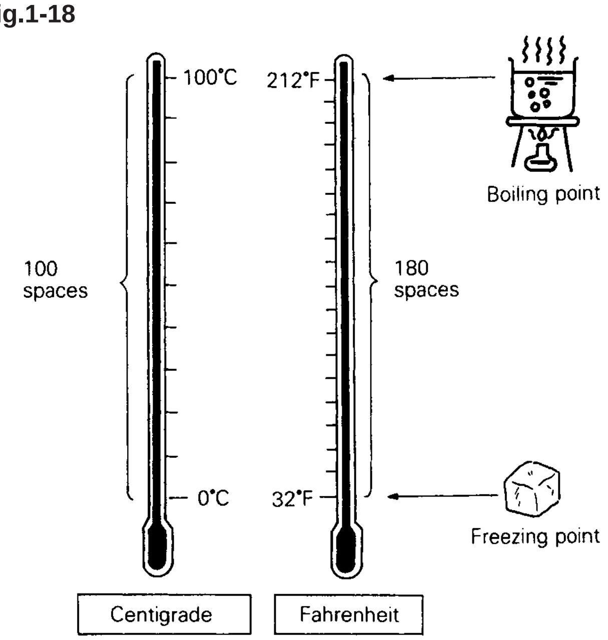
The most common thermometer scale in the metric system is the Celsius, sometimes called the Centigrade scale. Other common thermometer scale in the yard-pound system is the Fahrenheit. The S.I metric system uses the Kelvin which is explained in 1.2.7.
The calibration of thermometers for these two scales are determined by the temperature of melting ice and boiling water.

Centigrade... On the Centigrade scale, the temperature of melting ice or the freezing temperature of water is 0˚C.
The temperature of boiling water is 100˚C. There are 100 spaces or degrees on the scale between freezing and boiling temperatures.

Fahrenheit... On the Fahrenheit thermometer, the temperature of melting ice or the freezing temperature of water is 32˚F. The temperature of boiling water is 212˚F. This provides 180 spaces or degrees between the freezing and boiling temperature.

* The freezing and boiling points are based on freezing and boiling temperatures of water at the standard atmospheric pressure.

Fig.1-18



1.2.6 Absolute zero

Absolute zero... Absolute zero is that temperature at which molecular motion stops. It is the lowest temperature possible. There is no more heat remaining in the substance at this point.

Fig.1-19

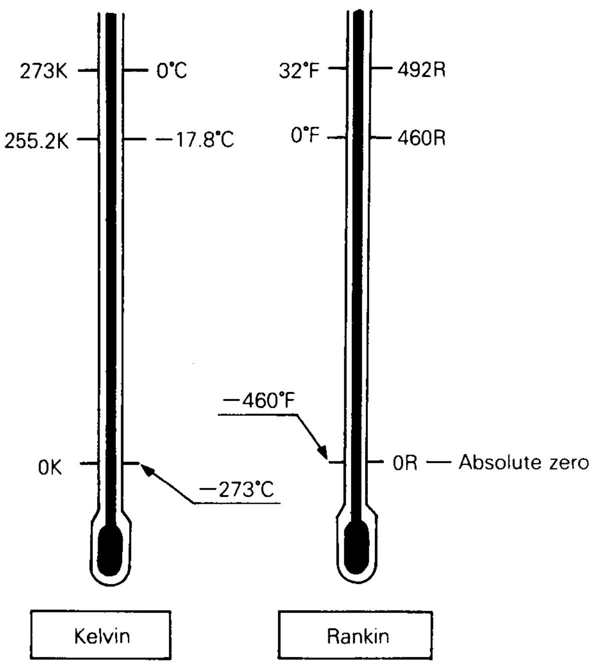
1.2.7 Absolute temperature scales

Two absolute temperature scales are used with very low temperature work or in solving thermodynamic problems. Both conventional metric and S.I metric system use the Kelvin scale and the yard-pound system uses the Rankine.

Kelvin [K]... The kelvin scale uses the same divisions as the Celsius scale. Zero on the Kelvin scale (0K) is 273 degrees below 0˚C.

Rankin [R]... The Rankine scale uses the same divisions as the Fahrenheit scale. Zero on the Rankine scale (0R) is 460 degrees below 0˚F.

Fig.1-20



1.2.8 Temperature conversion formulae

It is sometimes necessary to convert a temperature from one scale to another. Formulae are provided below.

(1) °C → °F To convert Celsius degrees into Fahrenheit degrees.

$$\text{Temp.°F} = \left(\frac{180}{100} \times \text{Temp.°C}\right) + 32$$
$$= \left(\frac{9}{5} \times \text{Temp.°C}\right) + 32$$

Example : Convert 40°C into Fahrenheit

Solution : $\text{Temp.°F} = \left(\frac{9}{5} \times 40\right) + 32 = 104\text{°F}$

(2) °F → °C To convert Fahrenheit degrees into Celsius degrees.

$$\text{Temp.°C} = \frac{100}{180} \times (\text{Temp.°F} - 32)$$
$$= \frac{5}{9} \times (\text{Temp.°F} - 32)$$

Example : Convert 50°F into Celsius

Solution : $\text{Temp.°C} = \frac{5}{9} \times (50 - 32) = 10\text{°C}$

(3) °C → K To convert Celsius degrees to Kelvin degrees.

Temp.K = Temp.°C + 273

Example : Convert −20°C to Kelvin

Solution : Temp.K = (−20) + 273 = 253K

(4) K → °C To convert Kelvin degrees to Celsius degrees.

Temp.°C = Temp.K − 273

Example : Convert 400K to Celsius

Solution : Temp.°C = 400 − 273 = 127°C

(5) °F → R To convert Fahrenheit degrees to Rankine degrees.

Temp.R = Temp.°F + 460

Example : Convert 20°F to Rankine

Solution : Temp.R = 20 + 460 = 480R

(6) R → °F To convert Rankine degrees to Fahrenheit degrees.

Temp.°F = Temp.R − 460

Example : Convert 200R to Fahrenheit

Solution : Temp.°F = 200 − 460 = −260°F

1.2.9 Units of heat

As explained already, a thermometer measures only the intensity of heat but not a quantity. However, in working with heat, it is often necessary to determine heat quantities. Obviously, certain units of heat are required. There are several units of heat. The conventional metric system uses the calorie [cal] or the kilocalorie [kcal]. The S.I metric system uses the joule [J] or the kilojoule [KJ]. The yard-pound system uses the British thermal unit [Btu].

Calorie [cal]... The amount of heat required/removed to raise/lower the temperature of 1g water 1˚C is equal to 1cal. [See Fig. 1-22(a).]

Kilocalorie [kcal]... The amount of heat required/removed to raise/lower the temperature of 1kg water1˚C is equal to 1kcal. [See Fig. 1-22(b).]

Joule [J]... The amount of heat required to raise the temperature of 1g water 1˚C is equal to 4.187J. On the contrary, the amount of heat removed to lower the temperature of 1g water 1˚C is also equal to 4.187J. [See Fig. 1-22(a).]

Kilojoule [kJ]... The amount of heat required/removed to raise/lower the temperature of 1kg water 1˚C is equal to 4.187kJ. [See Fig. 1-22(b).]

British thermal unit [Btu]... The amount of heat required/removed to raise/lower the temperature of 1lb water 1˚F is equal to 1Btu. [See Fig. 1-22(c).]

The relations among cal, kcal and other units are shown in Table 1-4.

Fig.1-21

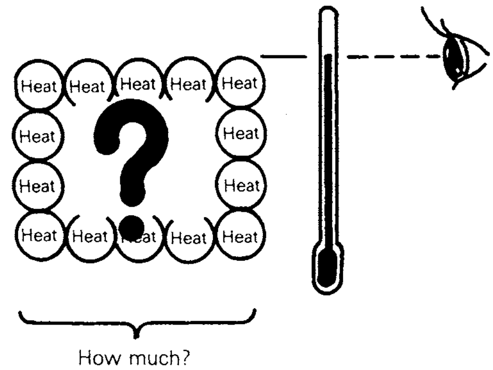


Fig.1-22

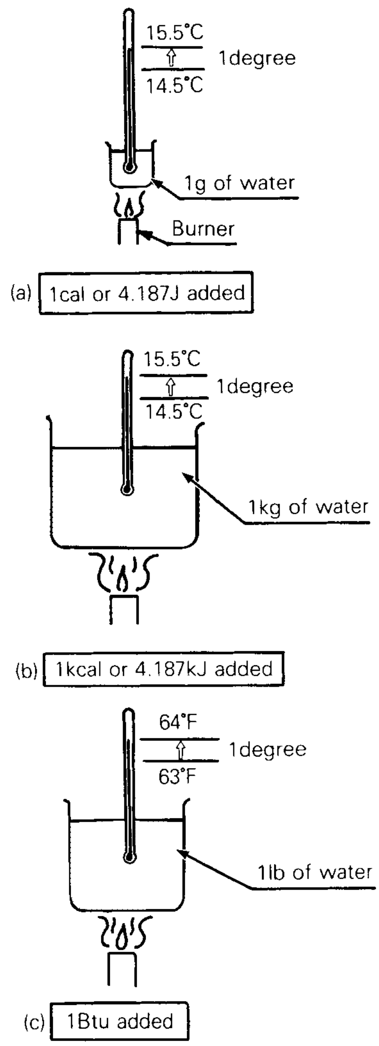


Table 1-4

Conventional metric systems		S.I metric system		Yard-pound system
cal	kcal	J	kJ	Btu
1	0.001	4.186	0.004186	0.003968
1000	1	4186	4.186	3.968
0.2389	0.0002389	1	0.001	0.000948
238.9	0.2389	1000	1	0.9480
252	0.2520	1055	1.055	1

To convert one unit to another, use the following conversions.

(1) cal → kcal To convert calories into kilocalories

kcal = 0.001 × cal

Example : Convert 2500cal into kcal

Solution : 2500cal × 0.001 = 2.5kcal

(2) kcal → cal To convert kilocalories into calories

cal = 1000 × kcal

Example : Convert 5kcal into cal

Solution : 5kcal × 1000 = 5000cal

(3) kcal → kJ To convert kilocalories into kilojoules

kJ = 4.186 × kcal

Example : Convert 5kcal into kJ

Solution : 5kcal × 4.186 ≒ 20.93kJ

(4) kJ → kcal To convert kilojoules into kilocalories

kcal = 0.2389 × kJ

Example : Convert 100kJ into kcal

Solution : 100kJ × 0.2389 = 23.89kcal

(5) kcal → Btu To convert kilocalories into British thermal units

Btu = 3.968 × kcal

Example : Convert 2500kcal into Btu

Solution : 2500kcal × 3.968 = 9920Btu

(6) Btu → kcal To convert British thermal units into kilocalories

kcal = 0.2520 × Btu

Example : Convert 20000Btu into kcal

Solution : 20000Btu × 0.2520 = 5040kcal

(7) Btu → kJ To convert British thermal units into kilojoules

kJ = 1.055 × Btu

Example : Convert 25000Btu into kJ

Solution : 25000Btu × 1.055 = 26375kJ

(8) kJ → Btu To convert kilojoules into British thermal units

Btu = 0.9480 × kJ

Example : Convert 500kJ into Btu

Solution : 500kJ × 0.9480 = 474Btu

(9) J → kJ To convert joules into kilojoules

kJ = 0.001 × J

Example : Convert 8000J into kJ

Solution : 8000J × 0.001 = 8kJ

(10) kJ → J To convert kilojoules into joules

J = 1000 × kJ

Example : Convert 2kJ into J

Solution : 2kJ × 1000 = 2000J

1.2.10 Work, energy and power

Work... Work is force multiplied by the distance through which it travels.

The units of work are the kilogram force meter [kgf·m] in the conventional metric system, the joule [J] in the S.I metric and the foot-pound force [ft·lbf] in the yard-pound system.

Kilogram force meter [kgf·m]... Kilogram force meter is the amount of work done by a force of 1kgf moving its point of application a distance of 1m. [See Fig. 1-23(a).]

Joule [J]... Joule is the amount of work done by a force of 1N moving its point of application a distance of one meter. [See Fig. 1-23(b).]

Energy... Energy is the capacity or ability to do work.

In the refrigeration work, three common, related forms of energy must be considered; i.e. mechanical, electrical and heat.
The study of refrigeration deals mainly with heat energy, but the heat energy is usually produced by a combination of electrical and mechanical energy. In a refrigerating unit, electrical energy flows into an electric motor, and this electrical energy is turned into mechanical energy, which is used to turn a compressor. The compressor compresses the vapor to a high pressure and high temperature, transforming mechanical energy into heat energy. (See Fig. 1-24.)
Various units are used for measuring mechanical, heat and electrical energy. Table 1-5 shows the relations among these units.

Power... Power is the time rate of doing work.
The units of power are kilogram force meter per second [kgfm/s] in the conventional metric system, kilowatt [kw] in the S.I metric and foot-pound force per second [ft.lbf/s] in the yard-pound system.
There are also various units other than above mentioned. Table 1-6 shows the relation among these units.

Fig.1-23

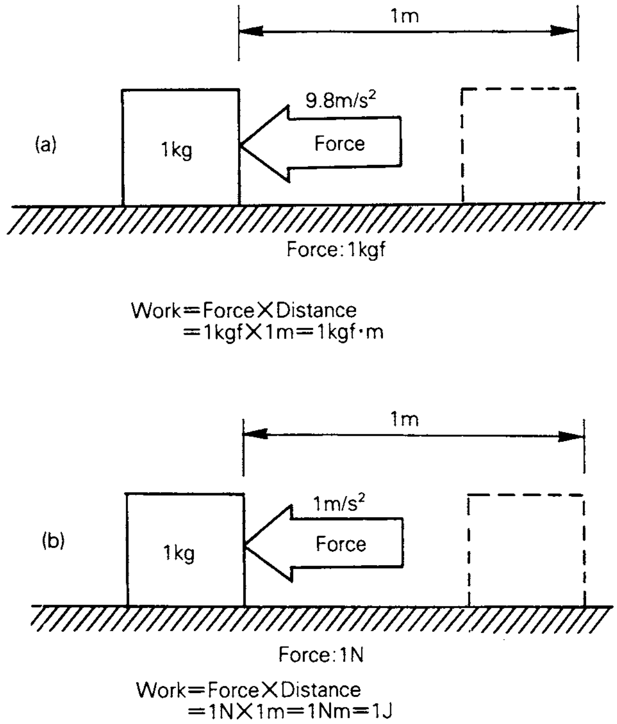


Fig.1-24

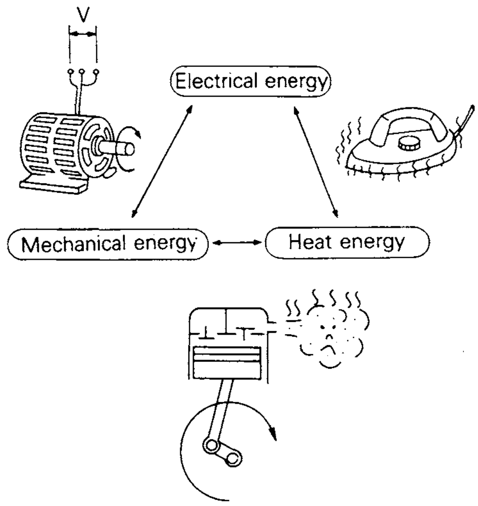


Table 1-5

Conventional metric system				S.I metric system	Yard-pound system		
Mechanical energy		Electrical energy	Heat energy	Mechanical electrical and heat energy	Mechanical energy		Heat energy
kgf·m	PS·h	kW·h	kcal	J	ft·lbf	HP·h	Btu
1	0.000003704	0.000002724	0.002343	9.807	7.233	0.000003652	0.009297
270000	1	0.7355	632.5	2648000	1953000	0.9859	2510
367100	1.3596	1	860.0	3600000	2655000	1.3405	3413
426.9	0.001581	0.001163	1	4186	3087	0.001559	3.968
0.1020	0.0000003777	0.0000002778	0.0002389	1	0.7376	0.0000003724	0.0009480
0.1383	0.0000005121	0.0000003766	0.0003289	1.356	1	0.0000005049	0.001285
273900	1.014	0.746	641.6	2686000	1981000	1	2546
107.6	0.0003984	0.0002930	0.2520	1056	778.0	0.0003928	1

Table 1-6

Conventional metric system			S.I metric system	Yard-pound system		
kgf·m/s	PS	kcal/s	kW	ft·lbf/s	HP	Btu/s
1	0.01333	0.002343	0.009807	7.233	0.01315	0.009297
75	1	0.1757	0.7355	542.5	0.9859	0.6973
426.9	5.691	1	4.186	3087	5.611	3.968
102	1.360	0.2389	1	737.6	1.340	0.9180
0.1383	0.001843	0.003239	0.001356	1	0.001817	0.001285
76.07	1.014	0.1782	0.746	550.2	1	0.7072
107.6	1.434	0.2520	1.055	778.0	1.414	1

* One must understand through this section that heat is one of energy forms and can be converted into other forms and vice versa. Many conversion units represented in this section are used for calculating loads and determining the capacity of an equipment required for specific refrigeration applications.

1.3 Sensible heat and latent heat

1.3.1 Three physical states (phases)

Substances exist in three states depending on their temperature, pressure and heat content. For example, water under the standard atmospheric pressure is a solid (ice) at temperature below 0˚C (32˚F), and liquid (water) from 0˚C (32˚F) to 100˚C (212˚F). At 100˚C (212˚F) and above, it becomes gas (vapor). (See Fig. 1-25.)

Solids...A solid is any physical substance which keeps its shape even when not contained. It consists of billions of molecules, all exactly the same size, mass and shape.
These stay in the same relative position to each other, and yet, they are in the condition of rapid vibration. The rate of vibration will depend upon temperature. The lower the temperature, the slower molecules vibrate, the higher the temperature, the faster the vibration. The molecules are strongly attracted to each other. Considerable force is necessary to separate them. [See Fig. 1-26(a).]

Liquids...A liquid is any physical substance which will freely take on the shape of its container. Yet, its molecules strongly attract each other. Think of the molecules as swimming among their fellow molecules without ever leaving them. The higher the temperature, the faster the molecules swim. [See Fig. 1-26(b).]

Gases...A gas is any physical substance which must be enclosed in a sealed container to prevent its escape into the atmosphere. The molecules, having little or no attraction for each other, fly in a straight line. They bounce off each other, off molecules of other substances, or off the container walls. [See Fig. 1-26(c).]

Most substances change their physical state with the addition or removal of heat.
Adding heat causes
- solids to become liquids...Fusion
- solids to become gases...Sublimation
- liquids to become gases...Vaporization

Removing heat causes
- gases to become liquids...Condensation
- liquids to become solids...Solidification

(See Fig. 1-27.)

Fig.1-25

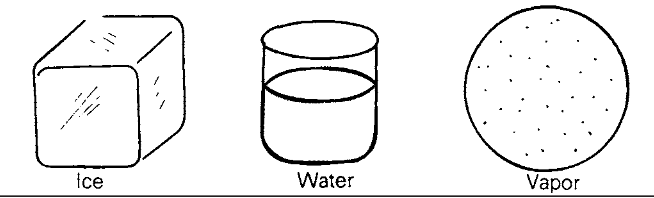


Fig.1-26

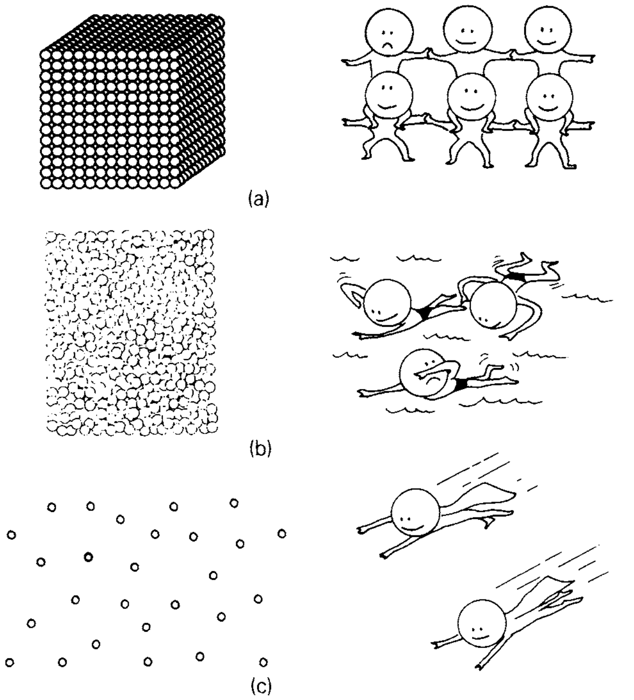
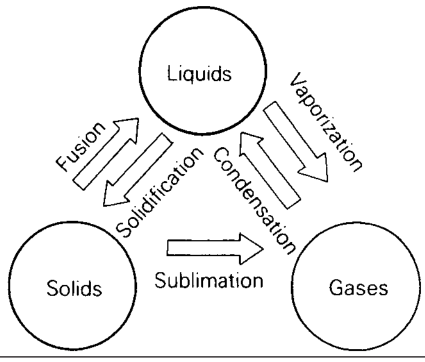


Fig.1-27



These changes of state occur at the same temperature and pressure combinations for any given substance.

1.3.2 Phase change of water

Suppose chipped ice of—50˚C is to be heated in an vessel over gas flame. As the heat is applied, the temperature of the chipped ice will rise until the ice begins to melt. Then the temperature will stop rising and will remain at 0˚C as long as there is any amount of ice left. Finally all the chipped ice becomes 0˚C water.
Obviously, the burning gas is supplying heat to the ice.
But if the ice temperature ceases to rise, where is this heat going? The answer is that the ice is melting; it is changing from solid to liquid. Now, to change any substance from solid to liquid requires the application of heat.
When the chipped ice has melted completely, further application of heat will raise the temperature until the water begins to boil. Then the temperature will stop rising and will remain at 100˚C as long as the water is boiling. Finally all the water becomes 100˚C vapor.
To change any substance from liquid to vapor also requires the application of heat.
When the water has vaporized completely, further application of heat to the 100˚C vapor will raise the temperature of the vapor.

Melting temperature... The temperature at which a solid will change into the liquid phase is called the "melting temperature" or "melting point".

Boiling temperature... The temperature at which a liquid will change into the vapor phase is called the "boiling temperature" sometimes referred to as "boiling point", "evaporation temperature", "vaporizing temperature" or "saturation temperature".

The above explanation is the case of adding heat to the substance. If heat is removed from the substance, the process is reversed. For instance, the vapor will be condensed and the liquid will be solidified by removing heat.

Condensing temperature... The temperature at which a vapor will change into the liquid phase is called the "condensing temperature" or "saturation temperature".

Solidification temperature... The temperature at which a liquid will change into the solid phase is called the "solidification temperature".

Fig.1-28

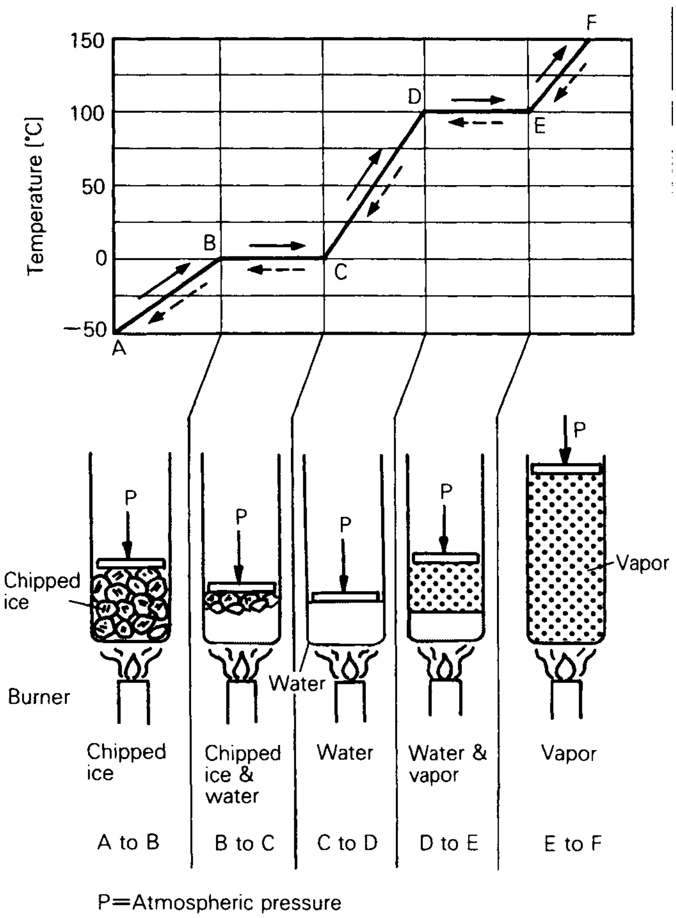


Fig.1-29

Melting temperature	=	Solidification temperature
Boiling temperature	=	Condensing temperature

* At the constant pressure

1.3.3 Saturation, super-heating and subcooling

Saturated liquid... When the temperature of a liquid is raised to the saturation temperature, that is, any additional heat applied to the liquid will cause a part of the liquid to vaporize, the liquid is said to be saturated. Such liquid is called a "saturated liquid".

Saturated vapor... When the temperature of a vapor is decreased to the saturation temperature, that is, any further cooing of the vapor will cause a portion of the vapor to condense, the vapor is said to be saturated. Such a vapor is called a "saturated vapor".
A saturated vapor may be described also as a vapor ensuring from the vaporizing liquid as long as the temperature and pressure of the vapor are the same as those of the saturated liquid from which it came.

Superheated vapor... When the temperature of a vapor is so increased above the saturation temperature, the vapor is said to be superheated and is called a "superheated vapor".
In order to superheat a vapor it is necessary to separate the vapor from the vaporizing liquid. As long as the vapor remains in contact with the liquid it will be saturated. This is because any heat added to a liquid-vapor mixture will merely vaporize more liquid and no superheating will occur.

Sub-cooled liquid... If, after condensation, a liquid is cooled so that its temperature is reduced below the saturation temperature, the liquid is said to be "sub-cooled". A liquid at any temperature and above the melting temperature is a sub-cooled liquid.

Amount of superheat and subcool are determined by applying the following equation:

Amount of superheat (S.H.)=temperature of the superheated vapor-saturation temperature corresponding to the pressure

Amount of subcool (S.C.)=saturation temperature corresponding to the pressure-temperature of the sub-cooled liquid

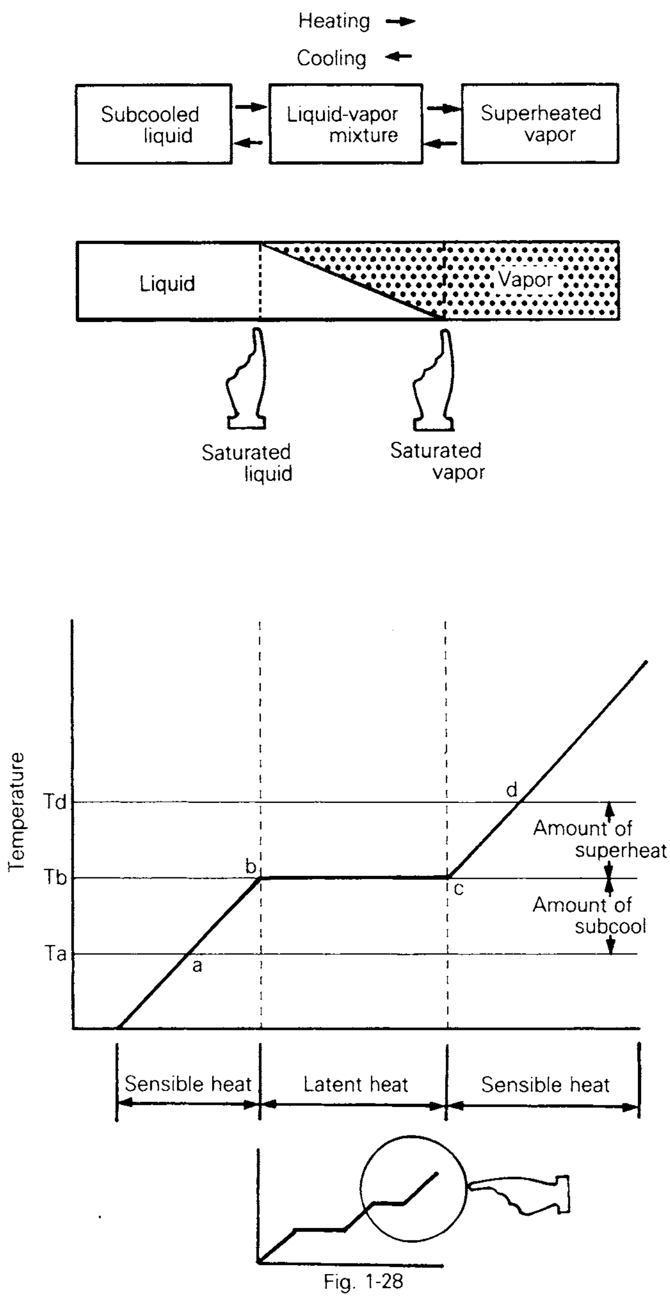
Example : Give the amount of superheat of a steam (water) at 120˚C, 1 atm.

Solution : Saturation temperature=100˚C
S.H.=120˚C-100˚C=20˚C

Example : Give the amount of subcool of water at 60˚C, 1 atm.

Solution : S.C.=100˚C-60˚C=40˚C

Fig.1-30



1.3.4 Saturation temperature

The saturation temperature of substances differs from one to others. Water boils at 100˚C, alcohol vaporizes at 78˚C and R-22 at-40.8˚C under the atmospheric pressure.

The saturation temperature of a liquid or a vapor varies with the pressure. Increasing the pressure raises the saturation temperature and decreasing the pressure lowers the saturation temperature.

For example, the saturation temperature of water at atmospheric pressure 0.1MPa(1.03kgf/cm^2abs) is 100˚C. If the pressure over the water is increased from 0.1MPa (1.03kgf/cm^2abs) to 0.2MPa (2.0kgf/cm^2abs), the saturation temperature of the water increases from 100˚C to 119˚C. On the other hand, if the pressure over the water is reduced from 0.1MPa (1.03kgf/cm^2abs) to 0.05MPa (0.5kgf/cm^2abs), the new saturation temperature of the water will be 81˚C.

Saturation chart... Fig. 1-31 shows the relationship between the pressure and the temperature of water and R-22. Such graph is called a "saturation chart".

The saturation chart is very useful to obtain the followings.

(1) To know the physical state of a substance
- If the intersection of temperature and pressure lines of a substance are on the left to the saturation curve, this substance is said to be sub-cooled.
- If the intersection is on the right to the curve, this substance is said to be superheated.
- If the intersection is exactly on the curve, this substance is said to be saturated. [See Fig. 1-32(a).]

(2) To obtain the saturation temperature corresponding to the pressure
- The saturation temperature is the temperature at which the pressure line and the saturation curve intersect. [See Fig. 1-32(b).]

(3) To obtain the saturation pressure corresponding to the temperature
- The saturation pressure is the pressure at which the temperature line and the saturation curve intersect. [See Fig. 1-32(b).]

(4) To find the amount of S.H. and S.C.
- The distance between the state point and the saturation curve represents the amount of S.H. or S.C. [See Fig. 1-32(c).]

Use the saturation table shown in Fig 362 instead of the saturation chart described previously, and reading accuracy is improved, which is very convenient for after-sales services.

Fig.1-31

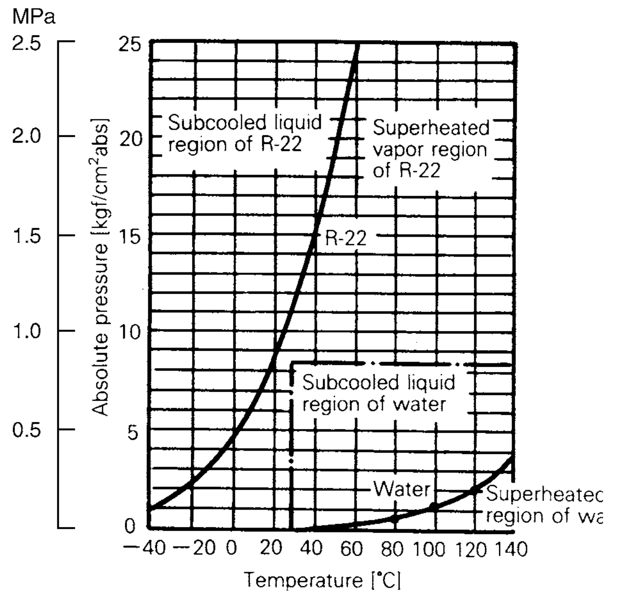
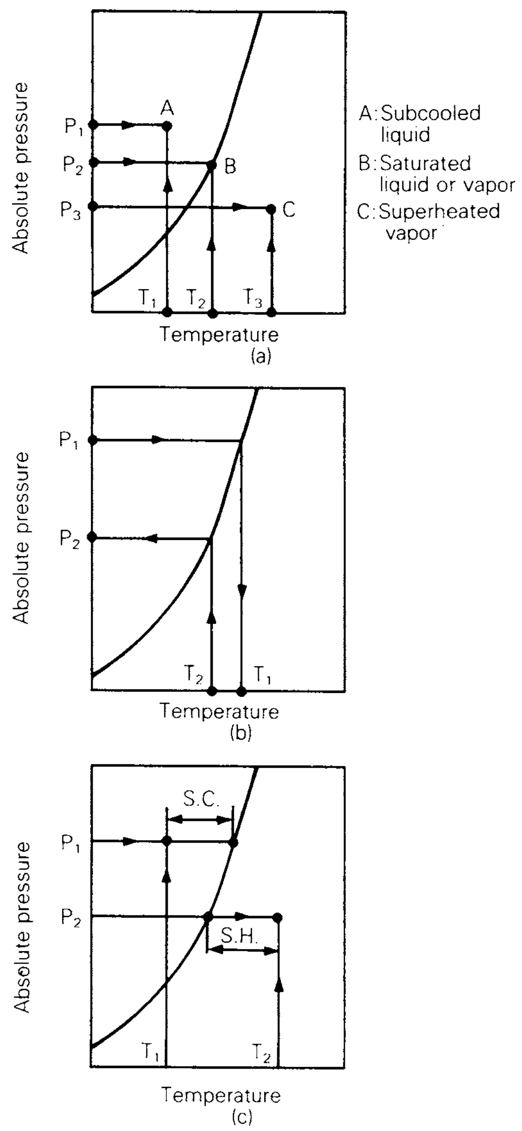
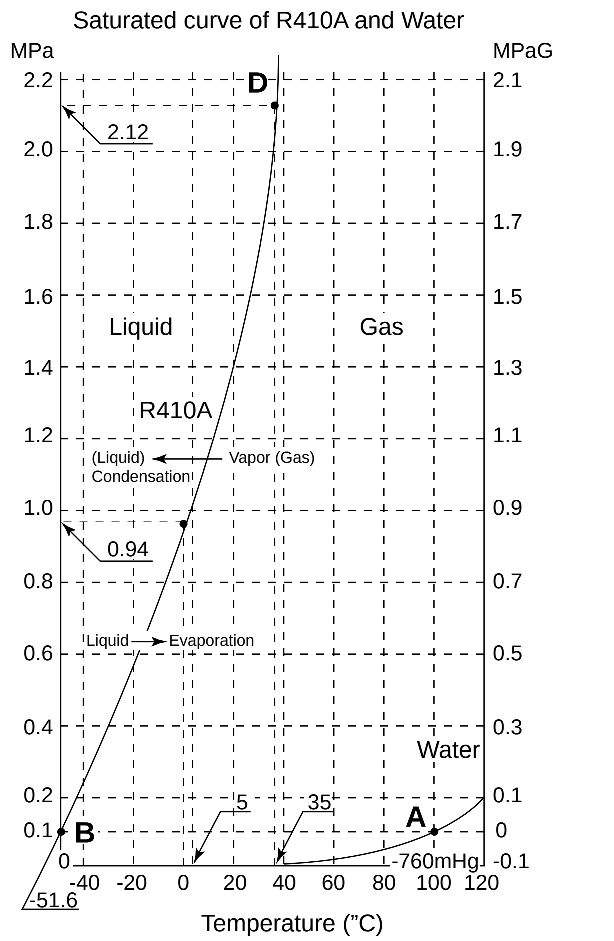


Fig.1-32



At Point B, the R410A refrigerant of 0.1MPa boils at a temperature of -51.6˚C.
Therefore, at **Point D**, if the R410A refrigerant having a temperature of 35˚C is in a state of saturated vapor at the pressure of 2.12MPa, it becomes refrigerant saturated liquid of 35˚C by removing the condensation latent heat from the said saturated vapor.
By contrast, at Point C, that means it is required to reduce the pressure down to 0.94MPa in order to boil the R410A refrigerant at 5˚C.

Fig.1-33



1.3.5 Sensible heat and latent heat

Fig. 1-34 shows the "temperatue-heat content diagram" for 1kg of water heated from -50˚C to 150˚C vapor under the atmospheric pressure.

(1) From A to B, 105.4kJ(25.2kcal) of heat were added to increase ice temperature from-50˚C to 0˚C.
(2) From B to C, 333.2kJ(79.6kcal) were added to melt ice without changing its temperature.
(3) From C to D, 418.6kJ(100kcal) were added to heat water to boiling point. (from 0˚C to 100˚C)
(4) From D to E, 2256kJ(539kcal) were added to change water to vapor without changing its temperature.
(5) From E to F, 92.5kJ(22.1kcal) were added to increase vapor temperature from 100˚C to 150˚C.

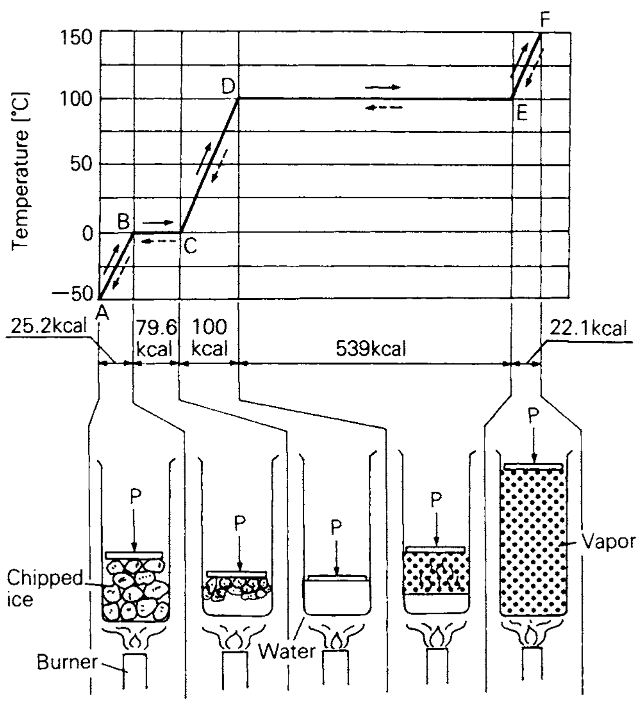
In this example,

- The heat which was required to increase the ice temperature is called "sensible heat". (A to B)
- The heat which was required to change the ice to water is called "latent heat of melting". (B to C)
- The heat which was required to increase the water temperature is also called "sensible heat". (C to D)
- The heat which was required to change the water to steam is called "latent heat of vaporization". (D to E)

If the process is reversed,

- The heat which must be rejected to change the steam to water is called "latent heat of condensation". (E to D)
- The heat which must be rejected to decrease the water temperature is called "sensible heat". (D to C)
- The heat which must be rejected to change the water to ice is called "latent heat of solidification". (C to B)
- The heat which must be rejected to decrease the ice temperature is called "sensible heat". (B to A)

Fig.1-34



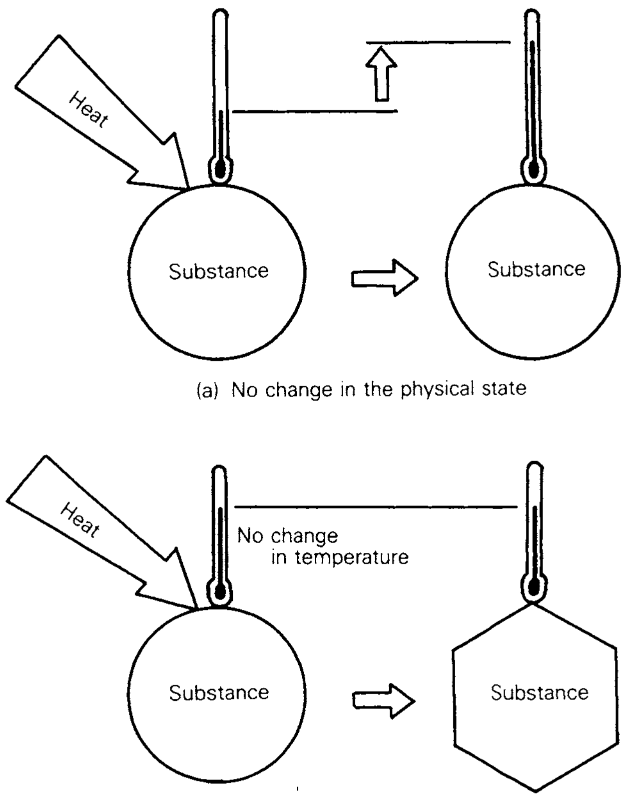
Sensible heat... If a substance is heated and the temperature rises as the heat is added, the increase in heat is called sensible heat. Likewise, heat may be removed from a substance. If the temperature falls, the heat removed is also called sensible heat. [See Fig. 1-35(a).]

Heat which causes a change in temperature in a substance is called sensible heat.

Latent heat... It has already been established that all pure substances are able to change their state. Solids become liquids, liquids become gases, etc. It takes the addition of heat or the removal of heat to produce these changes. Heat causes these changes are called latent heat. [See Fig. 1-35(b).]

Heat which brings about a change of state with no change in temperature is called latent heat.

Fig.1-35



(a) No change in the physical state

(b) Physical state is changed

1.3.6 Calculating heat amount

Specific heat... The specific heat of a substance is the amount of heat that must be added or released to change the temperature of one kilogram of the substance one degree Celsius.

Note that by the definition of kcal the specific heat of water is 1 kcal per kilogram per degree Celsius.
The heat required to cause a temperature change in substances varies with kinds and amounts of substances. Table 1-7 lists the specific heat of several common substances.

Table 1-7

Substance	Specific heat	
	Conventional metric and Yard-pound system	S.I metric system
	kcal/kg˚C, Btu/lb˚F	kJ/kg·K
Water	1.0	4.187
Ice	0.504	2.110
Wood	0.327	1.369
Iron	0.129	0.540
Mercury	0.0333	0.139
Alcohol	0.615	2.575
Copper	0.095	0.398

Note:The above values may be used for calculations which involve no change of state.

* The specific heat of any material also varies somewhat throughout the temperature scale. The variation is so slight that it can be considered that the specific heat is a constant amount for most calculations.

The amount of heat which must be added to or removed from any given mass of material in order to bring about a spcified change in its temperature can be computed by using the following equation:

$$Qs = M \cdot C(t_2 - t_1)$$

Where Qs= Amount of heat either absorbed or rejected by the substance
M= Mass of the substance
C= Specific heat of the substance
t_2= Final temperature
t_1= Initial temperature

Example : Find the amount of heat, in kcal, which must be added to heat 20kg of copper block from 30˚C to 250˚C

Solution : The specific heat of copper
= 0.095 kcal/kg˚C
Qs = 20kg × 0.095 kcal/kg˚C × (250 - 30)˚C
= 418kcal

Solution **<SI Metric>**

The specific heat of copper
= 0.398 kJ/kg·K
Qs = 20kg × 0.398kJ/kg·K × (250 - 30)˚C
= 1751.2 kJ

The latent heat required to cause a phase change in substances also differs with each material. Table 1-8 lists the latent heat of vaporization (condensation) of several substances.

Table 1-8

Substance	Latent heat of vaporization (condensation)		
	Conventional metric system	S.I metric system	Yard-pound system
	kcal/kg	kJ/kg	Btu/lb
Water	539 at 100˚C	2257 at100˚C	970.4 at 212˚F
R-502	38 at – 15˚C	160 at – 15˚C	68.96 at 5˚F
R-12	38 at – 15˚C	159 at – 15˚C	68.2 at 5˚F
R-22	52 at – 15˚C	217 at – 15˚C	93.2 at 5˚F
R-407C	58 at – 15˚C	244 at – 15˚C	
R-410A	56 at – 15˚C	233 at – 15˚C	
R-134a	50 at – 15˚C	209 at – 15˚C	

The latent heat value of any particular liquid varies with the pressure over the liquid. When the pressure increases, the latent heat value decreases.

The amount of heat which must be added to or removed from any given mass of material in order to cause a specified change of state can be calculated by using the following equation:

$$Q_L = M \cdot h$$

Where Q_L= Amount of heat either absorbed or rejected by the substance

M= Mass of the substance

h= Latent heat of the substance

Example : Find the amount of heat, in kcal, which must be added to vaporize 10kg of water at 100˚C

Solution : The latent heat of vaporization of the water = 539 kcal/kg

Q_L = 10kg × 539 kcal/kg = 5390kcal

Solution **<SI metric>**

The latent heat of vaporization of the water = 2257 kJ/kg

Q_L = 10kg × 2257kJ/kg = 22570 kJ

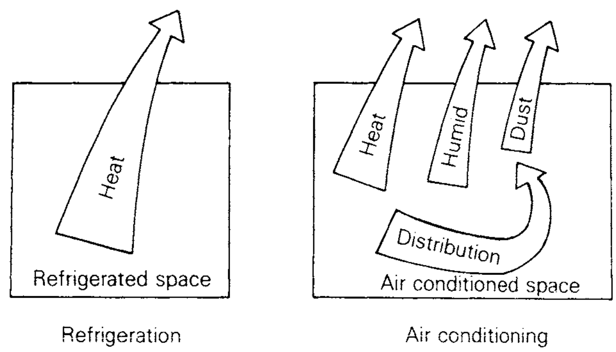
1.4 Refrigeration

1.4.1 What are "Refrigeration" and "Air conditioning"?

Refrigeration... It is defined as the process of reducing and maintaining the temperature of a space or material below the temperature of the surroundings.

Air conditioning... It is defined as the process of treating air so as to control simultaneously its humidity, cleanness, distribution as well as temperature to meet the requirements of the conditioned space.
Air conditioning is a part of refrigeration in a wide sense. (See Fig. 1-36)

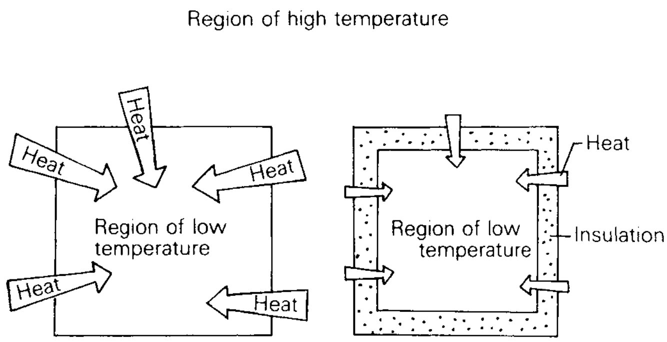
Fig.1-36



1.4.2 Heat insulation

Since heat always travels from a region of high temperature to a region of lower temperature, there is always a continuous flow of heat into the refrigerated region from the warmer surroundings. To limit the flow of heat into the refrigerated space to the practical minimum, it is necessary to isolate the space from its surroundings with a good heat insulating material.
(See Fig. 1-37)

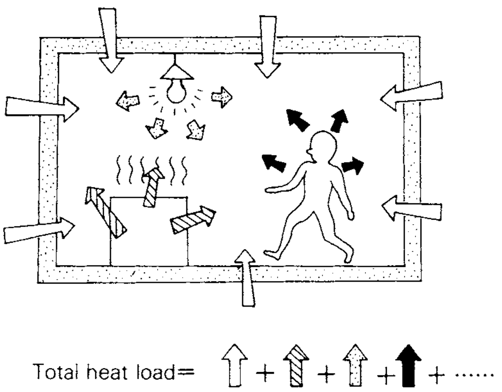
Fig.1-37



1.4.3 Heat load

Heat load... The rate at which heat must be removed from the refrigerated space or material in order to produce and maintain the desired temperature conditions is called the heat load.
In most refrigerating applications, the total heat load on the refrigerating equipment is the sum of the heat that leaks into the refrigerated space through the insulated walls, the heat that enters the space through door openings and the heat that must be removed from the refrigerated product in order to reduce the temperature of the product to the space or storage conditions. Heat given off by people working in the refrigerated space and by motors, lights, and other electrical equipment also contributes to the load on the refrigerating equipment. (See Fig. 1-38)

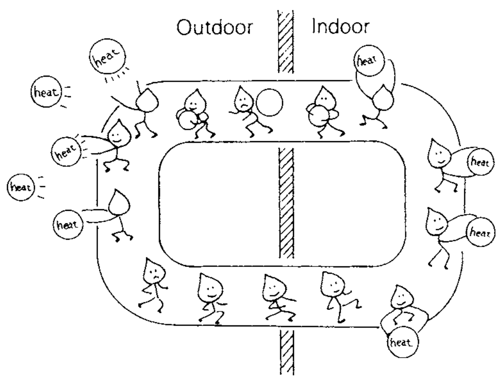
Fig.1-38



1.4.4 Refrigerant

To reduce and maintain the temperature of a space below the temperature of the surroundings, heat must be removed from the space and transferred to another body, the temperature of which is below that of the refrigerated space.
Something that takes this place is the refrigerant. (See Fig. 1-39)

Fig.1-39



Refrigerant...A refrigerant is a heat carrier to move heat from a room to be cooled to the outside. With regard to the vapor-compression cycle, the refrigerant is the working fluid of the cycle which alternately vaporizes and condenses as it absorbs and gives off heat respectively.
Generally speaking, fluid having the following properties is said to be suitable for use as a refrigerant.

(1) Inexpensive
(2) Nonpoisonous
(3) Nonexplosive
(4) Noncorrosive
(5) Nonflammable
(6) Stable (inert)
(7) High latent heat of vaporization
(8) Easy to vaporize and condense
(9) Easy to detect leaks
(10) No environmental pollution

Many substances have been used as refrigerants. In the past years, the most common refrigerants were air, ammonia, sulphur dioxide, carbon dioxide and methyl-chloride.
Fluorinated hydrocarbon refrigerants have been widely used in air conditioning systems so far. However, in recent years, especially the problem caused by fluorinated hydrocarbon refrigerant has attracted a great deal of attention from the view point of the ozone depletion potential (ODP). The relation between such pollution and flon refrigerant will be described later in the chapter of appendix together with the terminology under the new classification of refrigerant (CFC, HCFC, HFC) in terms of pollution.
Anyway, here in Table 1-9, most of refrigerant used in air conditioners and refrigeration equipment are listed from inorganic ones to organic ones. In addition, the nomenclature for flon refrigerant is shown in Table 1-10.

Fig.1-40

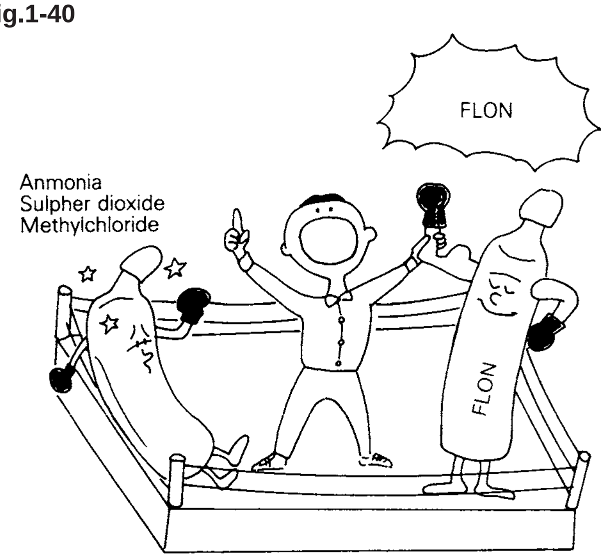


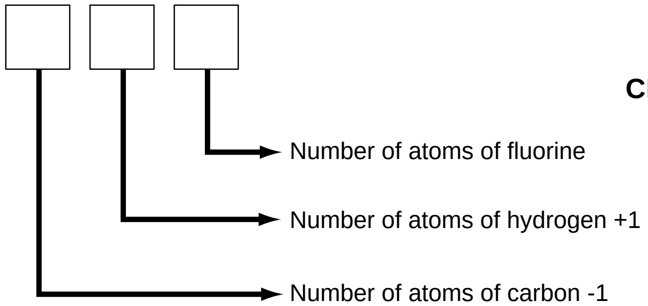
Table 1-9 Types of Refrigerants

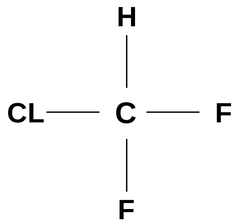
Refrigerant (symbol)	Composition	Boiling point (˚C)	ODP	GWP	Features	Classification
Carbon dioxide	CO_2	(Sublimation point) -79	0	1	Even though Daikin used the CO_2 compressor for the first time on the Ecocute Series, the CO_2 compressor existed in the refrigeration industry from long ago, which offers a significantly high pressure.	Inorganic
Ammonia	NH_3	-33.3	0	0	Most of chillers used ammonia over the prewar and postwar periods. Since ammonia has an overpowering smell, its leak can be immediately detected. Thanks to the high COP, it is still used in the refrigeration field. Copper is not allowed to use. Its inflammability is one of the disadvantages.	Inorganic
Water	H_2O	100	0	0	Water is used for the absorption type chillers as the refrigerant. If it is vacuumed, it evaporates at a low temperature. The vacuum pump is always ready in order to keep the pressure inside the machine negative at all times.	Inorganic
R-11	CCl_3F	23.8	1	4000	The R-11 was used as the refrigerant of the turbo chillers until the control of CFCs was provided. The R-11 has a low pressure and is allowed to store in metal drums. Alternately, it has a low refrigerating capacity. Therefore, unless it is used in a large quantity, it cannot meet the requirement. As a result, it is used for the machines offering a large circulation quantity, such as the turbo chillers. Since the evaporating pressure becomes below the atmospheric pressure, no refrigerant leaks are caused. By contrast, air mixes in while in the refrigeration cycle. A purge pump is used to purge this air.	CFC
R-12	CCl_2F_2	-29.8	1	8500	The R-12 has a refrigerating capacity of only 60% of the R-22. Therefore, it was not used for ordinary air conditioners. Since it is low in pressure at a high temperature, car air conditioners all used this refrigerant	CFC
R-22	$CHClF_2$	-40.8	0.05	1500	The R-22 is the most-highly used refrigerant for widely known air conditioners, which has a high degree of oil return performance and offers ease of application.	HCFC
R-114	$CClF_2CClF_2$	3.8	1	9300	Considering the low pressure, the boiling point is located at proper point, thus allowing to be used outside the vacuum area. Since it is resistant to high temperature, it was used for the cabin coolers of cranes at iron works and combat vehicles.	CFC
R-123	$CHClFCClF_2$	27	0.012	120	As the substitute refrigerant of the R-11, the R-123 is used for the current turbo chillers. The R-123 has a low pressure and can be handled in the same manner as that for the R-11. The refrigerating capacity is higher than that of the R-11, thus requiring no enhanced operation. However, in order to obtain the evaporating temperature (some 2˚C) as the chiller, the vacuum area is required. Therefore, like the R-11, a purge pump is required.	HCFC
R-134a	CH_2FCF_3	-26.1	0	1300	Since the R-134a resembles to the R-12 in the properties, it is used as the substitute refrigerant of the R-12 for car air conditioners. The R-134a has a little low refrigerating capacity compared to the R-12. In order to demonstrate the same capacity, the sizes of the compressor and heat exchanger become slightly larger. The R-134a is sensitive to the moisture mixing in. Therefore, a large-sized dryer filter is required to remove the moisture.	HFC
R-407C	CH_2F_2/ C_2HF_5/ CH_2FCF_3	-43.6	0	1530	The R-407C resembles to the R-22 in the pressure (1.1 times) and can use the same piping standard, thus facilitating the production. However, this is not azeotropic mixture, and the composition of the residual refrigerant in the machine and the characteristics vary whenever the refrigerant leaks. As a result, it is not suited to the air conditioners for house use, which is hard to control the piping work. Synthetic oil is used for lubricant. No mineral oils are allowed to use.	HFC
R410A	CH_2F_2/C_2HF_5	-51.6	0	1730	The R-410A has a significantly high pressure, which is 1.6 times as high as the R-22. For the piping work, the class 1 copper pipe (withstanding the pressure of 3.45MPa) cannot be used, while the class 2 one (withstanding the design pressure of each moduct) must be used. This has a minimum of changes in the composition due to the refrigerant leak and suited to use as a new refrigerant for houses. No mineral oils are allowed to use as the lubricant, while synthetic oil must be used. As for the performance characteristics, the R-410A shows similar properties to those of the R-22.	HFC

Notes)
1)ODP (Ozone Depletion Potential)
2)GWP (Global Warming Potential)
3)CFC, HCFC, HFC: The ozone layer destruction forecast is classified from the refrigerant name. Free ODP means HFC with completely no chlorine. The existing refrigerant is HCFC even though it has a small possibility of destruction. CFC has a large ODP and the production has been already discontinued.

Table 1-10 How to name refrigerants

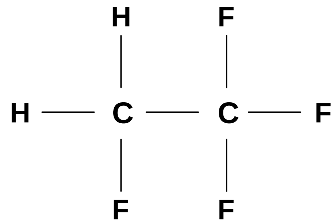
Single organic refrigerant





R-22

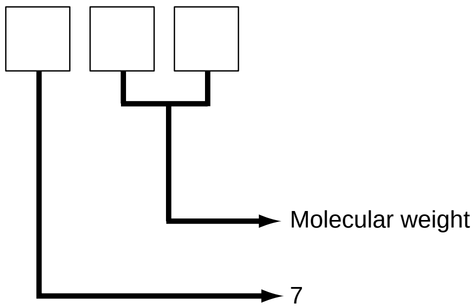
$CHClF_2$

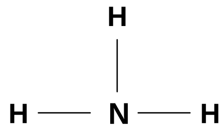


R-134a

CH_2FCF_2

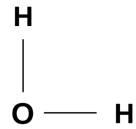
Single inorganic refrigerant





R-717

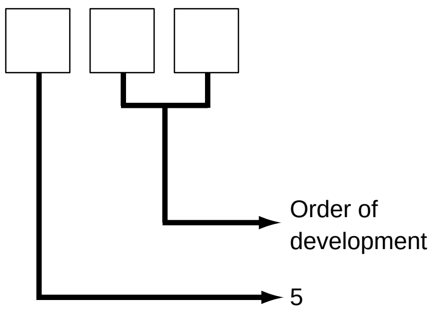
NH_3



R-718

H_2O

Azeotropic mixture refrigerant

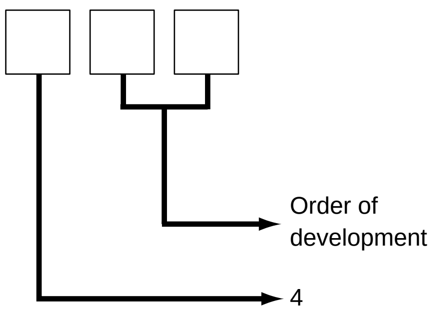


This refrigerant is a mixture of 2 or more types of gases having different boiling point, which has a property with the constant mixing ratio both of liquid phase and gas phase in a given weight ratio just as the single refrigerant. Therefore, even though evaporation and condensation are repeated, the composition of this refrigerant remains unchanged, thus making it possible to provide other thermodynamic characteristics different from respective refrigerants.

R-502:
Mixture of R-22 (48.8%) and R-151(51.2%)

$CHClF_2$-CH_3CHClF:
Before changing to new refrigerant, most of refrigerators for home use used this refrigerant.

Non-azeotropic mixture refrigerant (including quasi azeotropix mixture refrigerant)



This refrigerant is a mixture of two or more refrigerants having different boiling points. If a gas leak occurs, the mixed refrigerants evaporate from one having lower boiling point, thus causing changes in the composition of residual refrigerant in the air conditioner. Therefore, it is required to be sensitive to the refrigerant leaks in particular.
This has low conformability to mineral lubricants. Synthetic oil is to be used because gas, which is discharged once from the compressor, is hard to return.

R-407C
[R-32/125/134a(23/25/52wt%)]
CH_2F_2/C_2HF_5/CH_2FCF_3:
This refrigerant resembles to the R-22 in the properties such as pressure and facilitates the substitution as pollution-free refrigerant, thus enabling the application for the business purpose such as the SkyAir and VRV Series.

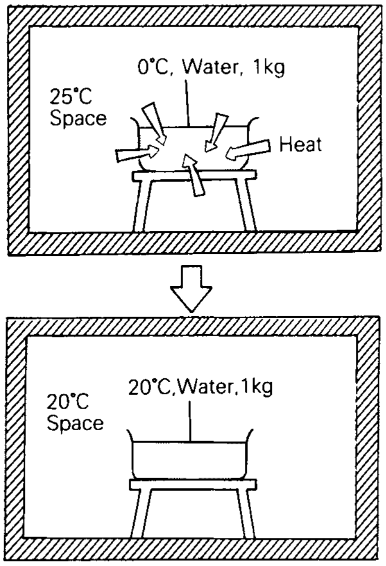
R-410A
[R-32/125(50/50wt%)]
CH_2F_2/C_2HF_5:
This refrigerant has a pressure 1.6 times as high as that of the R-22, which requires the pressure-resisting specifications, while has much less changes in composition due to leaks.

1.4.5 Principle of refrigeration

(1) Refrigeration by use of chilled water

Assume that 1kg of water of 0˚C is placed in an open container inside an insulated space having an initial temperature of 25˚C. For a certain lapse of time, heat will flow from the 25˚C space into the 0˚C water, so the temperature of the space will decrease. However, for each one kcal of heat that the water absorbs from the space, the temperature of the water will increase by 1˚C, so as the temperature of the space decreases, the temperature of the water increases. Soon the temperatures of the water and the space will be exactly the same and no heat transfer will take place (See Fig. 1-41.)

Fig.1-41



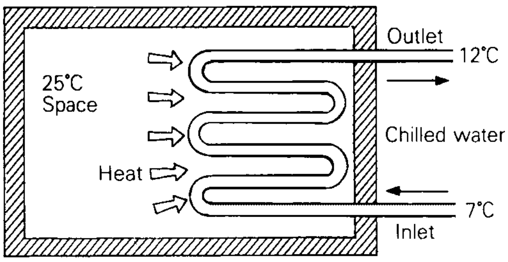
Disadvantages

- It is not possible to obtain the lower temperatures than the chilled water.
- Refrigeration is not continuous.
- It is impossible to control the room temperature.

To achieve continuous refrigeration, the water should be continuously chilled and recirculated. (See Fig. 1-42.)

Some sorts of air conditioning adopt this method.

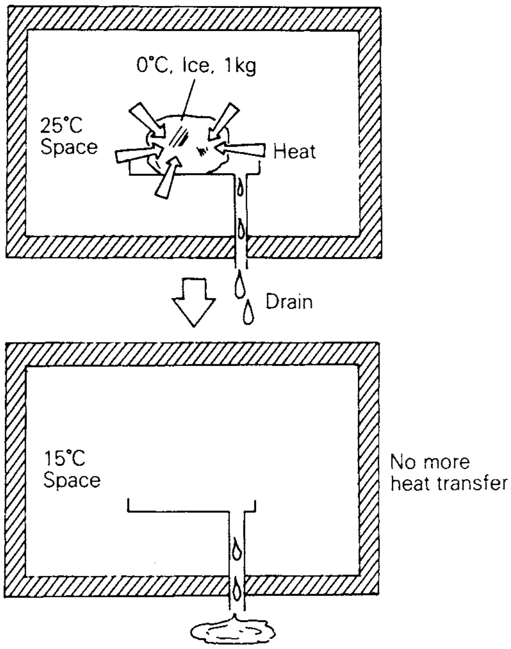
Fig.1-42



(2) Refrigeration by use of ice

Now assume that 1kg of ice of 0˚C is substituted for the water. This time the temperature of ice does not change as it absorbs heat from the space. The ice merely changes from the solid to the liquid state while its temperature remains constant at 0˚C. The heat absorbed by the ice leaves the space in water as drain and the refrigerating effect will be continuous until all the ice has melted. (See Fig. 1-43.)

Fig.1-43



Disadvantages

- It is also impossible to obtain low temperatures.
- It is necessary to replenish the supply of ice frequently.
- It is difficult to control the rate of refrigeration, which in turn makes it difficult to maintain the desired temperature.

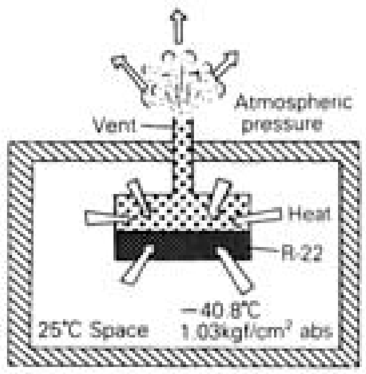
(3) Mechanical refrigerating system

1. Refrigeration by use of liquid refrigerant

An insulated space can be adequately refrigerated by merely allowing liquid R-22 to vaporize in a container vented to the outside as shown in Fig. 1-44. Since R-22 is under atmospheric pressure, its saturation temperature is -40.8˚C. Vaporizing at this low temperature, R-22 readily absorbs heat from the 25˚C space through the walls of the container. The heat absorbed by the vaporizing liquid leaves the space in the vapor escaping through the open vent. Since the temperature of the liquid remains constant during the vaporizing process, refrigeration continues until all the liquid is vaporized.

Any container, such as the one shown in Fig. 1-44, in which a refrigerant is vaporized is called an "evaporator".

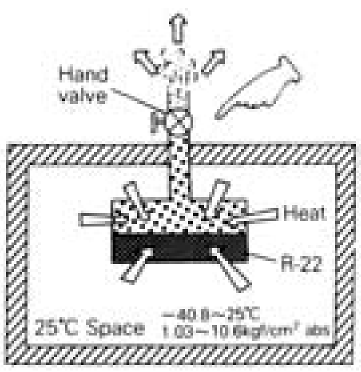
Fig.1-44



2. Controlling vaporizing temperature

The temperature at which the liquid vaporizes in the evaporator can be controlled by controlling the pressure of the vapor over the liquid. For example, if a hand valve is installed in the vent line and the vent is partially closed off so that the vapor cannot escape freely from the evaporator. By carefully adjusting the vent valve to regulate the flow of vapor from the evaporator, it is possible to control the pressure of the vapor over the liquid and cause R-22 to vaporize at any desired temperature between-40.8˚C and the space temperature 25˚C. (See Fig.1-45)

Fig.1-45



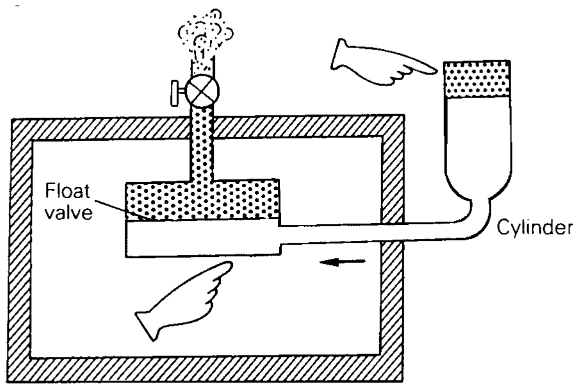
3. Maintaining continuous vaporization

Continuous vaporization of the liquid in the evaporator requires continuous supply of liquid replenished if the amount of liquid in the evaporator is to be maintained constant. One method of replenishing the supply of liquid in the evaporator is to use a float valve assembly as illustrated in Fig. 1-46.

The action of the float assembly is to maintain a constant level of liquid in the evaporator by allowing liquid to flow into the evaporator from the cylinder at exactly the same rate that the supply of liquid in the evaporator is being depleted by vaporization.

Any device, such as a float valve, used to regulate the flow of liquid refrigerant into the evaporator is called a "refrigerant flow control".

Fig.1-46



4. Salvaging the refrigerant

As a matter of convenience and economy, it is not practical to permit the refrigerant vapor to escape to the atmosphere. The vapor must be collected continuously and used over and over again.

In order to reuse the refrigerant, it must be delivered to the evaporator as a liquid because it can absorb heat only by vaporizing. In as much as the refrigerant leaves the evaporator in the form of a vapor, it must be reduced to a liquid before it can be used again. The simplest way of accomplishing this would be to condense the vaporized refrigerant as it leaves the evaporator. To condense the refrigerant, the latent heat surrendered by the vapor during condensation must be transferred to some other medium. For this purpose, air or water is ordinarily used. The air or water must be at a temperature lower than the condensing temperature of the refrigerant. At any given pressure, the condensing and vaporizing temperatures of a fluid are the same.

If a refrigerant which is vaporized at 10˚C is to be condensed at the same temperature, air or water at a lower temperature is needed for this purpose.

Obviously, if air or water at this lower temperature were available, mechanical refrigeration would not be required. As the temperature of available air or water is always higher than the temperature of the boiling refrigerant in the evaporator, the refrigerant cannot be condensed as it leaves the evaporator. In order to condense the vapor, its pressure must be increased to such a point that its condensing temperature will be above the temperature of the air or water available for condensing purposes. For example, if the pressure of vapor is $17kgf/cm^2$abs,it will condense at a temperature of 43.5˚C. Then the vapor at 43.5˚C can be cooled by air or water available. For this purpose a compressor is needed.

A pump used to pressurize the vaporized refrigerant and circulate the refrigerant is called a "compressor".

Any container, such as the one shown in Fig. 1-49, in which a refrigerant is condensed is called a "condenser".

By providing the compressor, the hand valve shown in Fig. 1-46 will not be necessary any more. The pressure in the evaporator can be controlled by the compressor and the float valve assembly.

Fig.1-47

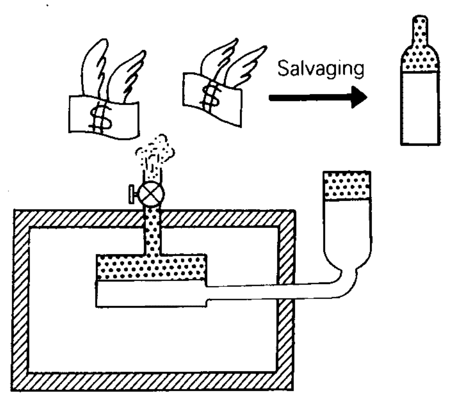


Fig.1-48

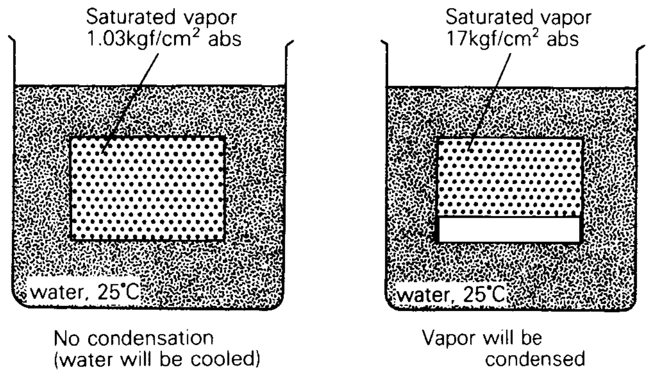
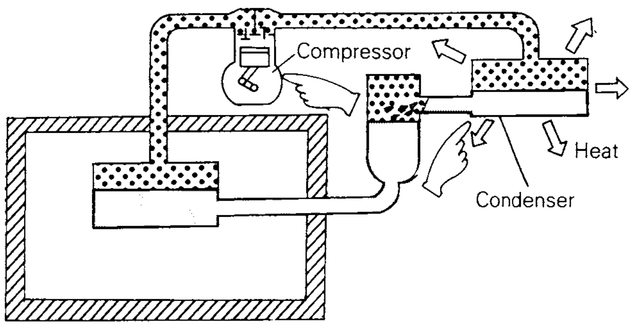
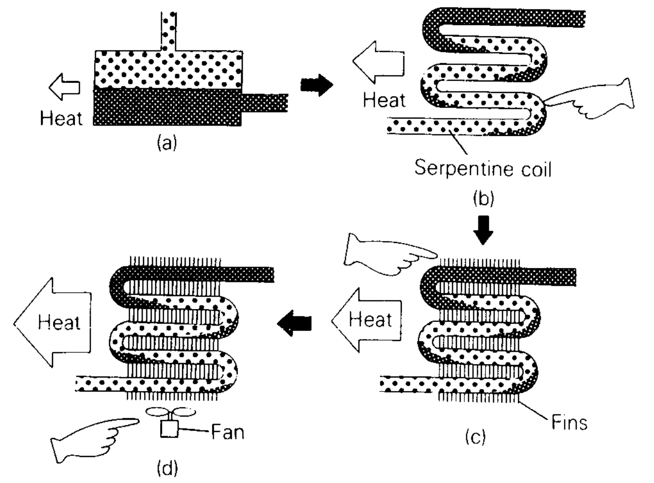


Fig.1-49



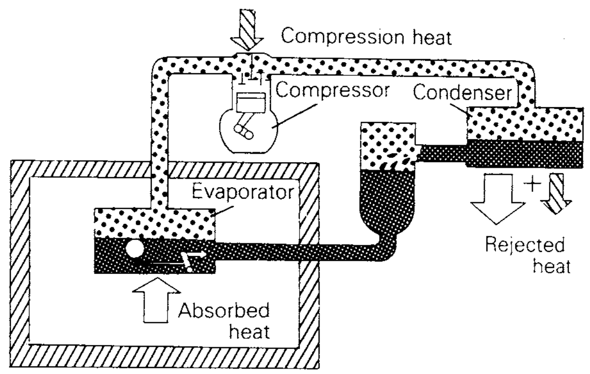
5. Improvement of heat exchange
   Efficiency of heat exchange depends on the surface area of the evaporator and the condenser at which the heat exchange occurs. If a serpentine coil is substituted for the simple container, the efficiency of heat exchange will be improved because of its greater surface area. [See Fig. 1-50(b)]
   Furthermore, supplying fins on the serpentine coil provides better efficiency of heat exchange. [See Fig. 1-50(c)]
   Air volume is also one of the main factors in heat exchange. A supply of an electric fan makes the heat transference more efficient. [See Fig. 1-50(d).]

Fig.1-50



During compression, mechanical work is done for compressing vapor to the higher pressure. Therefore, the heat to be given off to the condensing medium at the condenser is the sum of the heat absorbed at the evaporator and the compression heat corresponding to the mechanical work at the compressor. For this reason, the size of a condenser is usually larger than that of an evaporator. (See Fig. 1-51.)

Fig.1-51



6. Now, the refrigerant flowing out of the condenser into the cylinder is completely liquefied (condensed) and is ready to be recirculated to the evaporator.

   Any container, such as the one shown in Fig. 1-52, in which a condensed refrigerant is stored is called a "receiver".

7. The expansion valve, such as the one shown in Fig. 1-52, is commonly used instead of the float valve assembly. Now, the refrigeration system is completed.

Fig.1-52

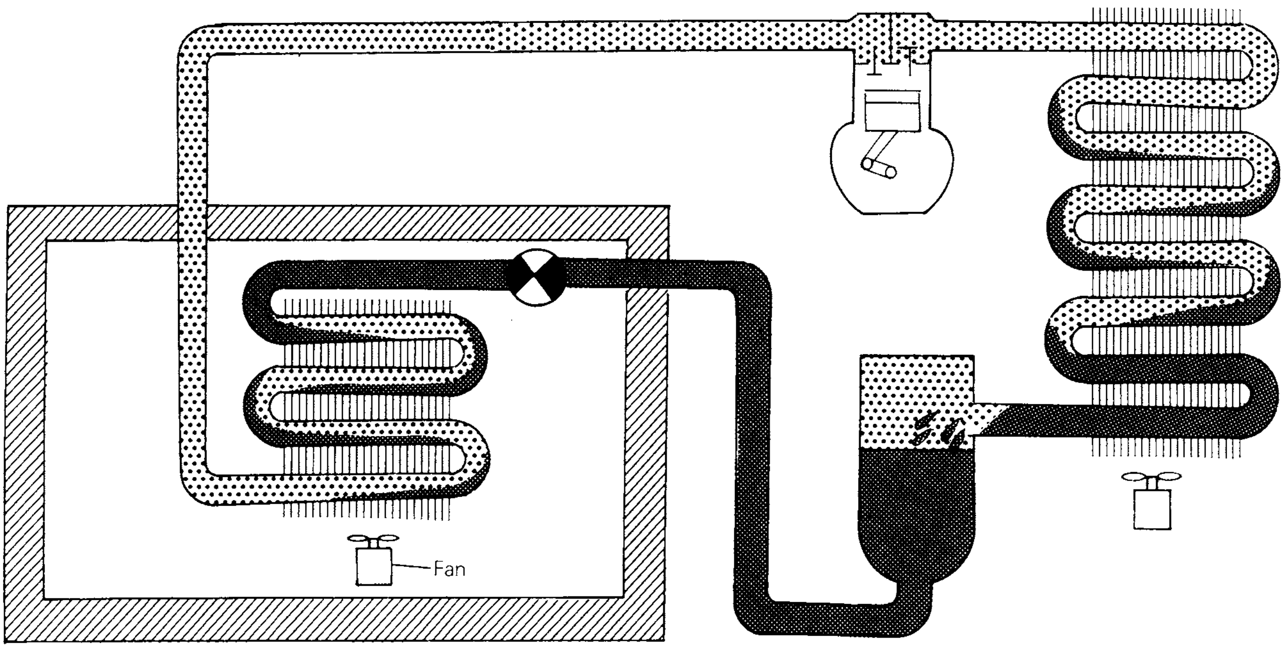
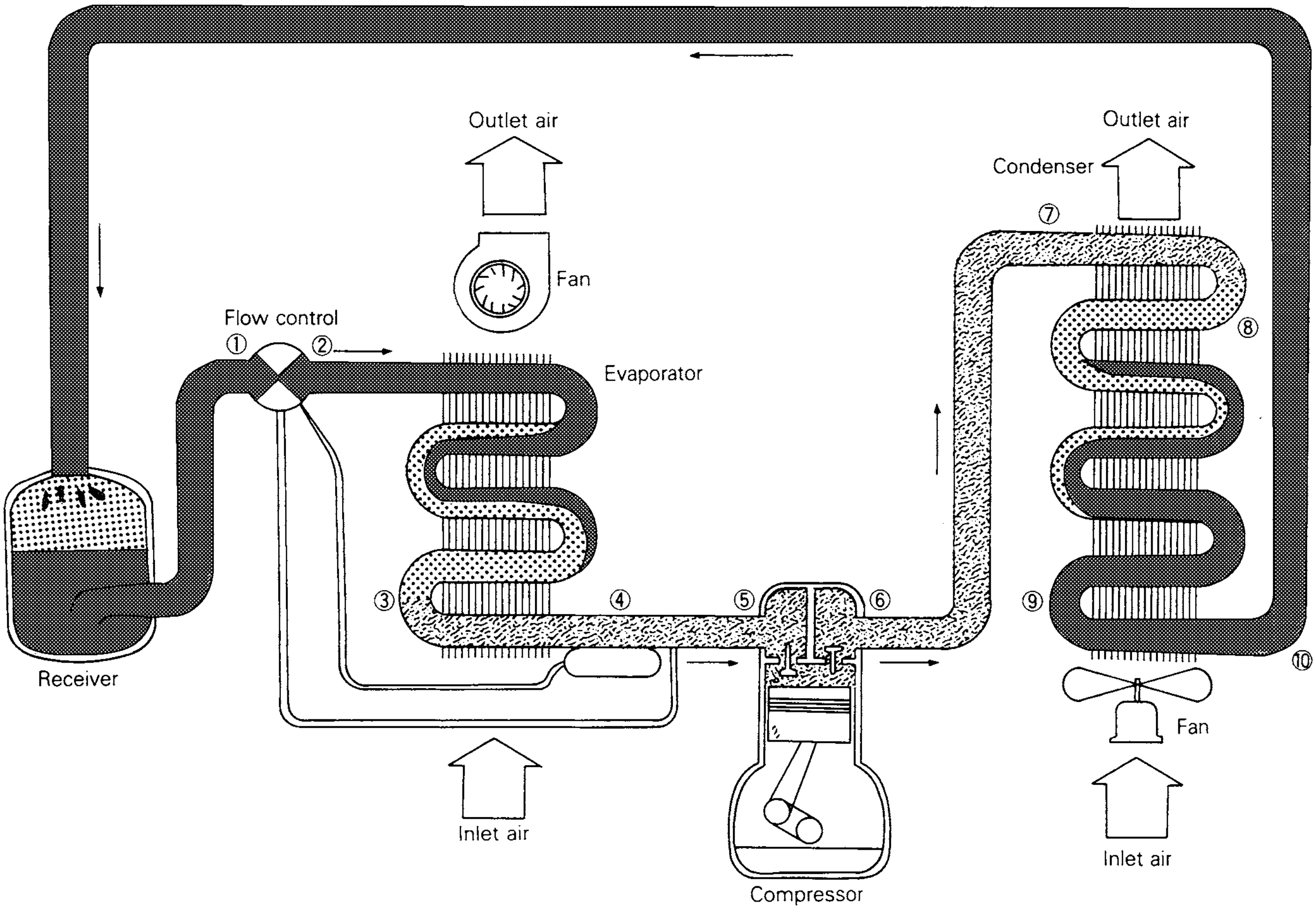
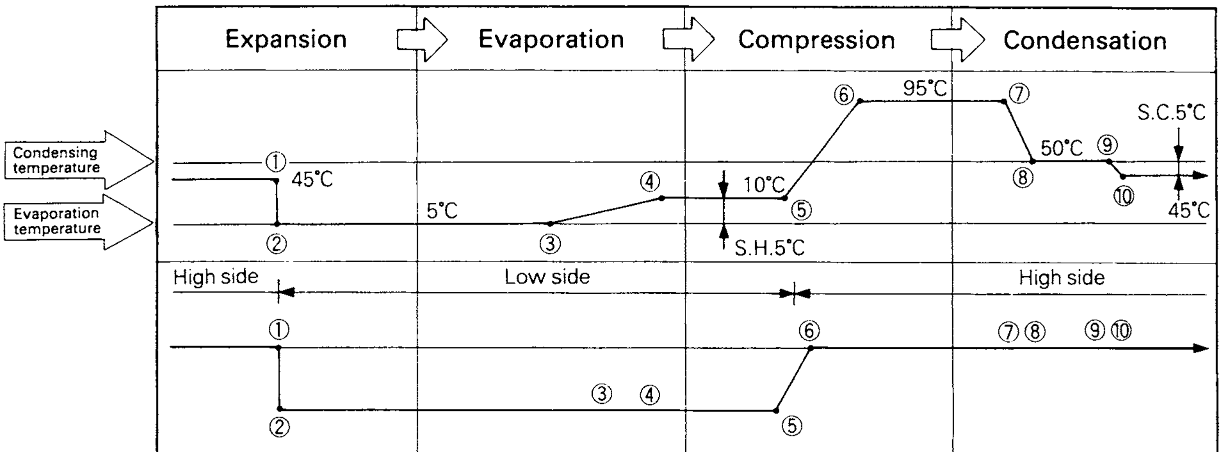


Fig.1-53





⑩~①	②~③	③~④~⑤	⑥~⑦~⑧	⑧~⑨	⑨~⑩
Subcooled liquid	Liquid-vapor mixture	Superheated vapor	Superheated vapor	Liquid-vapor mixture	Sub-cooled liquid

1.4.6 Refrigeration cycle

Refrigeration cycle... As the refrigerant circulates through the system, it passes through numbers of changes in state or condition, each of which is called a process. The refrigerant starts at some initial state or condition, passes through a series of processes in a definite sequence, and returns to the initial condition. This series of processes is called a "refrigeration cycle ". The simple refrigeration cycle is made up of four fundamental processes.

(1)Expansion
(2)Vaporization
(3)Compression
(4)Condensation

(1) Expansion
Starting at the receiver, high-temperature, high-pressure liquid refrigerant flows from the receiver through the liquid line to the refrigerant flow control.
The pressure of the liquid is reduced to the evaporator pressure as the liquid passes through the refrigerant flow control so that the saturation temperature of the refrigerant entering the evaporator will be below the temperature of the refrigerated space.
A part of the liquid vaporizes as it passes through the refrigerant control in order to reduce the temperature of the liquid to the evaporating temperature.

(2) Vaporization
In the evaporator, the liquid vaporizes at a constant pressure and temperature as heat to supply the latent heat of vaporization passes from the refrigerated space through the walls of the evaporator to the vaporizing liquid.
All the refrigerant is completely vaporized within the evaporator, and superheated by the end of the evaporator.
Although the temperature of the vapor increases somewhat by the end of the evaporator as the result of superheating, the pressure of the vapor does not change.
Although the temperature of the vapor increases somewhat by the end of the evaporator as the result of superheating, the pressure of the vapor does not change.
Although the vapor absorbs heat from the air surrounding the suction line, raising its temperature and also decreases its pressure slightly because of the friction loss in the suction line, those changes are neglected in the explanation of a simple refrigeration cycle.

(3) Compression
By the action of the compressor, the vapor resulting from the vaporization is drawn from the evaporator through the suction line into the suction inlet of the compressor.
In the compressor, the temperature and pressure of the vapor are raised by compression and the high-temperature, high-pressure vapor is discharged from the compressor into the discharge line.

(4) Condensation
The vapor flows through the discharge line to the condenser where it gives off heat to the relatively cool air being drawn across the condenser by the condenser fan.
As the hot vapor gives off heat to the cooler air, its temperature is reduced to the new saturation temperature corresponding to its new pressure, and the vapor condenses back into the liquid state as additional heat is removed.
By the time the refrigerant reaches the bottom of the condenser, all of the vapor is condensed and further sub-cooled.

Then the sub-cooled liquid passes into the receiver and ready to be recirculated.

1.4.7 Principal parts of the refrigeration system

The principal parts of the refrigeration system are as stated below.

(1) Receiver
Its function is to provide storage for the liquid condenser so that a constant supply of liquid is available to the evaporator as needed.

(2) Liquid line
Its function is to carry the liquid refrigerant from the receiver to the refrigerant flow control.

(3) Refrigerant flow control
Its functions are to meter the proper amount of refrigerant to the evaporator and to reduce the pressure of the liquid entering the evaporator so that the liquid vaporizes in the evaporator at the desired low temperature.

(4) Evaporator
Its function is to provide a heat transfer surface though which heat can pass from the refrigerated space into the vaporizing refrigerant.

(5) Suction line
Its function is to convey the low pressure vapor from the evaporator to the suction inlet of the compressor.

(6) Compressor
Its functions are to remove the vapor from the evaporator, and to raise the temperature and pressure of the vapor to such a point that the vapor can be condensed with normally available condensing media.

(7) Discharge line
Its function is to deliver the high-pressure, high-temperature vapor from the discharge of the compressor to the condenser.

(8) Condenser
Its function is to provide a heat transfer surface through which heat passes from the hot refrigerant vapor to the condensing medium.

1.4.8 Low side and high side

A refrigerating system is divided into two parts according to the pressure exerted by the refrigerant in the two parts.

Low side... The low pressure part of the system consists of the refrigerant flow control, the evaporator and the suction line. The pressure exerted by the refrigerant in these parts is the low pressure under which the refrigerant is vaporizing in the evaporator. This pressure is known variously as "low pressure", "low side pressure", "suction pressure" or "vaporizing pressure".

High side... The high pressure part of the system consists of the compressor, the discharge line, the condenser, the receiver and the liquid line. The pressure exerted by the refrigerant in this part of the system is the high pressure under which the refrigerant is condensed in the condenser. This pressure is called "high pressure", "discharge pressure" or "condensing pressure".

The dividing points between the high and low pressure sides of the system are the refrigerant flow control, where the pressure of the refrigerant is reduced from the condensing pressure to the vaporizing pressure, and the discharge valves in the compressor, through which the high pressure vapor is exhausted after compression.

Chapter 2 Mollier chart

Chapter 2 Mollier chart

The state of refrigerant in a refrigeration cycle varies with a wide range of conditions while an air conditioner or a chiller is in operation.
When the changes in state under these conditions are plotted on a chart, each state and the numerical values of the state in every part of the equipment can be estimated.
Furthermore, the capacity or the operating state can be estimated using these values. This chart is called the P-h Chart.
The vertical axis of the P-h Chart specifies the pressure (P), and the horizontal axis specifies the specific enthalpy (h). The P-h Chart is therefore sometimes referred to as "Pressure-enthalpy Chart". Furthermore, this Chart has received another name derived from the name of the inventor of the Chart, that is, "Mollier (or "Morieru" in Japanese) Chart".
The P-h Chart consists of 8 kinds of lines in all; saturated liquid line, saturated vapor line, constant temperature lines, constant specific volume lines, constant dryness lines and constant specific entropy lines as well as constant pressure lines and constant enthalpy lines. It looks like a map, which shows the refrigerant properties diagrammatically. The methods of drawing the lines vary to some extent with the types of refrigerants, while the basic method of reading the lines does not vary. In this textbook, the R22 refrigerant (fluorocarbon: HCFC22, most-often used for air conditioning), is used as the teaching material. Furthermore, SI unit (International System of Units) is used to represent the unit.

2.1 Composition of P-h Chart

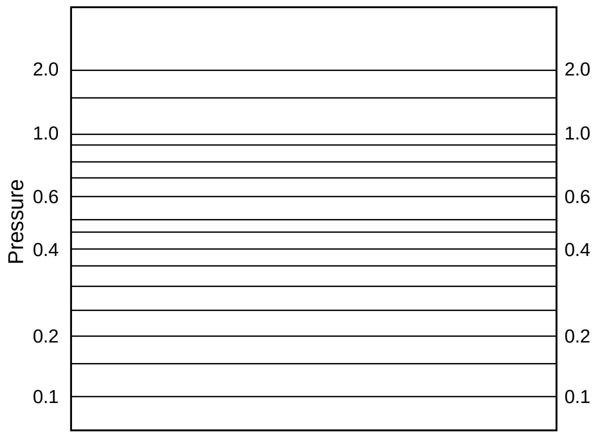
2.1.1 Pressure: P [MPa abs]

In the P-h Chart, pressure is graduated on the vertical axis. Therefore, horizontal lines represent constant pressure lines; and all points on the same horizontal line show the same pressure.
The scale is logarithmic but not required to be bound for use.
The pressure scale is expressed in the value of absolute pressure.

Absolute pressure = Gauge pressure + Atmospheric pressure
[MPa abs] = [MPa G] + 0.1 [MPa abs]

Note: Under normal conditions, the "abs" of "MPa abs" is often omitted. In this textbook, however, the "abs" consciously remains shown for ease of understanding.

Fig.2-1



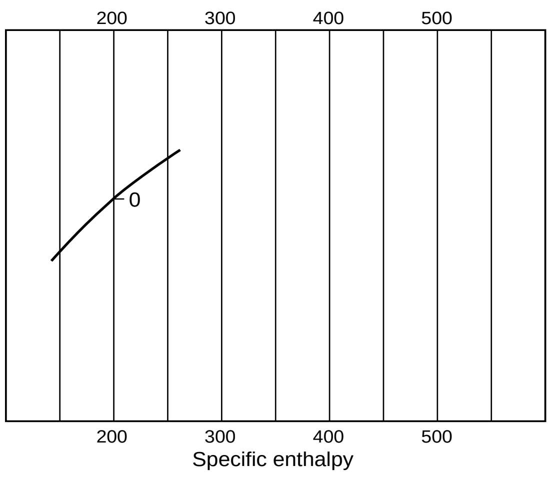
Q. 1

Chiller is operating with the use of R22 refrigerant. The low pressure gauge shows 0.5MPa G and the high pressure gauge shows 1.7MPa G. Show each of these pressures on the P-h Chart using horizontal lines.

2.1.2 Specific enthalpy: h [kJ/kg]

The specific enthalpy is graduated on the horizontal axis. Therefore, constant specific enthalpy lines are shown with vertical lines. This scale is proportionally graduated. Therefore, the numerical values must be read as accurately as possible.
The specific enthalpy is the sum of internal energy and work energy; which can be defined as the total amount of heat held by the refrigerant in a given state.
On the P-h Chart, the specific enthalpy of 1 kg mass of saturated liquid at 0˚C is defined as 200 kJ/kg.

Fig.2-2



Note: The specific enthalpy is scientifically defined as:

h = ue + Pv
h: Specific enthalpy
ue: Internal energy
P: Absolute pressure
v: Specific volume

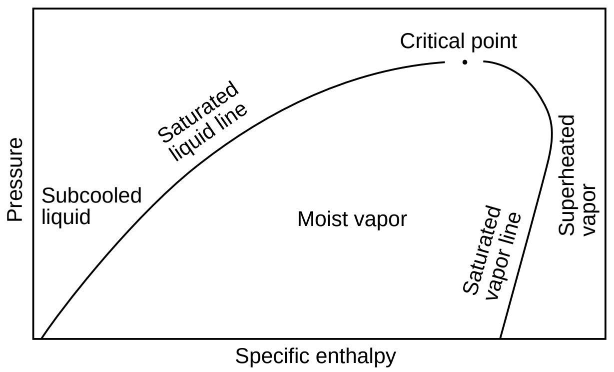
2.1.3 Saturated liquid line and saturated vapor line

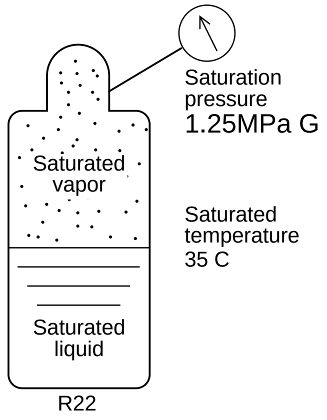
Liquefied refrigerant at its boiling point is a saturated liquid. A line connecting all boiling points is called the saturated liquid line.
Similarly, a vaporized refrigerant at its boiling point is a saturated vapor. A line connecting all boiling points is called the saturated vapor line.
Saturated temperature equivalent to the pressure is graduated on these lines.
When liquid refrigerant of a given pressure is heated, its specific enthalpy increases. In the liquid refrigerant region, when the temperature reaches the boiling point (saturated liquid), vapors are generated, thus resulting in moist vapors. A point, where the moisture has completely vaporized by further heating, is called the saturated vapor. When heat is applied to the saturated vapor, the temperature rises to form the superheated vapor region.

[Critical point]

When the refrigerant pressure increases up to a limit, the refrigerant vaporizes without boiling. This vaporization point is called the critical point. Since there is no practical occurrence of the critical point, some P-h Charts are produced at or below the critical point.

Fig.2-3





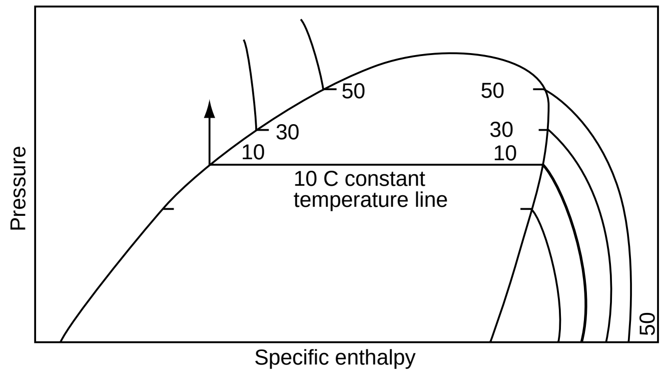
Q. 2

How is the state and what is the dryness factor at the point having a pressure of 0.7MPa abs and a specific enthalpy of 340 kJ/kg? (R22)

2.1.4 Temperature: t (˚C)

When the points of equal refrigerant temperature are connected with lines throughout the sub-cooled liquid, moist vapor, and superheated vapor regions, these lines are called the constant temperature lines.
The constant temperature lines show up as vertical lines in the sub-cooled liquid region, and parallel to the constant pressure lines in the moist vapor region. In the superheated vapor region, they show up as downward-sloping curve.
Temperature graduation is marked in 10˚C increments and numerical values in 20˚C increments.

Fig.2-4



Q. 3

In which of the following regions is the state at a pressure of 0.4MPa abs and a temperature of 60˚C represented?
Furthermore, find the specific enthalpy value in the state? (R22)
(1) Moist vapor region
(2) Superheated vapor region
(3) Sub-cooled liquid region

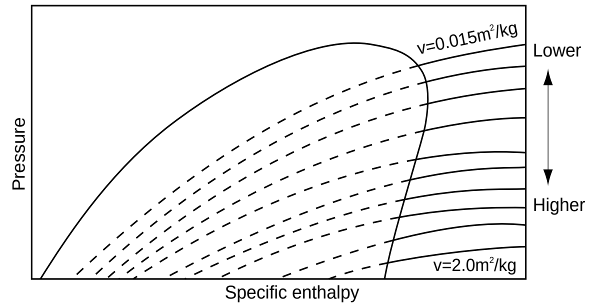
Q. 4

In which of the following regions is the state at a pressure of 0.8MPa abs and a temperature of 0˚C represented?
Furthermore, find the specific enthalpy value in the state? (R22)
(1) Moist vapor region
(2) Superheated vapor region
(3) Sub-cooled liquid region

2.1.5 Specific volume: v [m^3/kg]

The volume occupied by 1 kg mass of refrigerant is the specific volume. Lines that connect the points of equal volume are the constant volume lines. The values are written on the right side of the superheated vapor region. The scale is logarithmic, while the numerical values can be read without paying much attention to the scale.
The larger the specific volume of refrigerant vapor is, the lower the gas density becomes. In other words, the gas becomes lighter in weight. By contrast, the smaller the specific volume is, the higher the gas density becomes, that is, the gas becomes heavier in weight.
Sometimes, these constant volume lines are shown with broken lines, or the lines are omitted in the moist vapor region.

Fig.2-5



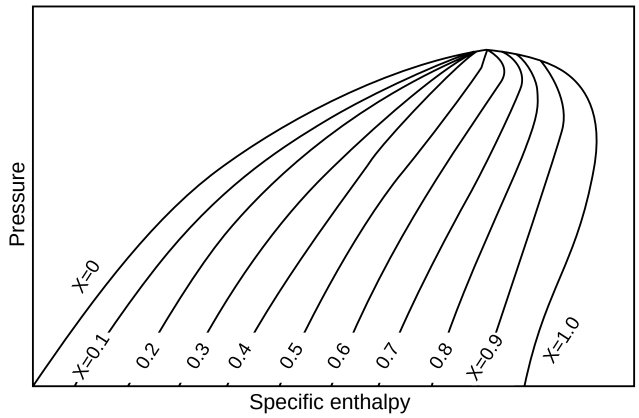
Q. 5

Find the value of the specific volume and the specific enthalpy of refrigerant vapor at a pressure of 0.4MPa abs and a temperature of 30˚C. (R22)

2.1.6 Dryness factor: X

In the liquid/vapor mixture state, that is, in the moist vapor region, the percentage of vapor in the mixture is called the dryness factor. Lines drawn by connecting points of equal dryness factor are called the constant dryness lines.
Dry saturated vapors have a 1.0 dryness factor. If the dryness factor is 0.3, it means that 30% of the moist vapor is dry saturated vapor and 70% is saturated liquid.
However, this is the percentage by weight of refrigerant.
The dryness factor strictly represents the percentage of vapor in the moist vapor region.

Fig.2-6



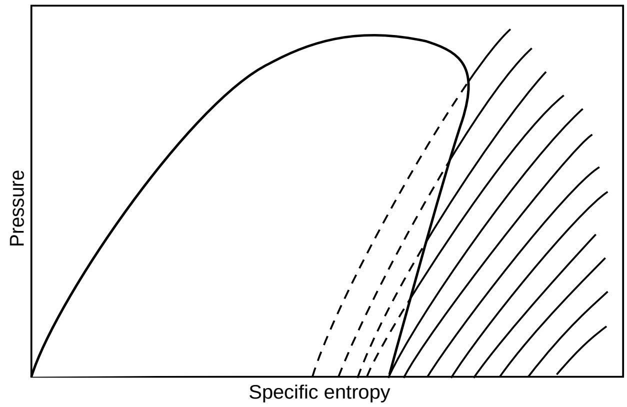
Q. 6

Find the value of the dryness factor of moist vapor having a specific enthalpy of 240 kJ/kg and a pressure of 0.2MPa abs. (R22)

2.1.7 Specific entropy: s [kJ/(kg·K)]

The lines which connect the points of equal specific entropy are called the constant entropy lines. There may be the cases where these lines are drawn only in the superheated vapor region with steep upward-sloping line or extended up to the moist vapor region. In the latter case, pay attention so as not to confuse with the constant dryness factor lines.
The compression process of refrigerant with a compressor completes in an extremely short period of time. Therefore, it is normally assumed that there is no heat exchange between the refrigerant and the surroundings. In other words, compression occurs with constant specific entropy. This is called an adiabatic compression. In the adiabatic compression, the conditions vary along the constant specific entropy lines.

Fig.2-7



Note: The specific entropy is scientifically defined as follows.

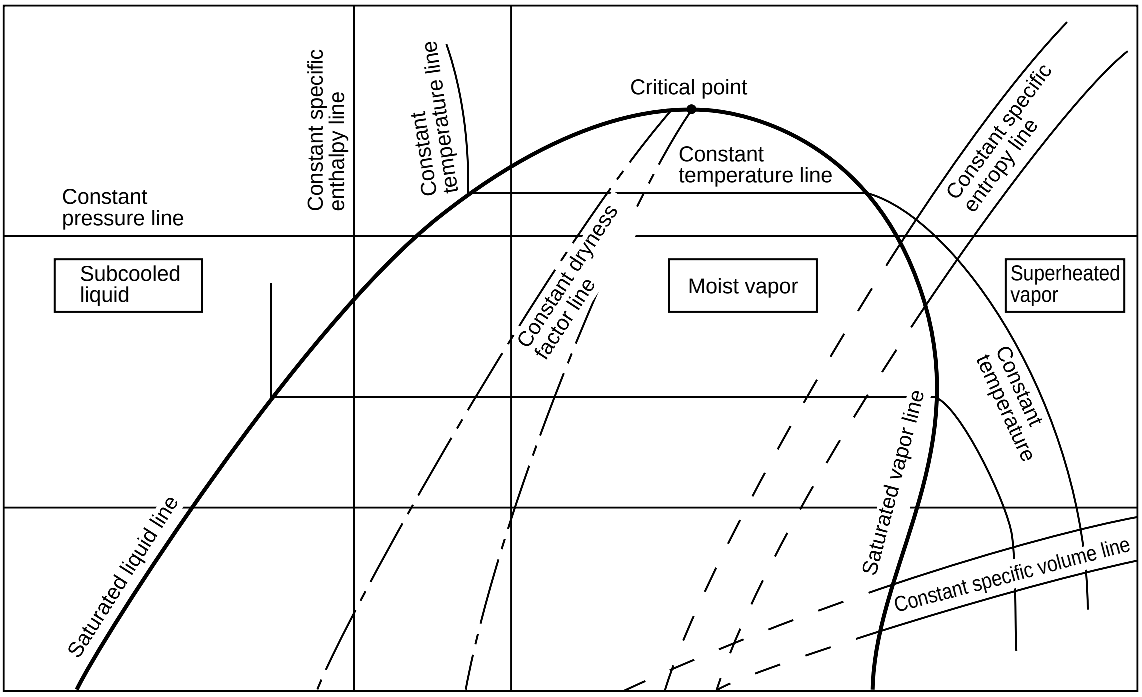
The amount obtained by dividing the heat amount transferred to a material of unit mass at a given temperature by the absolute temperature is taken as the increase of the specific entropy. When heat amount of dQ is transferred to a material of absolute temperature T, the increase of the specific entropy dS is calculated with the following formula.

$$dS = dQ/T$$

This "S" is defined as "specific entropy".

2.1.8 Summary

Fig.2-8



Exercise 1

Put down from Point A to Point E shown in the following table on the P-h Chart (R22) and fill in blanks (1) to (20) in the table with respective numerical values obtained from the Chart using such points. (If the column which cannot be filled from the Chart, fill it with an oblique line.)

Table 2-1

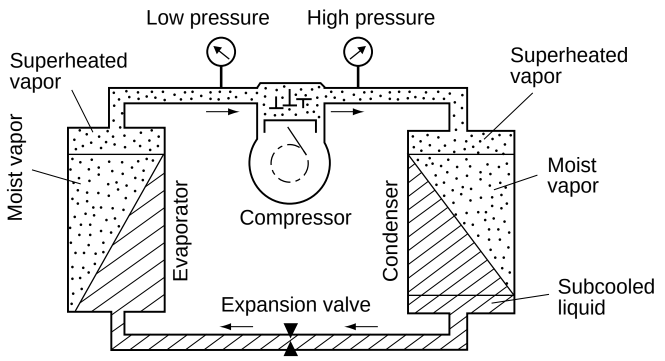
	P Absolute pressure MPa abs	t Temperature C	h Specific enthalpy kJ/kg	s Specific entropy kJ/(kg•K)	v Specific volume m^3/kg	x Dryness factor
Point A	0.8	80	(1)	(2)	(3)	(4)
Point B	1.0	(5)	200	(6)	(7)	(8)
Point C	0.2	(9)	350	(10)	(11)	(12)
Point D	0.4	(13)	450	(14)	(15)	(16)
Point E	(17)	0	(18)	(19)	0.1	(20)

2.2 How to draw refrigeration cycle

2.2.1 Vapor compression refrigeration cycle

Chiller and air conditioners consist of four major components such as evaporator, compressor, condenser, and expansion valve. The refrigerant flows through these components and the process of evaporation → compression → condensation → expansion repeats to carry out refrigeration. This process is called the refrigeration cycle.

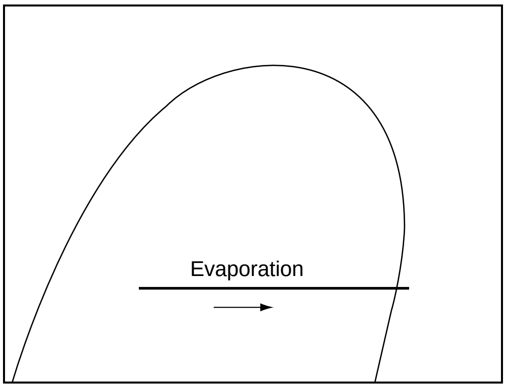
Fig.2-9



1. Evaporation (Change of phase in the evaporator)

The evaporation is a process in which the low-temperature low-pressure liquid refrigerant evaporates while removing heat from the indoor air or moisture. On the P-h Chart, this change of phase is represented by drawing a line from left to right with a constant pressure line, that is, a horizontal line.

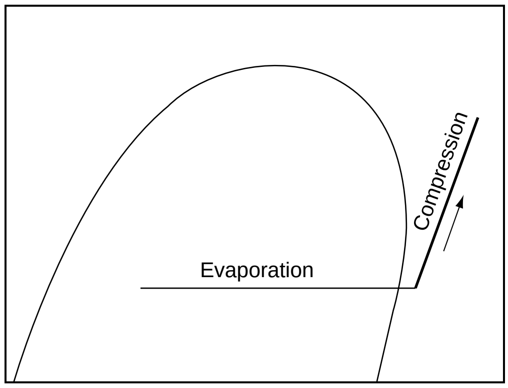
Fig.2-10



2. Compression (Change of phase in the compressor)

The compression is a process in which the compressor sucks in gases generated through the evaporation process and compresses the gases into high-temperature high-pressure superheated vapor. This process is taken as the adiabatic compression, that is, the constant specific entropy change.
In general, the suction gas into the compressor has a superheated degree of 5˚C. Therefore, on the P-h Chart, this change of phase stage is represented by drawing an upward-sloping line from the right side of the saturated vapor line, along the constant specific entropy line.

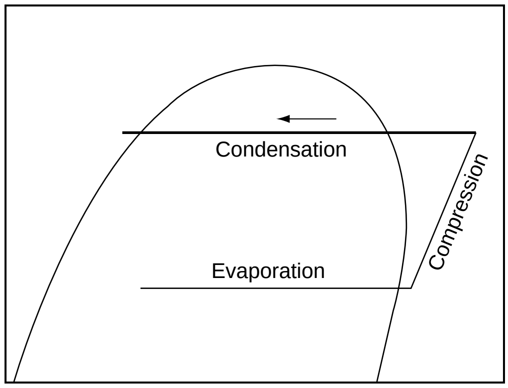
Fig.2-11



3. Condensation (Change of phase in the condenser)

The condensation is a process in which the high-temperature high-pressure discharge gas from the compressor is condensed (liquefied) through cooling water or outdoor air in the condenser. On the P-h Chart, this change of phase is represented by drawing a line from right to left with a constant pressure line, that is, a horizontal line.

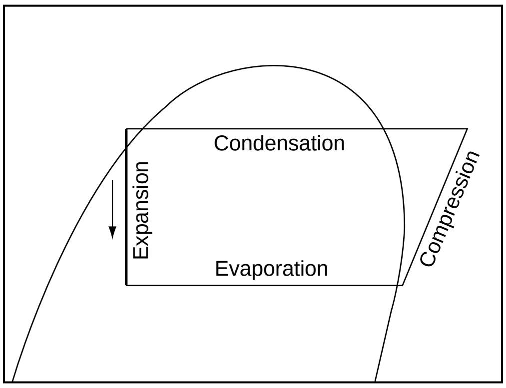
Fig.2-12



4. Expansion (Change of phase in the expansion valve or capillary tube)

The expansion is a process in which the pressure of the condensed liquid refrigerant is reduced through the expansion valve (or capillary tube) to an evaporation pressure required. In this process, since there is no heat transmission between the refrigerant and the surroundings, the phase changes according to the constant specific enthalpy.
In general, the liquid refrigerant at the inlet of the expansion valve is sub-cooled by 5˚C below the condensing temperature. Therefore, on the P-h Chart, this change of phase is represented by drawing a vertical line from top to bottom from the left side of the saturated liquid line.

Fig.2-13



2.2.2 How to draw actual operating state on P-h Chart

In order to draw the refrigeration cycle on the P-h Chart, the following four operating conditions are required. In other words, if the four conditions are known, the refrigeration cycle can be drawn on the P-h Chart.
Conditions:
1. Evaporating pressure or evaporating temperature
2. Suction gas temperature or superheated degree
3. Condensing pressure or condensing temperature
4. Liquid temperature at expansion valve inlet or sub-cooled degree

Superheated degree = Suction gas temperature - Evaporating temperature
Sub-cooled degree = Condensing temperature - Liquid temperature at expansion valve inlet

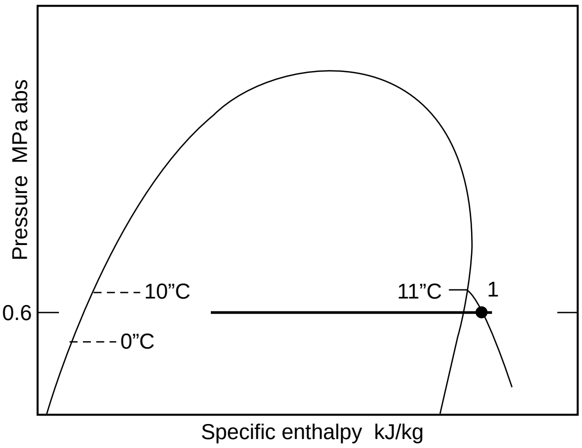
■ Procedure

Draw the refrigeration cycle on the R22 P-h Chart based on the following operating conditions.
Conditions:
Evaporating temperature = 6˚C
Condensing temperature = 36˚C
Superheated degree = 5˚C
Liquid temperature at expansion valve inlet = 31˚C

1. Evaporation process

Even though the refrigeration cycle can be started to draw from anywhere on the P-h Chart, it is usually started from the compressor suction point, that is, the completion point of the evaporation process.
Since the evaporating temperature is 6˚C, a horizontal line is drawn from the 6˚C graduations on the saturated liquid line and the saturated vapor line. The starting point of the evaporation process has not yet been known at this stage. Therefore, the horizontal line may be tentatively drawn to the right from a point with a dryness factor of about 0.4.
The evaporation process is represented with a horizontal line due to changes under constant pressure. In this case, the pressure is 0.6MPa abs, which is referred to as the evaporating (or low) pressure.
Check the superheated degree given in the above conditions to determine the point where the refrigerant is discharged from the evaporator and sucked into the compressor. In this case, since the superheated degree is 5˚C, the suction gas temperature rises by 5˚C from the evaporating temperature of 6˚C, thus reaching a temperature of 11˚C. The pressure is kept constant up to this point, therefore the Point 1 of intersection of the extension of the constant pressure line of 0.6MPa abs and the 11˚C constant temperature line that tilts toward the right by 1˚C from the 10˚C constant temperature line is taken as the suction point of the compressor.

Fig.2-14

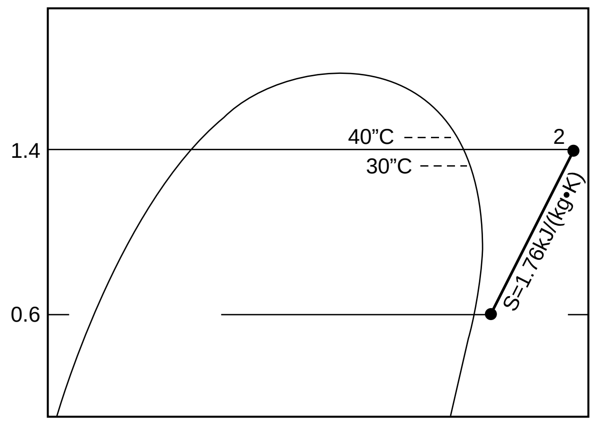


Note: Strictly speaking, the pressure varies while showing a slight drop in the evaporation process, while the pressure is assumed to be constant on the P-h Chart.

2. Compression process

The compression process starts from the Point 1. While in this process, a line is drawn according to the changes of the constant specific entropy, that is, in parallel with the specific entropy line up to the Point 2 of intersection with the line of condensing pressure (high pressure) of 1.4MPa abs corresponding to 36˚C condensing temperature.
Whereas, this specific entropy line is slightly curved, and the Point 1 does not always comes on the specific entropy line on the Chart. Therefore, it is practical to find the Point 2 according to a position on the condensing pressure line having the numerical value of specific entropy equal to that at the Point 1 and draw the line of the compression process by connecting the Points 1 and 2.
The Point 2 represents the discharge gas state from the compressor.

Fig.2-15



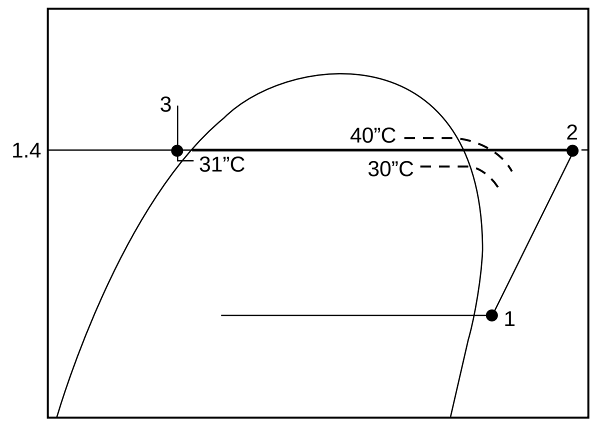
Note: The compression process is drawn as theoretical adiabatic compression. Therefore, it may be slightly different from that in actual operation.

3. Condensation process

The condensation process starts from the Point 2. Heat exchange in this process is performed mostly in the condenser, but the condensation process itself starts at the discharge point of the compressor.

At the Point 2, the condensing (high) pressure is 1.4MPa abs, which is equal to the condensing temperature of 36˚C. Since the condensation process is a heat radiation process under constant pressure, draw a line horizontally to the left from the Point 2. While in the condensation process, the refrigerant changes from superheated vapor to moist vapor, and further to sub-cooled liquid, thus proceeding to the expansion process. In this case, the temperature of liquid at the expansion valve inlet is 31˚C. Therefore, the Point 3 of intersection of the pressure line of 1.4MPa abs with the 31˚C constant temperature line that tilts toward the right by 1˚C immediately before the 30˚C constant temperature line is taken as the point where the condensation process is complete.

Fig.2-16



Note: The pressure also varies while showing a slight drop in the condensation process, while the pressure is assumed to be constant on the P-h Chart.

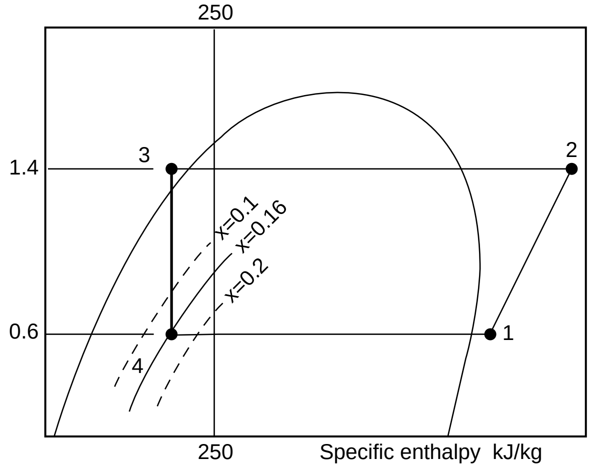
4. Expansion process

The expansion process starts from the Point 3. While in this process, a line is drawn according to the changes of the constant specific enthalpy, that is, in parallel with and perpendicular to the specific enthalpy line up to the Point 4 of intersection with the line of the evaporating pressure of 0.6MPa abs.

The distance between the Point 4 where the evaporation starts and the Point 1 represents the evaporation process.

The expansion process is performed according to the constant change of the specific enthalpy. Even though there are no external heat exchanges, the temperature of the liquid refrigerant falls from 31˚C to 6˚C. The reason is that when the liquid refrigerant pressure is reduced due to the frictional resistance while passing through the expansion valve or capillary tube, part of the liquid instantaneously vaporizes to decrease the liquid temperature.

Fig.2-17



Note: It is understood that, even though the refrigerant is in the low-temperature low- pressure liquid state when it is discharged from the expansion valve, actually moist vapor having a dryness factor of 0.16 enters the evaporator.

Exercise 2

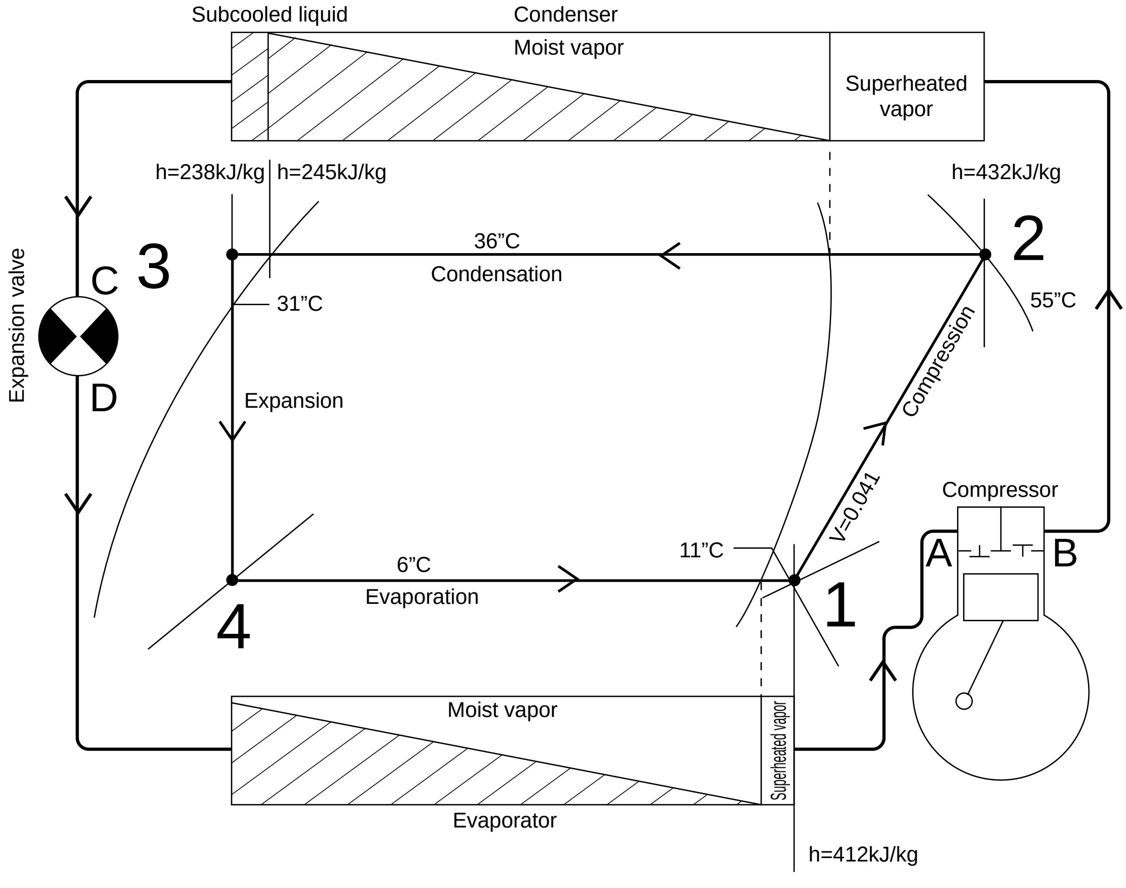
Draw a refrigeration cycle on the P-h Chart under the above-mentioned conditions. Then, read the following numerical values of the four Points 1, 2, 3, and 4. (If the column which cannot be read from the Chart, fill it with an oblique line.)

Table 2-2

	P Absolute pressure MPa abs	t Temperature C	h Specific enthalpy kJ/kg	v Specific volume m^3/kg	x Dryness factor	s Specific entropy kJ/(kg•K)
Point						
Point						
Point						
Point						

2.2.3 Summary

Fig.2-18



The four Points 1, 2, 3, and 4 on the chart represent the following states respectively.

Point 1: Refrigerant gas, which is discharged from the evaporator and sucked into the compressor, is the superheated vapor having a slightly higher superheated degree than dry saturated vapor.

Point 2: Refrigerant vapor, which is discharged from the compressor and sucked into the condenser is the superheated vapor having a considerably high superheated.

Point 3: Sub-cooled liquid, which is produced by slight subcooling in the condenser and enters the expansion valve.

Point 4: Moist vapor, which is produced by reducing pressure through the expansion valve and entering the evaporator.

The compression process (Point 1 → Point 2) is drawn in parallel to the constant specific entropy line. The condensation process (Point 2 → Point 3) and the evaporation process (Point 4 → Point 1) are performed according to the constant pressure changes and, therefore, drawn with horizontal lines.

The expansion process (Point 3 → Point 4) represents the throttling process and is drawn in parallel to the constant specific enthalpy lines.

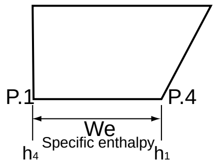
Thus, the Chart is represented in a remarkably simple form, facilitating the calculation of the amount of heat as well.

2.2.4 Calculation method of refrigeration cycle

1. Refrigeration effect We [kJ/kg]

The amount of heat (We(absorbed by 1-kg mass of refrigerant in the evaporation process is called refrigeration effect or the refrigerating capacity, which is found by the difference in the specific enthalpy between the suction gas of the compressor (Point 1) and the liquid at the evaporator inlet (Point 4).
The refrigeration effect represents the amount of heat absorbed by 1-kg mass of refrigerant flowing through the evaporator but does not represent the refrigerating capacity (kJ/h).
On the same compressor, it can be said that the larger the refrigeration effect is0, the better its operation is.
We (kJ/kg) = h1 (kJ/kg) - h4 (kJ/kg)

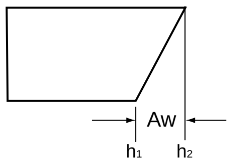
F.A



2. Thermal equivalent of compressor work Aw [kJ/kg]

The change in the refrigerant state while in the compression process, that is, the increase of specific enthalpy is performed by adding the compressor work of an electric motor as the amount of heat due to adiabatic compression, in other words, no external heat exchanges.
This value is found by drawing the refrigeration cycle on the P-h Chart, and based on the calculation of the specific enthalpy difference with the work volume taken as the amount of heat.
It means that the amount of heat has been found by taking the work volume of a electric motor required for compressing 1-kg mass of refrigerant as heat energy.
Aw [kJ/kg] = h2 [kJ/kg] - h1[kJ/kg]

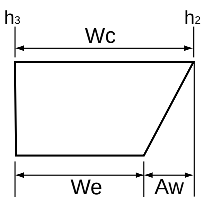
F.B



3. Condensing load Wc [kJ/kg]

The amount of heat extracted while in the condensation process is called condensing load, which is found by the difference in the specific enthalpy between the discharge gas from the compressor (Point 2) and the refrigerant at the inlet of the expansion valve (Point 3).
Wc [kJ/kg] = h2 [kJ/kg] - h3[kJ/kg]
In addition, it is found by the sum of the refrigerating effect [We] and the thermal equivalent of compressor work [Aw]. Thus, the transfer of the refrigerant heat is balanced.
Wc [kJ/kg] = We + Aw

F.C



4. Coefficient of performance (COP)

The coefficient of performance represents how much cooling capacity is obtained per input of an electric motor (the thermal equivalent). Comparing evaporation heat [We] absorbed while in the evaporation process with the amount of heat [Aw] required for compression work, it is understood that the amount of heat absorbed while cooling is many times higher than the thermal equivalent of the compressor work, which is called "coefficient of performance". Namely, the larger the coefficient of performance is, the higher effective operation is performed. In other words, energy saving operation is enabled.

$$COP = \frac{We}{Aw} = \frac{h1 - h4}{h2 - h1}$$ There are no measured of the COP.

5. Compression ratio

The ratio of high (condensing) pressure to low (evaporating) pressure is called "compression ratio".
In this case, absolute pressure (MPa abs) is used.
While in the compression process, low-pressure gas is compressed to high-pressure gas and discharged. The high-pressure gas remains in the narrow space on top of the cylinder (referred to as "top clearance"). This residual high-pressure gas expands while the piston moves downward, thus disabling the suction valve to open until the internal pressure of the cylinder becomes lower than the low pressure and resulting in no suction of the refrigerant gas.
Therefore, the larger the compression ratio is, the smaller refrigerant circulated and capacity become.

$$\text{Compression ratio} = \frac{PH(MPa\ abs)}{PL(MPa\ abs)}$$

There are no measured of the compression ratio.
PH: High pressure(MPa abs)
PH: Low pressure(MPa abs)

6. Suction gas density · [kg/m^3]

The suction gas density [·] is found using the reciprocal of the specific volume v [m^3/kg].
While in the compression process, the larger the gas density absorbed in the cylinder is, the higher amount of refrigerant circulated and the higher capacity are achieved. Therefore, the smaller the specific volume of suction gas is, the larger capacity operation becomes.

$$\text{Suction gas density } [kg/m^3] = \frac{1}{V(m^3/kg)}$$

Exercise 3

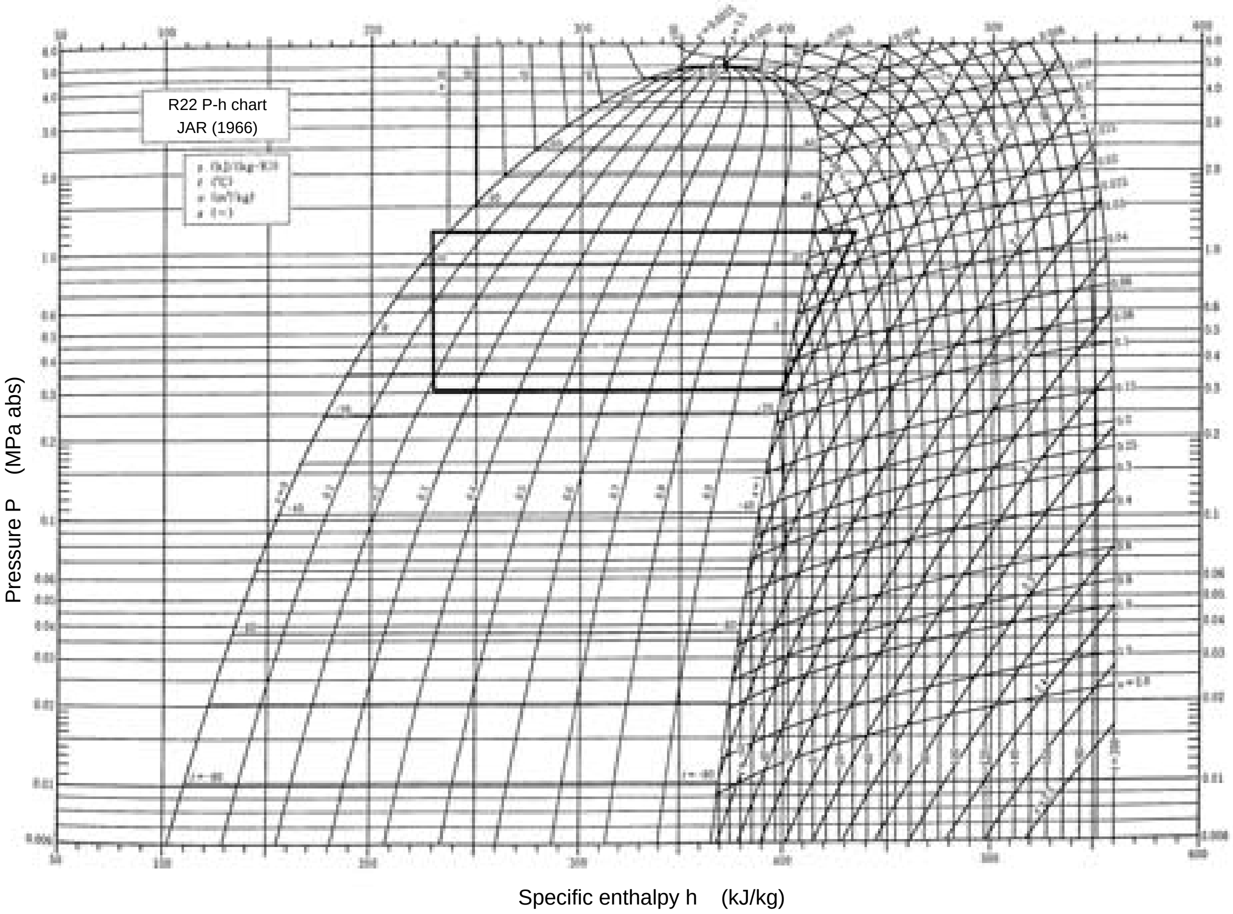
Perform the following calculations using the numerical values of Exercise 2.

(1) Refrigerating effect
(2) Thermal equivalent of compressor work
(3) Condensing load
(4) Coefficient of performance
(5) Compression ratio
(6) Suction gas density

2.3 Basic cycle by model

2.3.1 Standard refrigeration cycle

Fig.2-19



- **Operating Conditions**

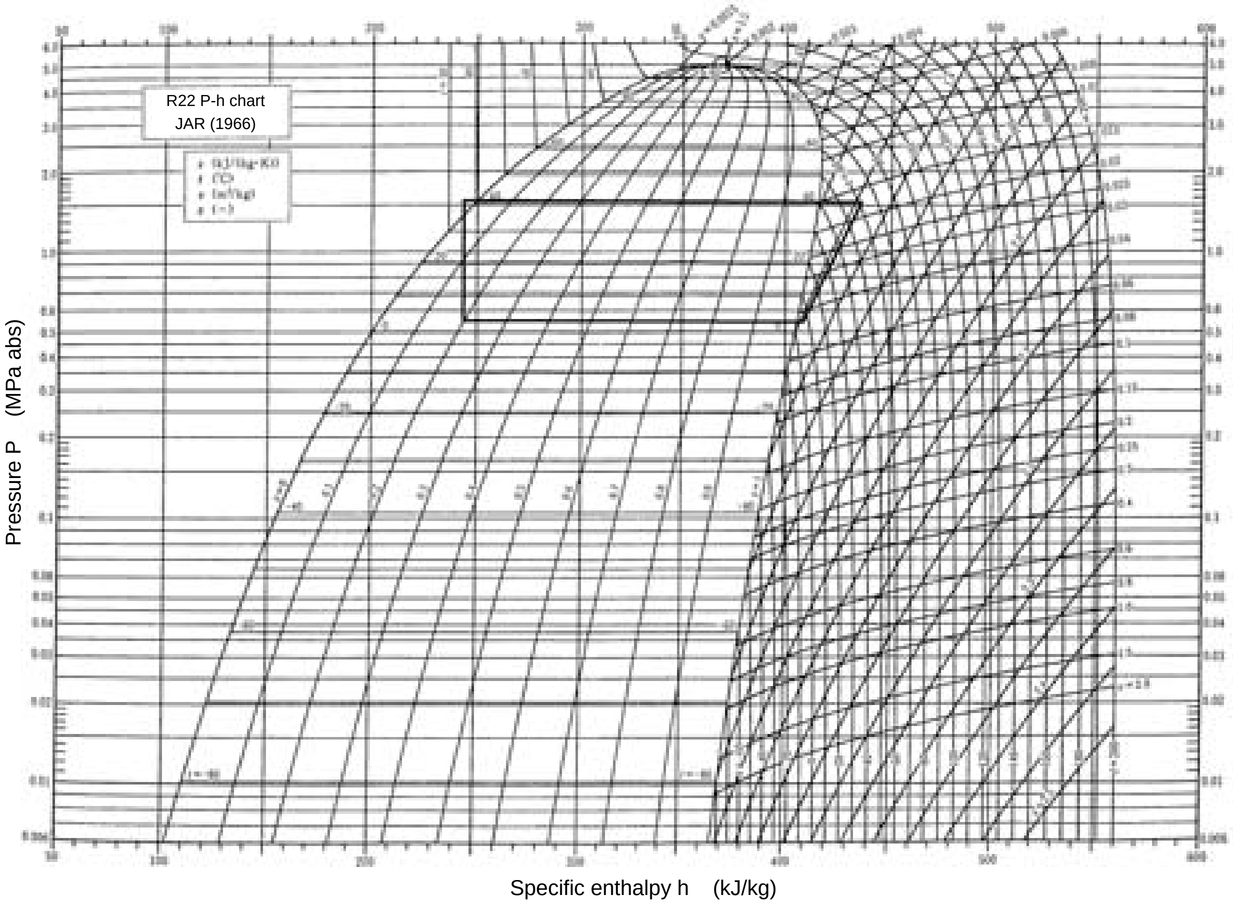
Evaporating temperature	-15˚C
Superheated degree	0˚C
Condensing temperature	30˚C
Liquid temperature at expansion valve inlet	25˚C

- **Data**

Evaporating pressure	0.3MPa abs
Suction gas	
Temperature	-15˚C
Specific enthalpy	399 kJ/kg
Specific volume	0.08 m^3/kg
Specific enthalpy at expansion valve inlet	230 kJ/kg
Sub-cooled degree	5˚C
Refrigerating effect	169 kJ/kg
Thermal equivalent of compressor work	36 kJ/kg
Condensing load	205 kJ/kg
Coefficient of performance	4.69
Compression ratio	4.0
Condensing pressure	1.2MPa abs
Discharged gas	
Temperature	54˚C
Specific enthalpy	435 kJ/kg

2.3.2 Cooling cycle in water-cooled air conditioner

Fig.2-20



■ **Operating Conditions**

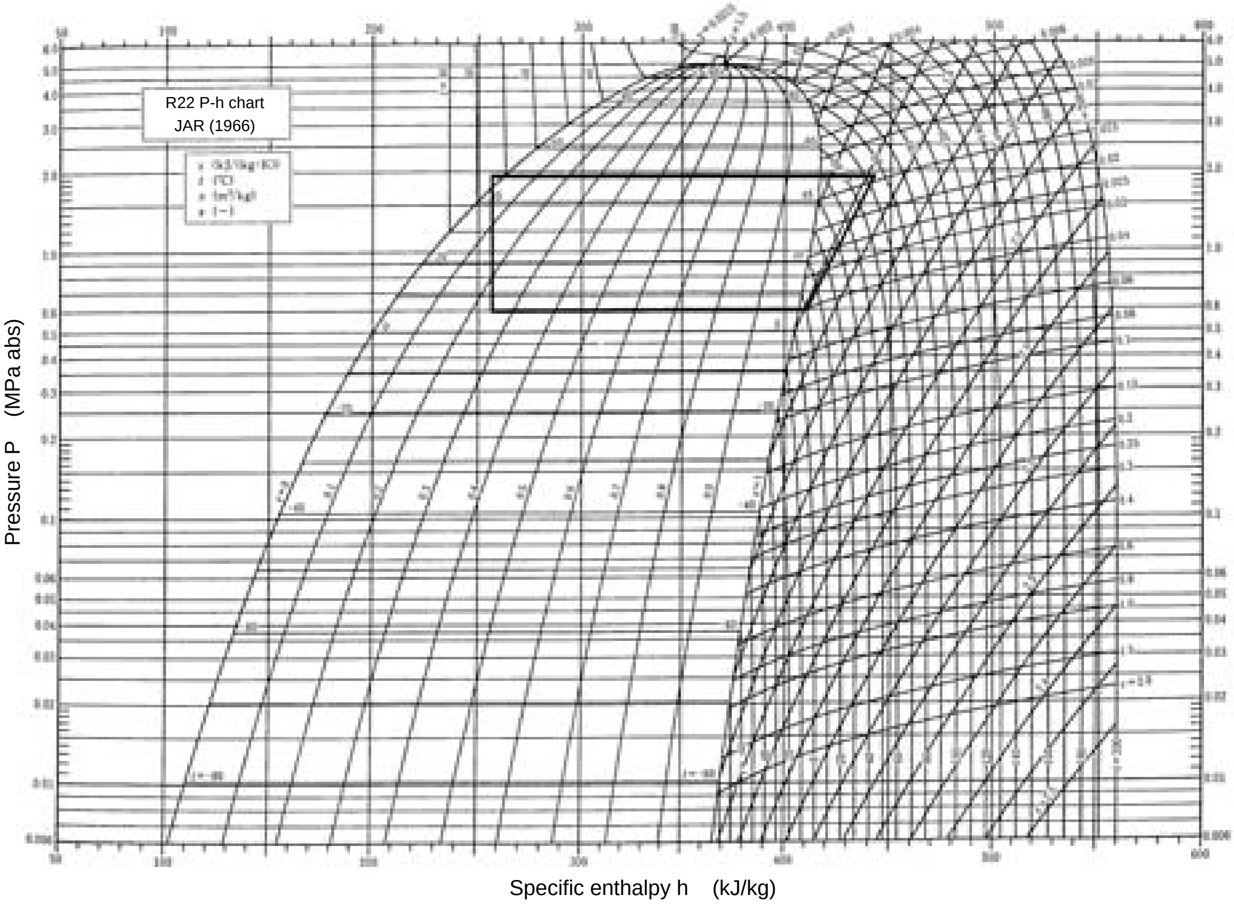
Evaporating temperature	2˚C
Superheated degree	5˚C
Condensing temperature	40˚C
Liquid temperature at expansion valve inlet	35˚C

■ **Data**

Evaporating pressure	0.53MPa abs
Suction gas	
Temperature	7˚C
Specific enthalpy	410 kJ/kg
Specific volume	0.046 m^3/kg
Specific enthalpy at expansion valve inlet	243 kJ/kg
Sub-cooled degree	5˚C
Refrigerating effect	167 kJ/kg
Thermal equivalent of compressor work	26 kJ/kg
Condensing load	193 kJ/kg
Coefficient of performance	6.42
Compression ratio	2.89
Condensing pressure	1.53MPa abs
Discharged gas	
Temperature	61˚C
Specific enthalpy	436 kJ/kg

2.3.3 Cooling cycle in air-cooled air conditioner

Fig.2-21



- **Operating Conditions**

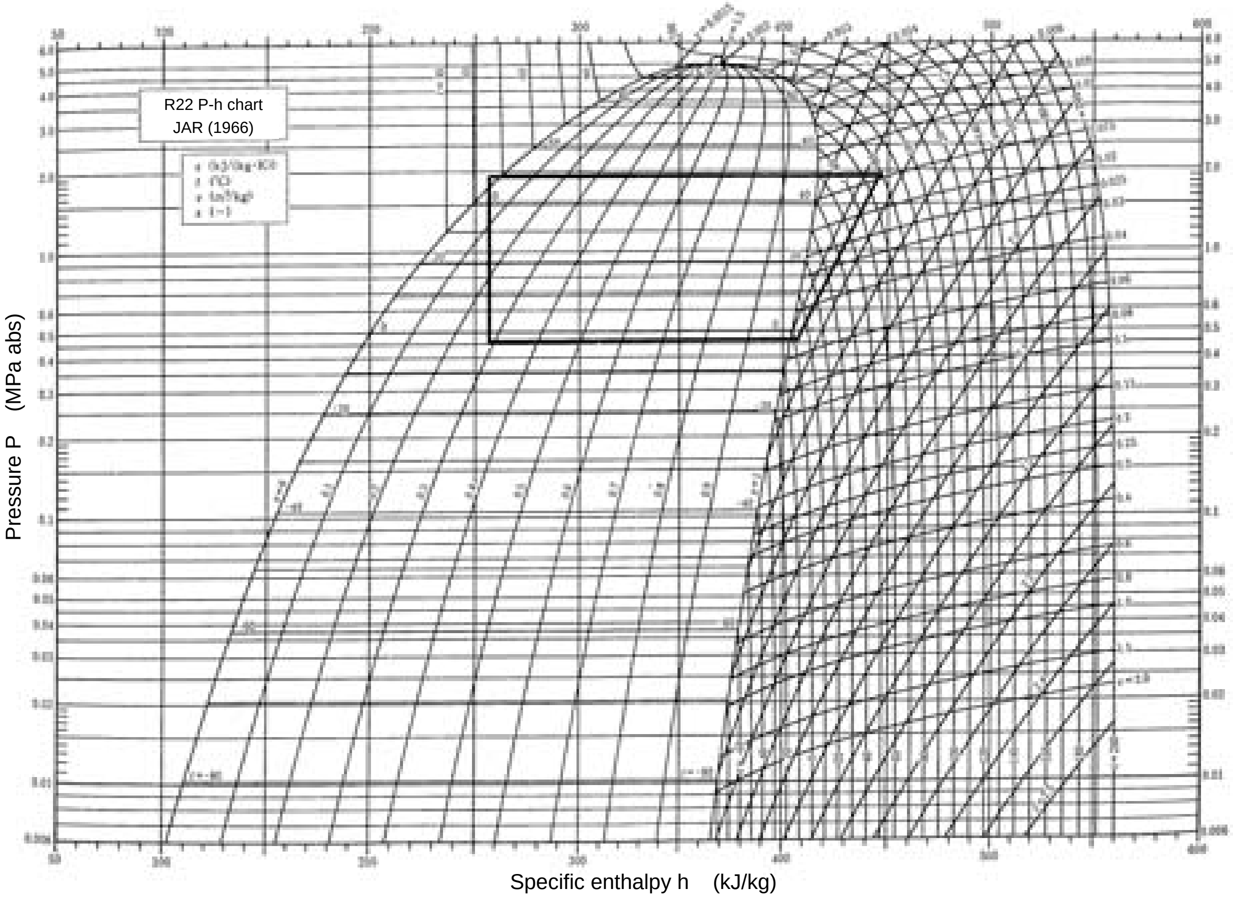
Evaporating temperature	5˚C
Superheated degree	5˚C
Condensing temperature	50˚C
Liquid temperature at expansion valve inlet	45˚C

- **Data**

Evaporating pressure	0.6MPa abs
Suction gas	
Temperature	10˚C
Specific enthalpy	410 kJ/kg
Specific volume	0.04 m^3/kg
Specific enthalpy at expansion valve inlet	257 kJ/kg
Sub-cooled degree	5˚C
Refrigerating effect	153 kJ/kg
Thermal equivalent of compressor work	33 kJ/kg
Condensing load	186 kJ/kg
Coefficient of performance	4.64
Compression ratio	3.27
Condensing pressure abs	1.96MPa
Discharged gas	
Temperature	75˚C
Specific enthalpy	443 kJ/kg

2.3.4 Heating cycle in air-cooled air conditioner

Fig.2-22



- **Operating Conditions**

Evaporating temperature	-3˚C
Superheated degree	5˚C
Condensing temperature	50˚C
Liquid temperature at expansion valve inlet	45˚C

- **Data**

Evaporating pressure	0.46MPa abs
Suction gas	
Temperature	2˚C
Specific enthalpy	407 kJ/kg
Specific volume	0.053 m^3/kg
Specific enthalpy at expansion valve inlet	257 kJ/kg
Sub-cooled degree	5˚C
Refrigerating effect	150 kJ/kg
Thermal equivalent of compressor work	41 kJ/kg
Condensing load	191 kJ/kg
Coefficient of performance	4.66
Compression ratio	4.26
Condensing pressure	1.96MPa abs
Discharged gas	
Temperature	80˚C
Specific enthalpy	448 kJ/kg

Exercise 4

Find each data from the P-h Chart according to the following conditions:

Evaporating temperature	-10˚C
Superheated degree	10˚C
Condensing temperature	50˚C
Liquid temperature at expansion valve inlet	40˚C

2.4 Variations on P-h Chart in accordance with changes in operating conditions

In order to track down the operating conditions of air conditioners and chillers, conjuring the P-h Chart enables accurate understanding of a variety of their symptoms.

2.4.1 Factors influencing on equipment

1. Insufficient refrigerating effect

Less refrigerating effect causes the reduction in the amount of heat absorbed per 1-kg mass refrigerant flowing in the evaporator and the degradation of the refrigerating capacity. Furthermore, it decreases the coefficient of performance, thus resulting in operation of decreased efficiency.

2. Excessive specific volume of suction gas

Excessive specific volume of suction gas causes the reductions in the specific weight of the suction gas, the weight of refrigerant circulated discharging from the compressor, and the refrigerating capacity. The reduced weight of refrigerant circulated results in less running current.

3. Excessive compression ratio

Excessive compression ratio causes a significant difference in pressure ratio between the suction gas pressure and the discharge gas pressure, which increases the volumetric expansion of discharge gas remaining in the cylinder top clearance, thus resulting in the reductions in the suction gas amount and the refrigerating capacity.
The thermal equivalent of compressor work increases and the coefficient of performance decreases. If there are no changes in the specific volume of the suction gas, the running current increases in proportion to the increase in the thermal equivalent of compressor work.

4. Too high discharge gas temperature

Refrigerating oil gets mixed with refrigerant gas and circulates. If the discharge gas temperature is too high, the chiller oil temperature becomes high to develop oil deterioration (carbonization), thus causing clogged dryer or faulty startup of the compressor.

5. Superheated degree other than 5˚C

Too high superheated degree abnormally increases the temperature of the motor coil in the (semi-) hermetic system compressor, resulting in actuated compressor protective thermostat (C.T.P.) and shortened motor life span, and furthermore increased discharge gas temperature.
When the superheated degree reaches 0˚C, that is, the system turns into wet compression, uneven temperature is caused in the motor coil, resulting in burnt motor. In addition, if the liquid refrigerant melts in the lubricating oil, diluted oil or oil-forming symptom occurs, thus resulting in a drop in hydraulic pressure. Furthermore, in the extreme case, the liquid compression (liquid hammering) occurs to cause a broken valve.

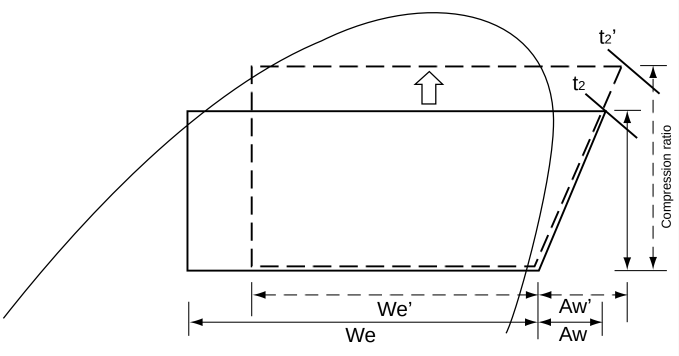
6. Insufficient sub-cooled degree

If there is a large pressure loss in the liquid pipe between the condenser and the expansion valve or the cooling load increases, flushing gas is generated and moist vapor enters the expansion valve, thus resulting in increased dryness factor at the expansion valve outlet to degrade the refrigerating effect.

2.4.2 Changes on P-h Chart and problems while in malfunctions

Take the basic cycle under the operation conditions by model described in Chapter 3 as standard operation. If the operating conditions vary with the conditions of indoor and outdoor air, external contamination, or gas leaks, the operation differs from the standard operation, thus causing problems described in Section 4-1 Factors influencing on equipment.
The following section shows the changes on the P-h Chart due to the changes in the basic conditions.
Actually, the system operates in a cycle with different conditions conspired.

Fig.2-23



1. Abnormal rise of high pressure

Possible causes (Example)

Water-cooled type:	Insufficient cooling water
	Dirty condenser
	Poor heat exchange in cooling tower
Air-cooled type:	Dirty heat exchanger
	Short-circuit of hot air
Common:	Over change of refrigerant
	Air mixed in refrigerant system

Symptoms

The low pressure slightly rises as the high pressure rises. In the case of units using a capillary tube, the low pressure sometimes rises noticeably. In this case, the superheated degree decreases and the discharge gas temperature becomes significantly high.
The sub-cooled degree rises only if the refrigerant is overcharged, while in other cases it shows little change or, if anything, a downward tendency.

Problems

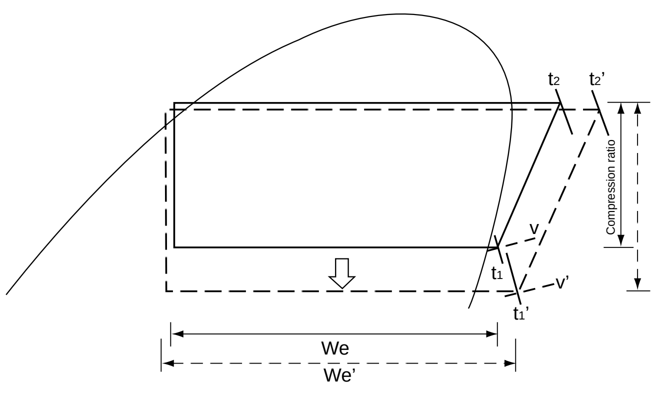
When the high pressure reaches the set point of the pressure switch, the machine stops running, or it does not stop running but the following problems may be caused.
1. The discharge gas temperature becomes too high, thus exerting an adverse influence upon equipment.
2. The refrigeration effect decreases while the compression ratio increases, thus causing a reduction in the refrigerating capacity.
3. The coefficient of performance drops to degrade the operating efficiency.
4. The thermal equivalent of compression work increases to cause increases of running current, that is, power consumption.

2. Abnormal drop of low pressure while in superheated compression

Possible causes (Example)

Insufficient refrigerant (gas leak)
Clogged dryer
Clogged filter
Clogged expansion valve or capillary tube
Faulty operation of expansion valve

Fig.2-24



Symptoms

In this case, the weight of refrigerant circulated has decreased. Therefore, with the reduction of the amount of evaporated heat, the amount of condensed heat reduces, thus slightly decreasing the condensing temperature (pressure).
The suction gas increases in the temperature and specific volume.
The discharge gas temperature becomes significantly high as well.
The subcooling degree decreases in the case of insufficient refrigerant, while it increases in the case of other causes due to clogging.

Problems

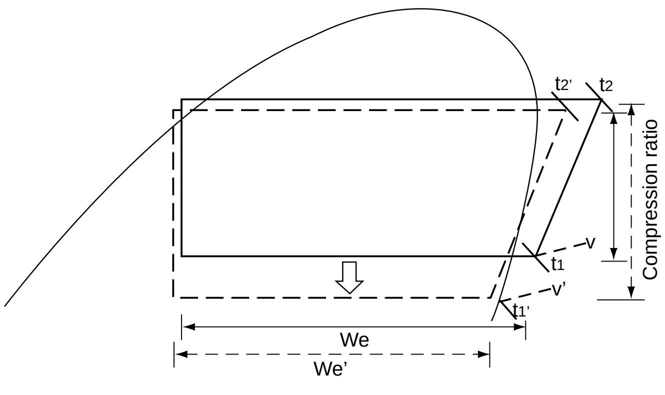
The suction gas temperature has become too high. Safety devices such as the compressor protective thermostat may be actuated or the machine may stop running due to the actuation of the low pressure switch.
Or the machine does not stop running but the following problems may be caused.
1. The discharge gas temperature becomes too high, thus exerting an adverse influence upon equipment.
2. Even though the refrigerating effect increases, the compression ratio as well as the specific volume of the suction gas becomes larger, thus resulting in decreased weight of refrigerant circulated and in a substantial reduction in refrigerating capacity.
3. Regardless of little change in the thermal equivalent of compression work, since the specific volume of the suction gas is large, the running current decreases.

3. Abnormal drop of low pressure while in wet compression

Possible causes (Example)

Insufficient air quantity
Insufficient cooling water
Dirty evaporator
Inadequate cooling load

Fig.2-25



Symptoms

In this case, the heat to the evaporator has decreased. Therefore, with the decrease of the evaporating temperature (pressure), the condensing temperature (pressure) shows a slight decrease.
The suction gas shows a hunting phenomenon between the moist vapor and the superheated vapor on units using an expansion valve while it turns into moist vapor on units using a capillary tube. In any of these cases, the specific volume becomes larger.
The discharge vapor temperature decreases.

Problems

Since the compressor sucks in moist vapor, the hydraulic pressure is not built up. Therefore, the pressure switch for hydraulic pressure protection or the low-pressure pressure switch may be actuated.

If the moist vapor is sucked in, the following problems may be caused.

1. The hydraulic pressure is not built up, developing wear of bearings or metal parts in the compressor.
2. The refrigerating effect is small, while the compression ratio of the suction gas as well as the specific volume of the suction gas is large. Therefore, the refrigerating capacity shows a substantial reduction.
3. Regardless of a slight increase in the thermal equivalent of compressor work, since the specific volume of the suction gas is large, the running current decreases.

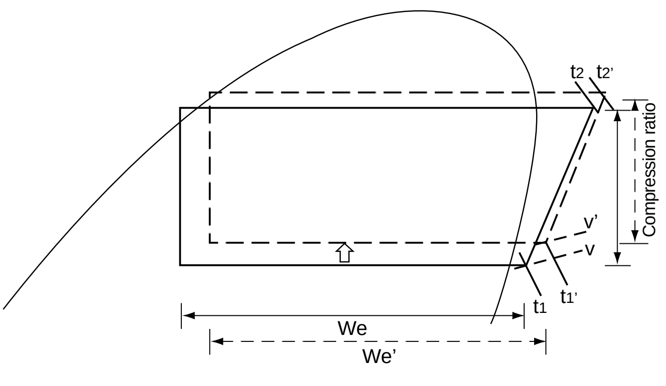
4. Abnormal rise of low pressure while in superheated compression

Possible causes (Example)

Increased cooling load

Wrong selection of unit (too small)

Fig.2-26



Symptoms

The high pressure slightly rises as the low pressure rises.

The suction gas increases in the temperature while decreases in the specific volume.

The discharge gas temperature becomes high.

The sub-cooled degree becomes low.

Problems

The suction gas temperature has become too high. Safety devices such as the compressor protective thermostat may be actuated to stop the machine running.

Or the machine does not stop running but the following problems may be caused.

1. The discharge gas temperature becomes too high, thus exerting an adverse influence upon equipment.
2. Since the specific volume of the suction gas decreases, the weight of refrigerant circulated and the refrigerating capacity increases. Furthermore, the running current increases as well, thus resulting in increased power consumption.

5. Abnormal rise of low pressure while in wet compression

Possible causes (Example)

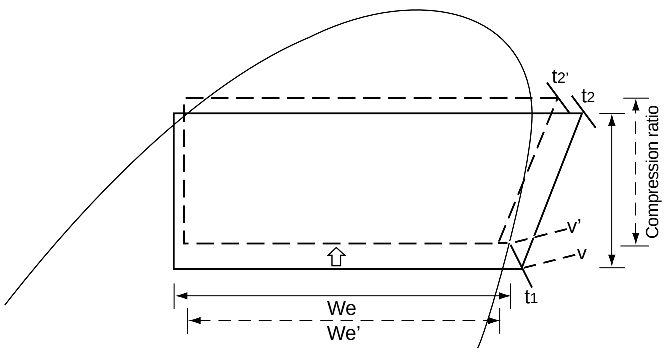
Faulty function of expansion valve

(Faulty installation of feeler bulb)

Overcharged refrigerant

(In the case of units using a capillary tube)

Fig.2-27



Symptoms

Units using an expansion valve show a downward tendency of sub-cooled degree. By contrast, units using a capillary tube show an upward tendency of sub-cooled degree. In either of these two cases, the high pressure rises.

The suction gas decreases in the specific volume while the temperature remains roughly the same as that in the standard operation.

The discharge gas increases in the high pressure, while it shows a slight decrease in the temperature.

Problems

Since the compressor sucks in moist vapor, the oil pressure is not built up. Therefore, the pressure switch for oil pressure protection may be actuated.

If the high-pressure moist vapor is sucked in, the following problems may be caused.

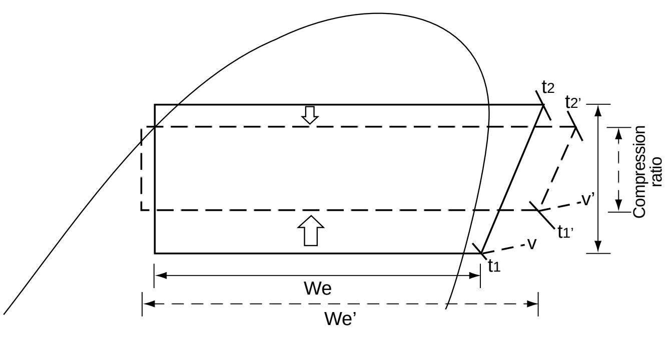
1. The oil pressure is not built up, developing wear of bearings or metal parts in the compressor.
2. Since the specific volume of the suction gas decreases, the refrigerating capacity increases, thus increasing the running current and the power consumption.

6. Abnormal rise of low pressure and drop of high pressure

Possible causes (Example)

Faulty compression
Faulty four-way valve
Faulty check valve

Fig.2-28



Symptoms

The suction gas substantially increases in the temperature but decreases in the specific volume.
The discharge gas substantially increases in the temperature as well.
Since the compression ratio is small, the running current decreases.
If the four-way valve is faulty, both of suction gas temperatures and discharge gas temperature do not rise.

Problems

The suction gas temperature has become too high. Safety devices such as the compressor protective thermostat may be actuated to stop the machine running.
Or the machine does not stop running but the following problems may be caused.
1. Since the compressor piston is in a freewheeling condition, the refrigerating capacity decreases substantially.
2. Even with pump-down operation, the low pressure does not fall to 0MPa G or less.
3. Even if the cooling water supply is interrupted, it may take time for the high pressure to rise and high-pressure cut may not be performed.

2.5 Refrigeration capacity calculation

By drawing refrigeration cycle on the P-h Chart, refrigerating effect, that is, the amount of heat per 1-kg mass of refrigerant during the evaporating process, and the state of suction gas to the compressor can be found.
However, the above data is not enough to reveal the refrigerating (cooling) capacity. In order to find the refrigerating capacity, it is required to calculate the capacity using numerical values on the P-h Chart and a variety of the compressor parameters.
The following section describes reciprocating compressors.

2.5.1 Compressor Parameters

1. Piston displacement V [m³/h]

The piston displacement is the total volume swept through the piston suction and compression strokes per unit of time.
The piston displacement of a reciprocating compressor is calculated by the following expression according to the compressor specifications.

Table 2-3

Examples of compressor specifications

Type	2T55HF	3T55RF
Nos. of cylinders	2	3
Cylinder diameter	55mm	55mm
Cylinder stroke	20.2mm	25.4mm
Revolutions speed (50/60)	2900/3450rpm	2900/3450rpm

$$V = \left[\frac{\pi}{4}\right]\cdot D^2\cdot L\cdot Z\cdot n\times 60\ [m^3/h]$$

Where
Va= Piston displacement [m³/h]

$\left[\frac{\pi}{4}\right]$ = Constant

D= Cylinder diameter (m)
L= Piston stroke (m)

Cylinder volume[cm]: $\left[\frac{\pi}{4}\right]\cdot D^2\cdot L\times 10^6$

Z= Number of cylinders
n = Revolutions per minute (rpm)

Exercise

Find the piston displacement for the 2T55HF compressor operating at 60 Hz.

D = 0.055 m L = 0.0202 m Z = 2 n = 3450

$$V = \left[\frac{\pi}{4}\right]\times \underset{D}{0.055}\times \underset{D}{0.055}\times \underset{L}{0.0202}\times \underset{Z}{2}\times \underset{n}{3450}\times 60$$

$\fallingdotseq 19.9\ m^3/h$

How to find the piston displacement from the Japanese legal refrigeration ton (i.e., nominal refrigerating capacity)

The legal refrigeration ton in technical information represents refrigerating capacity during operation in a standard refrigeration cycle, which is referred to as nominal refrigerating capacity. (Refer to information in Section 3-1.)
In the Refrigeration Safety Regulation in the High Pressure Gas Control Law (Japan), the nominal refrigerating capacity is represented by refrigeration ton. Furthermore, assuming that the refrigerating capacity R of compressor having a piston replacement of V[m³/h] is computed by using the formula R = V/C, the value of the constant C is defined by the type of refrigerant.
Thus, when the legal refrigeration ton is known, the piston displacement can be found:

V = R·C

V = Piston displacement

R = Legal refrigeration ton

C = Constant

1 refrigeration ton = 19,300 kJ/h = 3.86 kW (3,320 kcal/h)

Table 2-4

Nominal refrigerating capacity:
Calculation reference coefficient (C)

Refrigerant	Volume of a single cylinder	
	5000 cm^3 or less	More than 5000 cm^3
R12	13.9	13.1
R22	8.5	7.9
R500	12.0	11.3
R502	8.4	7.9

Example

Find the piston displacement, assuming that the 2T55HF compressor operating at 60 Hz has a legal refrigeration ton of 2.34.

C = 8.5 (R22)

V = 2.34×8.5=19.9 m^3/h

2. Volumetric efficiency ηv

Volumetric efficiency is the ratio of the gas volume actually sucked into the cylinder to the cylinder volume.
When the gas sucked into the cylinder is compressed and discharged, the gas remains in the cylinder top clearance. Due to this residual gas, the volume of fresh suction gas decreases. In addition, since there are some gas leaks from the piston ring, the piston displacement becomes 70% to 80% of the cylinder volume.
The volumetric efficiency is found using the compression ration. The larger the compression ratio is, the smaller the volumetric efficiency becomes. By contrast, the smaller the compression ratio is, the larger the volumetric efficiency becomes.

Fig.2-29

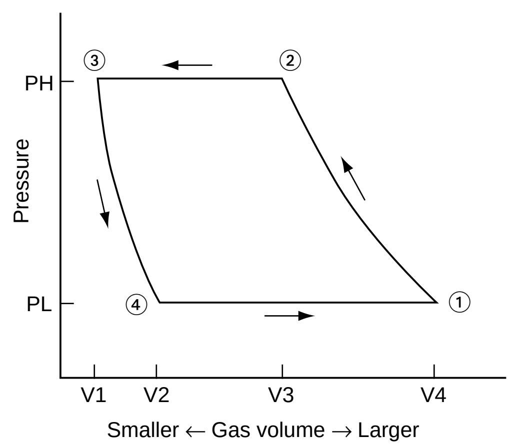


Fig.2-30

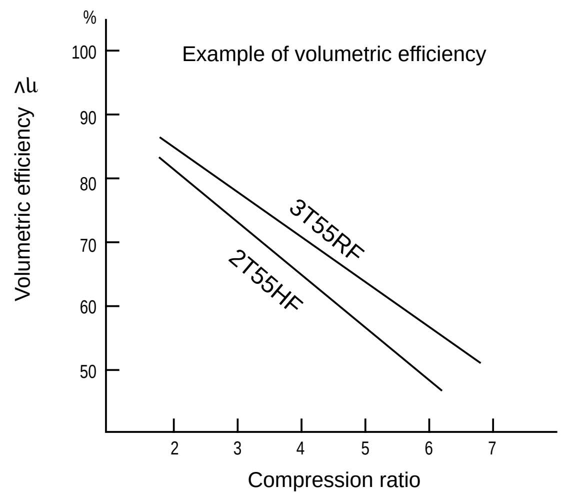
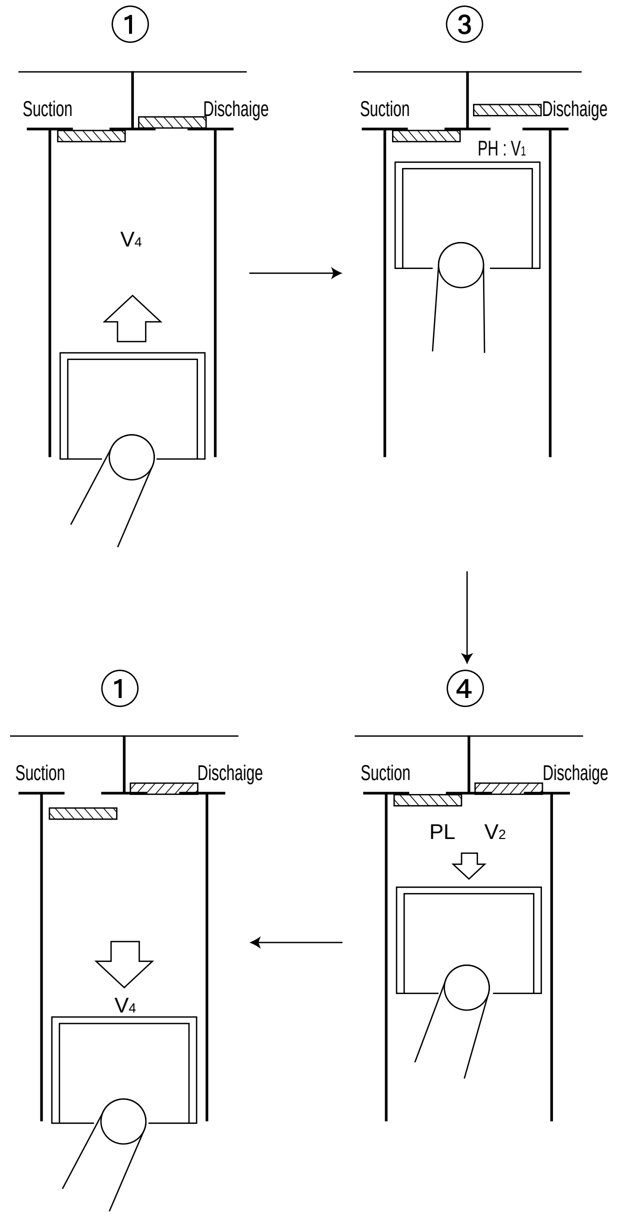


Fig.2-31



3. Actual volume of suction vapor compressed qv [m^3/h]

The actual piston displacement [qv] can be found by multiplying the suction vapor volume [V] obtained according to the compressor specifications by the volumetric efficiency [ηv].

qv = V×ηv

Example

Find the actual volume of suction vapor compressed while the 2T55HF compressor is operating under the following conditions.

High pressure : 1.9MPa G → 2.0MPa abs

Low pressure : 0.5MPa G → 0.6MPa abs

Compression ratio $\frac{2.0}{0.6}$ = 3.33 Referring to the volumetric efficiency chart, ηv = 0.7

From Example 5-1(1), V = 19.9 m^3/h

Thus, qv = 19.9×0.7= 13.93 m^3/h

4. Weight of refrigerant circulated qm [kg/h]

The weight of refrigerant circulated is that of refrigerant circulated per hour by the compressor, which is equal to the weight of the suction vapor of the compressor. If the refrigerating capacity (· kJ/h(and the refrigerating effect [We kJ/kg] are known, the weight of refrigerant circulated can be is found using the following formula:

$$qm\ (kg/h) = \frac{\phi\cdot[kJ/h]}{We[kJ/kg]}$$

The refrigerating capacity, however, cannot be determined according to the operating state. By multiplying the actual volume of suction vapor qv [m^3/h] by the density of the suction gas 1/v [kg/m^3], the weight of refrigerant circulated qm [kg/h] can be found.

qm [kg/h] = [m^3/h] × [kg/m^3]

Example

Assuming that the specific volume of the suction gas is 0.04 m^3/kg with reference to Example 5-1(3), find the weight of refrigerant circulated.

qv = 13.93 m^3/h

v = 0.04 m^3/kg

$$qm = 13.93 \times \frac{1}{0.04} \fallingdotseq 348.3\ kg/h$$

2.5.2 Refrigeration capacity calculation

As mentioned above, the weight of refrigerant circulated has been found according to the compressor parameters. In order to find the refrigeration capacity according to the actual operating state, multiply the weight of refrigerant circulated qm [kg/h] by the refrigeration effect We [kJ/kg].

ϕ[kJ/h] = qm [kg/h] × We [kJ/kg]

Example

Find the refrigerating capacity while the 2HC55HF (60Hz) compressor is operating under the conditions in Section 3-3.

From Example 5-1(4), the weight of refrigerant circulated (qm) is 348.3 kg/h, and

from operating data in Section 3-3, the refrigerating effect (We) is 153 kJ/kg,

ϕ = 348.3 ×153 ≒ 53.290 kJ/h

Summary

In order to calculate the refrigerating capacity according to the P-h Chart:

1. Draw a refrigeration cycle on the P-h (Mollier) Chart according to the operating state.
2. Find the refrigerating effect, specific volume of suction gas, and compression ratio.
3. Calculate the piston displacement of the compressor.
4. Find the volumetric efficiency according to compression ratio and calculate the actual volume of suction vapor of the compressor.
5. Calculate the weight of refrigerant circulated according to the specific volume of the suction gas and the actual weight of suction vapor of the compressor.
6. By multiplying the refrigerating effect by the weight of refrigerant circulated, the refrigerating capacity can be found.

Exercise 5

For air conditioners using a 3T55RF compressor (with legal refrigerating capacity of 3.70/4.41 tons) operating under the following conditions, find the refrigeration capacity according to the P-h Chart.

High pressure:
 1.9MPa

Low pressure:
 0.5MPa

Suction gas temperature: 8˚C

Liquid temperature at expansion valve inlet: 45˚C

Power supply: 3 phase, 200 VAC, 60 Hz

However, assume that the volumetric efficiency is 0.75

Answers

Q1.	Low pressure:	0.6MPa abs
	High pressure:	1.8MPa abs
Q2.	Moist vapor:	X = 0.65
Q3.	Superheated vapor:	h = 450 kJ/kg
Q4.	Sub-cooled liquid:	h = 200 kJ/kg
Q5.	V = 0.07 m^3/kg	
	h = 427 kJ/kg	
Q6.	0.29	

Exercise 1

Table 2-5

	P Absolute pressure MPa abs	t Temperature C	h Specific enthalpy kJ/kg	s Specific entropy kJ/(kg•K)	v Specific volume m^3/kg	x Dryness factor
Point A	0.8	80	460	1.88	0.04	Superheated vapor
Point	1.0	0	200	/	/	Subcooled liquid
Point C	0.2	-25	350	/	/	0.8
Point D	0.4	60	450	1.92	0.078	Superheated vapor
Point	0.25	0	410	1.83	0.1	Superheated vapor

Exercise 2

Table 2-6

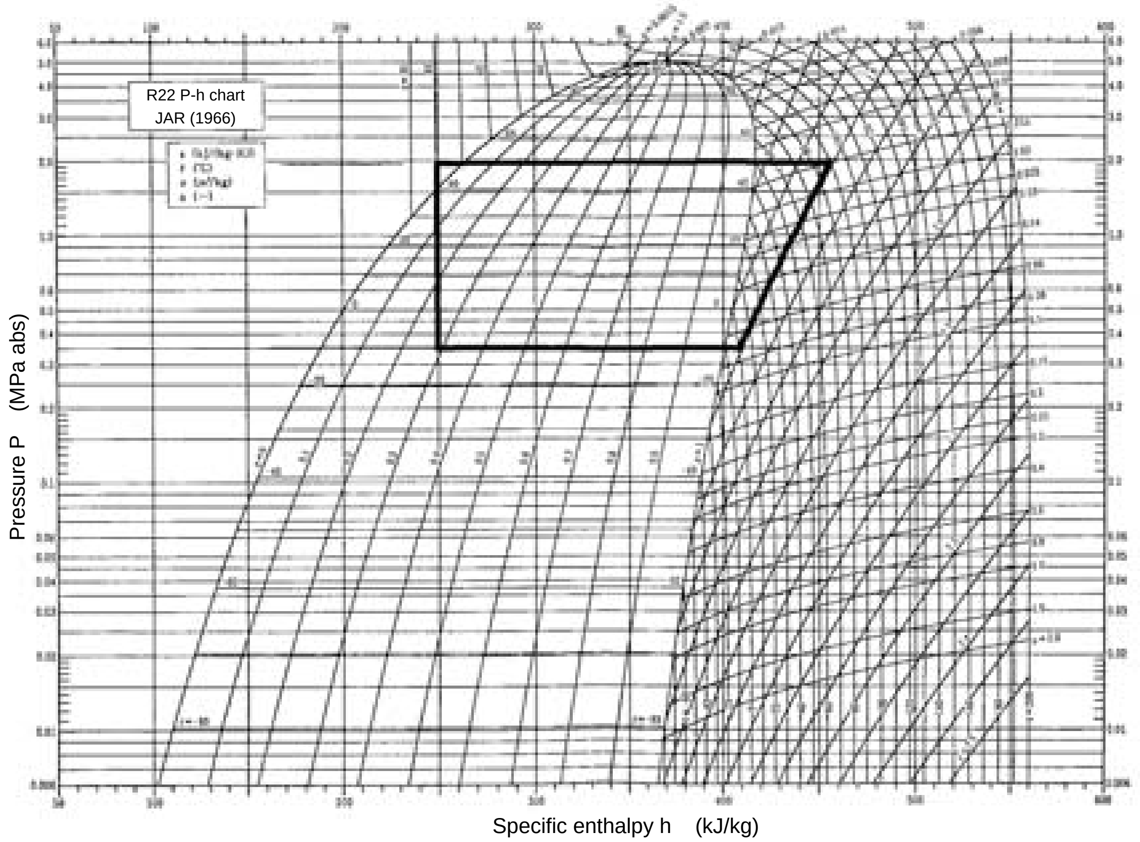
	P Absolute pressure MPa abs	t Temperature C	h Specific enthalpy kJ/kg	v Specific volume m^3/kg	x Dryness factor	s Specific entropy kJ/(kg•K)
Point 1	0.6	11	412	0.041	/	1.76
Point 2	1.4	55	432	0.019	/	1.76
Point 3	1.4	31	238	/	/	/
Point 4	0.6	6	238	/	0.16	/

Exercise 3

(1) 174 kJ/kg
(2) 20 kJ/kg
(3) 194 kJ/kg
(4) 8.7
(5) 2.33
(6) 24.4 kg/m^3

Exercise 4

Fig.2-32

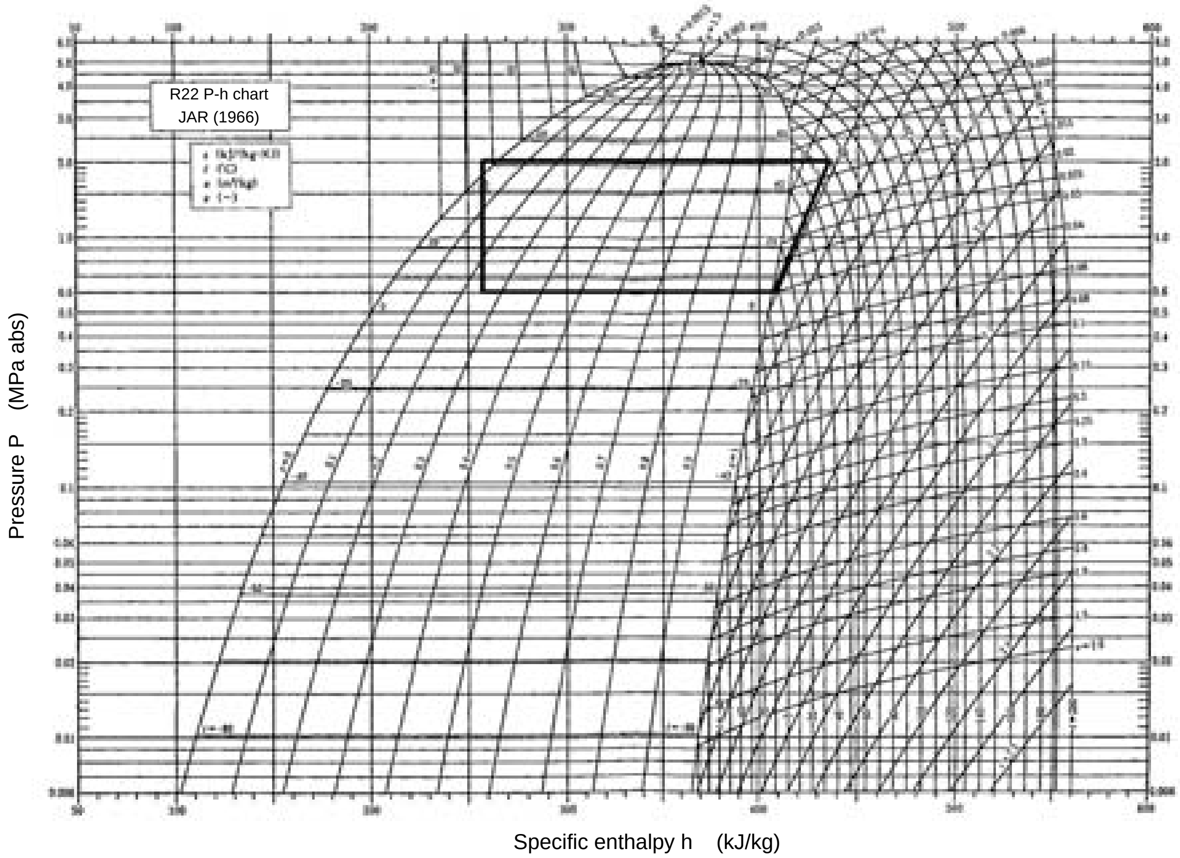


■ Data

Evaporating pressure	0.35MPa abs
Suction gas	
Temperature	0˚C
Specific enthalpy	410 kJ/kg
Specific volume	0.07 m³/kg
Specific enthalpy at expansion valve inlet	250 kJ/kg
Sub-cooled degree	10˚C
Refrigerating effect	160 kJ/kg
Thermal equivalent of compressor work	45 kJ/kg
Condensing load	205 kJ/kg
Coefficient of performance	3.56
Compression ratio	5.43
Condensing pressure	1.9MPa abs
Discharge gas	
Temperature	88˚C
Specific enthalpy	455 kJ/kg

Exercise 5

Fig.2-33



According to the P-h Chart,

h_1 = 408 kJ/kg

h_2 = 436 kJ/kg

$h_3 = h_4$ = 256 kJ/kg

Refrigerating effect We = 152 kJ/kg

Specific volume of suction gas v = 0.04 m^3/kg

Piston displacement

V = 4.41 tons × 8.5=37.485 m^3/h

Actual volume of suction vapor

Since the volumetric efficiency is 0.75,

qv = 37.485 × 0.75 = 28.11 m^3/h

Weight of refrigerant circulated

qm = 28.11 × 1/0.04 = 702.8 kg/h

Refrigeration capacity

ϕ = 702.8 kg/h ×152 kJ/kg ≒ 106.826 kJ/h

2.6 Thermodynamic Properties & P-h Chart of refrigerants

Table 2-7 R-22 Thermodynamic properties (SI unit)

Temperature	Pressure	Specific volume		Density		Specific enthalpy			Specific entropy	
C t	MPa P	/kg Liquid V'	 Vapor V''	/kg Liquid p'	 Vapor V''	 Liquid h'	kJ/kg Vapor h''	Latent heat h''-h'	kJ/(kg•K Liquid s'	 Vapor s''
-60	0.037468	0.00068348	0.53672	1463.1	1.8632	133.17	378.72	245.55	0.7253	1.8774
-59	0.039667	0.00068477	0.50894	1460.4	1.9649	134.28	379.19	244.91	0.7305	1.8742
-58	0.041970	0.00068607	0.48288	1457.6	2.0709	135.40	379.67	244.27	0.7357	1.8711
-57	0.044378	0.00068737	0.45841	1454.8	2.1814	136.51	380.14	243.64	0.7408	1.8681
-56	0.046897	0.00068869	0.43543	1452.0	2.2966	137.62	380.62	243.00	0.7460	1.8651
-55	0.049529	0.00069001	0.41383	1449.3	2.4164	138.73	381.09	242.36	0.7511	1.8621
-54	0.052277	0.00069134	0.39352	1446.5	2.5412	139.83	381.56	241.73	0.7561	1.8592
-53	0.055147	0.00069268	0.37440	1443.7	2.6709	140.94	382.03	241.09	0.7611	1.8563
-52	0.058140	0.00069403	0.35640	1440.9	2.8058	142.05	382.51	240.46	0.7661	1.8535
-51	0.061262	0.00069539	0.33944	1438.0	2.9460	143.15	382.97	239.82	0.7711	1.8507
-50	0.064517	0.00069676	0.32345	1435.2	3.0917	144.25	383.44	239.19	0.7761	1.8480
-49	0.067907	0.00069813	0.30836	1432.4	3.2429	145.36	383.91	238.55	0.7810	1.8453
-48	0.071438	0.00069952	0.29413	1429.6	3.3999	146.46	384.38	237.92	0.7859	1.8426
-47	0.075112	0.00070092	0.28068	1426.7	3.5628	147.56	384.84	237.28	0.7907	1.8400
-46	0.078935	0.00070232	0.26797	1423.8	3.7317	148.66	385.30	236.64	0.7956	1.8374
-45	0.082911	0.00070374	0.25596	1421.0	3.9068	149.76	385.77	236.00	0.8004	1.8349
-44	0.087043	0.00070516	0.24460	1418.1	4.0883	150.86	386.23	235.37	0.8052	1.8324
-43	0.091337	0.00070660	0.23384	1415.2	4.2763	151.96	386.69	234.73	0.8100	1.8299
-42	0.095795	0.00070804	0.22366	1412.3	4.4710	153.06	387.14	234.08	0.8147	1.8275
-41	0.10042	0.00070950	0.21401	1409.4	4.6726	154.16	387.60	233.44	0.8195	1.8251
-40.810	0.101325	0.00070977	0.21224	1408.9	4.7117	154.37	387.69	233.32	0.8203	1.8246
-40	0.10523	0.00071096	0.20487	1406.5	4.8812	155.26	388.05	232.80	0.8242	1.8227
-39	0.11021	0.00071244	0.19620	1403.6	5.0970	156.35	388.51	232.15	0.8288	1.8204
-38	0.11537	0.00071393	0.18797	1400.7	5.3201	157.45	388.96	231.51	0.8335	1.8181
-37	0.12073	0.00071542	0.18015	1397.8	5.5508	158.55	389.41	230.86	0.8382	1.8158
-36	0.12627	0.00071693	0.17274	1394.8	5.7892	159.65	389.86	230.21	0.8428	1.8135
-35	0.13202	0.00071845	0.16569	1391.9	6.0355	160.75	390.31	229.56	0.8474	1.8113
-34	0.13796	0.00071999	0.15898	1388.9	6.2899	161.85	390.75	228.90	0.8520	1.8092
-33	0.14412	0.00072153	0.15261	1385.9	6.5526	162.95	391.19	228.25	0.8566	1.8070
-32	0.15048	0.00072308	0.14655	1383.0	6.8237	164.05	391.64	227.59	0.8611	1.8049
-31	0.15707	0.00072465	0.14078	1380.0	7.1035	165.15	392.08	226.93	0.8656	1.8028
-30	0.16387	0.00072623	0.13528	1377.0	7.3922	166.25	392.52	226.26	0.8702	1.8007
-29	0.17090	0.00072782	0.13004	1374.0	7.6899	167.35	392.95	225.60	0.8747	1.7987
-28	0.17817	0.00072943	0.12505	1370.9	7.9968	168.46	393.39	224.93	0.8792	1.7967
-27	0.18567	0.00073104	0.12029	1367.9	8.3132	169.56	393.82	224.26	0.8836	1.7947
-26	0.19341	0.00073267	0.11575	1364.9	8.6393	170.67	394.25	223.58	0.8881	1.7927
-25	0.20140	0.00073431	0.11142	1361.8	8.9752	171.77	394.68	222.90	0.8925	1.7908
-24	0.20965	0.00073597	0.10728	1358.8	9.3212	172.88	395.10	222.22	0.8970	1.7889
-23	0.21815	0.00073764	0.10333	1355.7	9.6776	173.99	395.53	221.54	0.9014	1.7870
-22	0.22692	0.00073932	0.099558	1352.6	10.044	175.10	395.95	220.85	0.9058	1.7851
-21	0.23595	0.00074102	0.095951	1349.5	10.422	176.21	396.37	220.16	0.9102	1.7833
-20	0.24527	0.00074273	0.092502	1346.4	10.811	177.32	396.79	219.46	0.9145	1.7815
-19	0.25486	0.00074446	0.089203	1343.3	11.210	178.44	397.20	218.76	0.9189	1.7797
-18	0.26473	0.00074620	0.086047	1340.1	11.622	179.55	397.61	218.06	0.9233	1.7779
-17	0.27490	0.00074795	0.083025	1337.0	12.045	180.67	398.03	217.35	0.9276	1.7762
-16	0.28537	0.00074972	0.080132	1333.8	12.479	181.79	398.43	216.64	0.9319	1.7744
-15	0.29613	0.00075151	0.077361	1330.7	12.926	182.91	398.84	215.93	0.9363	1.7727
-14	0.30721	0.00075331	0.074706	1327.5	13.386	184.04	399.24	215.21	0.9406	1.7710
-13	0.31860	0.00075513	0.072161	1324.3	13.858	185.16	399.64	214.48	0.9449	1.7693
-12	0.33031	0.00075696	0.069720	1321.1	14.343	186.29	400.04	213.75	0.9492	1.7677
-11	0.34234	0.00075881	0.067380	1317.9	14.841	187.42	400.44	213.02	0.9534	1.7660
-10	0.35471	0.00076068	0.065134	1314.6	15.353	188.55	400.83	212.28	0.9577	1.7644
-9	0.36741	0.00076256	0.062978	1311.4	15.879	189.68	401.22	211.54	0.9620	1.7628
-8	0.38046	0.00076446	0.060908	1308.1	16.418	190.82	401.61	210.79	0.9662	1.7612
-7	0.39386	0.00076638	0.058920	1304.8	16.972	191.96	401.99	210.03	0.9705	1.7596
-6	0.40761	0.00076832	0.057011	1301.5	17.541	193.10	402.37	209.27	0.9747	1.7581
-5	0.42172	0.00077028	0.055175	1298.2	18.124	194.24	402.75	208.51	0.9790	1.7565
-4	0.43620	0.00077225	0.053411	1294.9	18.723	195.39	403.12	207.74	0.9832	1.7550
-3	0.45106	0.00077425	0.051715	1291.6	19.337	196.54	403.50	206.96	0.9874	1.7535
-2	0.46629	0.00077626	0.050083	1288.2	19.967	197.69	403.87	206.18	0.9916	1.7520
-1	0.48191	0.00077830	0.048513	1284.9	20.613	198.84	404.23	205.39	0.9958	1.7505
0	0.49792	0.00078035	0.047001	1281.5	21.276	200.00	404.59	204.59	1.0000	1.7490
1	0.51433	0.00078243	0.045547	1278.1	21.956	201.16	404.95	203.79	1.0042	1.7476
2	0.53114	0.00078452	0.044146	1274.7	22.652	202.32	405.31	202.99	1.0084	1.7461
3	0.54837	0.00078664	0.042796	1271.2	23.367	203.49	405.66	202.17	1.0126	1.7447
4	0.56601	0.00078878	0.041497	1267.8	24.099	204.66	406.01	201.35	1.0167	1.7433
5	0.58407	0.00079094	0.040243	1264.3	24.849	205.83	406.36	200.52	1.0209	1.7418
6	0.60257	0.00079313	0.039034	1260.8	25.619	207.01	406.70	199.69	1.0251	1.7404
7	0.62149	0.00079534	0.037869	1257.3	26.407	208.19	407.04	198.85	1.0293	1.7390
8	0.64087	0.00079757	0.036745	1253.8	27.214	209.37	407.37	198.00	1.0334	1.7377
9	0.66069	0.00079983	0.035661	1250.3	28.042	210.56	407.70	197.14	1.0376	1.7363

Temperature	Pressure	Specific volume		Density		Specific enthalpy			Specific entropy	
C t	MPa P	/kg Liquid V'	Vapor V''	/kg Liquid p'	Vapor V''	Liquid h'	kJ/kg Vapor h''	Latent heat h''-h'	kJ/(kg•K Liquid s'	Vapor s''
10	0.68096	0.00080211	0.034615	1246.7	28.890	211.75	408.03	196.28	1.0417	1.7349
11	0.70170	0.00080442	0.033604	1243.1	29.758	212.94	408.35	195.41	1.0459	1.7336
12	0.72291	0.00080676	0.032629	1239.5	30.648	214.14	408.67	194.53	1.0500	1.7322
13	0.74459	0.00080912	0.031687	1235.9	31.559	215.34	408.98	193.64	1.0542	1.7309
14	0.76675	0.00081151	0.030777	1232.3	32.492	216.54	409.29	192.75	1.0583	1.7295
15	0.78941	0.00081393	0.029897	1228.6	33.448	217.75	409.60	191.85	1.0624	1.7282
16	0.81255	0.00081638	0.029047	1224.9	34.427	218.96	409.90	190.94	1.0666	1.7269
17	0.83620	0.00081885	0.028226	1221.2	35.429	220.18	410.20	190.02	1.0707	1.7256
18	0.86036	0.00082136	0.027431	1217.5	36.455	221.40	410.49	189.09	1.0748	1.7243
19	0.88503	0.00082390	0.026662	1213.7	37.506	222.63	410.78	188.15	1.0790	1.7230
20	0.91022	0.00082647	0.025919	1210.0	38.582	223.85	411.06	187.20	1.0831	1.7217
21	0.93594	0.00082907	0.025199	1206.2	39.684	225.09	411.34	186.25	1.0872	1.7204
22	0.96220	0.00083171	0.024503	1202.3	40.812	226.32	411.61	185.29	1.0913	1.7191
23	0.98900	0.00083438	0.023828	1198.5	41.967	227.57	411.88	184.31	1.0955	1.7178
24	1.0163	0.00083708	0.023175	1194.6	43.150	228.81	412.14	183.33	1.0996	1.7165
25	1.0443	0.00083983	0.022543	1190.7	44.360	230.06	412.40	182.33	1.1037	1.7153
26	1.0727	0.00084261	0.021930	1186.8	45.600	231.32	412.65	181.33	1.1078	1.7140
27	1.1018	0.00084542	0.021336	1182.8	46.869	232.58	412.89	180.32	1.1120	1.7127
28	1.1314	0.00084828	0.020761	1178.9	48.168	233.84	413.13	179.29	1.1161	1.7114
29	1.1616	0.00085118	0.020203	1174.8	49.498	235.11	413.37	178.26	1.1202	1.7102
30	1.1924	0.00085412	0.019662	1170.8	50.860	236.39	413.60	177.21	1.1243	1.7089
31	1.2238	0.00085710	0.019137	1166.7	52.255	237.66	413.82	176.16	1.1284	1.7076
32	1.2557	0.00086013	0.018628	1162.6	53.683	238.95	414.04	175.09	1.1326	1.7063
33	1.2884	0.00086320	0.018134	1158.5	55.145	240.24	414.25	174.01	1.1367	1.7051
34	1.3216	0.00086631	0.017655	1154.3	56.643	241.53	414.45	172.92	1.1408	1.7038
35	1.3554	0.00086948	0.017189	1150.1	58.176	242.83	414.65	171.81	1.1450	1.7025
36	1.3899	0.00087270	0.016737	1145.9	59.746	244.14	414.84	170.70	1.1491	1.7012
37	1.4251	0.00087597	0.016299	1141.6	61.355	245.45	415.02	169.57	1.1532	1.6999
38	1.4609	0.00087929	0.015872	1137.3	63.002	246.76	415.19	168.43	1.1574	1.6987
39	1.4973	0.00088266	0.015458	1132.9	64.690	248.09	415.36	167.27	1.1615	1.6974
40	1.5344	0.00088609	0.015056	1128.5	66.419	249.41	415.52	166.11	1.1656	1.6961
41	1.5722	0.00088958	0.014665	1124.1	68.191	250.75	415.67	164.92	1.1698	1.6948
42	1.6106	0.00089314	0.014284	1119.6	70.006	252.09	415.82	163.73	1.1739	1.6934
43	1.6498	0.00089675	0.013915	1115.1	71.867	253.43	415.95	162.52	1.1781	1.6921
44	1.6896	0.00090043	0.013555	1110.6	73.774	254.79	416.08	161.29	1.1822	1.6908
45	1.7302	0.00090418	0.013205	1106.0	75.729	256.14	416.20	160.05	1.1864	1.6895
46	1.7715	0.00090800	0.012865	1101.3	77.733	257.51	416.31	158.80	1.1906	1.6881
47	1.8134	0.00091189	0.012533	1096.6	79.788	258.88	416.41	157.52	1.1947	1.6868
48	1.8562	0.00091585	0.012211	1091.9	81.896	260.26	416.50	156.24	1.1989	1.6854
49	1.8996	0.00091990	0.011896	1087.1	84.059	261.65	416.58	154.93	1.2031	1.6840
50	1.9438	0.00092402	0.011591	1082.2	86.278	263.04	416.65	153.61	1.2073	1.6826
51	1.9888	0.00092824	0.011292	1077.3	88.555	264.44	416.70	152.26	1.2115	1.6812
52	2.0345	0.00093254	0.011002	1072.3	90.892	265.85	416.75	150.90	1.2157	1.6798
53	2.0810	0.00093693	0.010719	1067.3	93.293	267.27	416.79	149.52	1.2199	1.6784
54	2.1282	0.00094142	0.010443	1062.2	95.758	268.69	416.81	148.12	1.2242	1.6769
55	2.1763	0.00094601	0.010174	1057.1	98.290	270.12	416.82	146.70	1.2284	1.6754
56	2.2251	0.00095071	0.0099115	1051.8	100.89	271.57	416.82	145.26	1.2326	1.6739
57	2.2748	0.00095552	0.0096555	1046.5	103.57	273.02	416.81	143.79	1.2369	1.6724
58	2.3253	0.00096045	0.0094056	1041.2	106.32	274.48	416.78	142.30	1.2412	1.6709
59	2.3766	0.00096550	0.0091617	1035.7	109.15	275.95	416.74	140.79	1.2454	1.6693
60	2.4288	0.00097068	0.0089235	1030.2	112.06	277.43	416.68	139.26	1.2497	1.6677
61	2.4818	0.00097599	0.0086909	1024.6	115.06	278.92	416.61	137.69	1.2541	1.6661
62	2.5356	0.00098145	0.0084636	1018.9	118.15	280.42	416.52	136.10	1.2584	1.6645
63	2.5903	0.00098705	0.0082415	1013.1	121.34	281.93	416.42	134.48	1.2627	1.6628
64	2.6459	0.00099282	0.0080244	1007.2	124.62	283.46	416.29	132.83	1.2671	1.6611
65	2.7024	0.00099876	0.0078120	1001.2	128.01	285.00	416.15	131.15	1.2715	1.6593
66	2.7598	0.0010049	0.0076043	995.15	131.51	286.55	415.99	129.44	1.2759	1.6576
67	2.8181	0.0010112	0.0074009	988.94	135.12	288.12	415.81	127.69	1.2804	1.6557
68	2.8773	0.0010177	0.0072019	982.61	138.85	289.70	415.60	125.91	1.2848	1.6539
69	2.9375	0.0010244	0.0070069	976.15	142.72	291.29	415.38	124.08	1.2893	1.6520
70	2.9986	0.0010314	0.0068158	969.56	146.72	292.90	415.12	122.22	1.2938	1.6500
71	3.0607	0.0010386	0.0066285	962.82	150.86	294.53	414.85	120.31	1.2984	1.6480
72	3.1237	0.0010461	0.0064447	955.94	155.17	296.18	414.54	118.36	1.3030	1.6459
73	3.1878	0.0010539	0.0062643	948.88	159.63	297.85	414.21	116.36	1.3076	1.6438
74	3.2528	0.0010620	0.0060872	941.66	164.28	299.54	413.84	114.31	1.3123	1.6415
75	3.3188	0.0010704	0.0059132	934.24	169.11	301.25	413.45	112.20	1.3170	1.6393
76	3.3859	0.0010792	0.0057420	926.62	174.16	302.99	413.01	110.03	1.3218	1.6369
77	3.4540	0.0010884	0.0055735	918.78	179.42	304.75	412.54	107.79	1.3266	1.6344
78	3.5232	0.0010981	0.0054076	910.69	184.92	306.54	412.03	105.49	1.3315	1.6319
79	3.5935	0.0011082	0.0052440	902.35	190.70	308.36	411.47	103.10	1.3365	1.6292
80	3.6648	0.0011189	0.0050824	893.71	196.76	310.22	410.86	100.64	1.3415	1.6265

Fig.2-34 R-22 P-h Chart (SI unit)

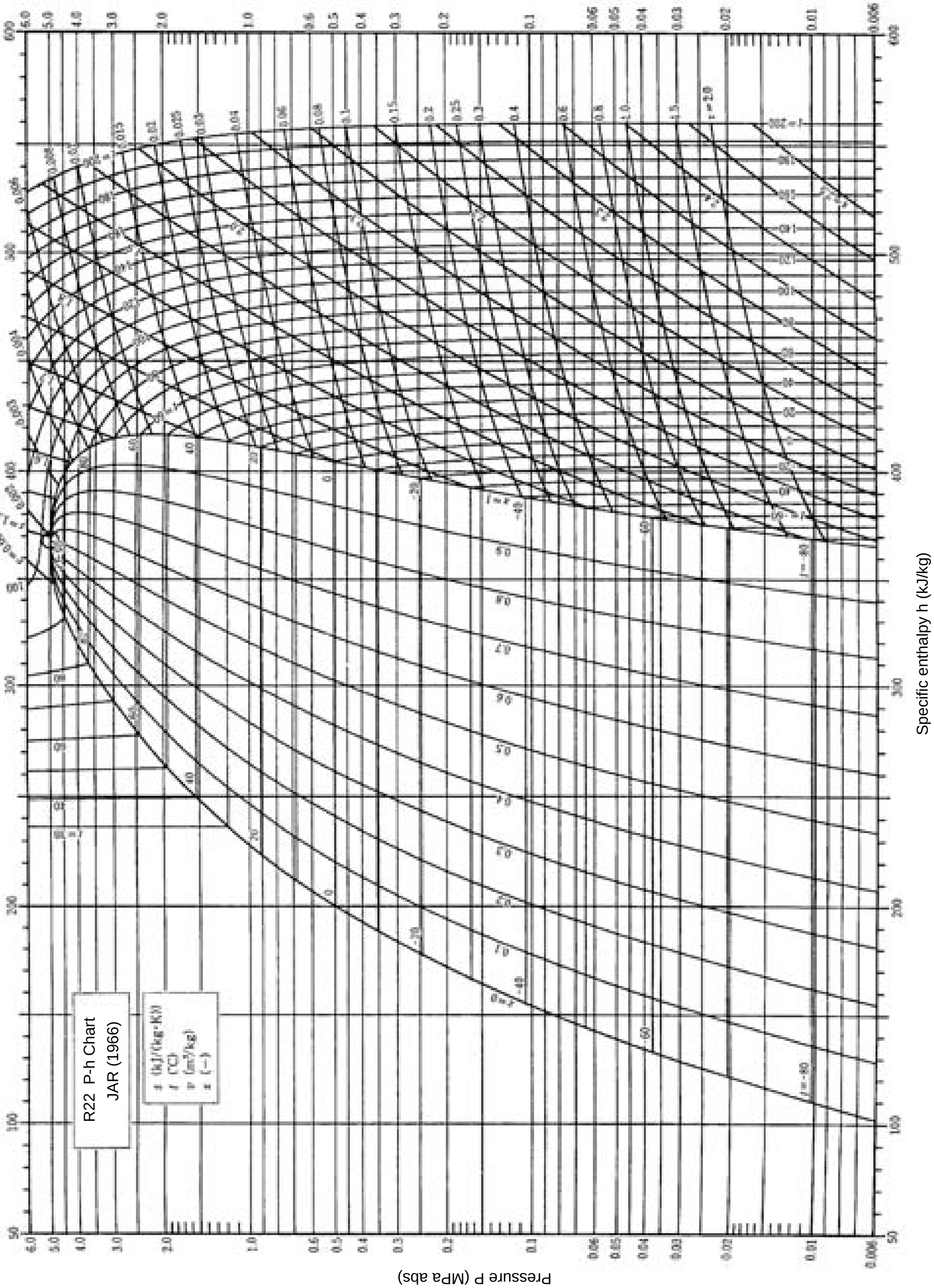


Table 2-8 R407C Thermodynamic properties
Composition ratio: R32 / R125 / R134a (23 / 25 / 52 mass%)

Temperature	Pressure		Density		Specific volume		Specific enthalpy		Specific entropy	
C	kPa		kg/		/kg		kJ/kg		kJ/(kg•K	
t	Boiling point P'	Dew point P"	Liquid p'	Vapor p"	Liquid V'	Vapor v"	Liquid h'	Vapor h''	Liquid s'	Vapor s''
-58	48.01	31.30	1424.2	1.5360	0.00070215	0.65104	122.06	377.09	0.6815	1.8881
-56	53.61	35.35	1418.3	1.7216	0.00070507	0.58086	124.63	378.31	0.6933	1.8822
-54	59.72	39.81	1412.4	1.9247	0.00070801	0.51956	127.20	379.52	0.7051	1.8766
-52	66.39	44.72	1406.5	2.1466	0.00071098	0.46585	129.79	380.73	0.7168	1.8710
-50	73.63	50.12	1400.5	2.3884	0.00071403	0.41869	132.37	381.93	0.7285	1.8657
-48	81.50	56.02	1394.5	2.6516	0.00071710	0.37713	134.97	383.13	0.7400	1.8606
-46	90.02	62.48	1388.5	2.9373	0.00072020	0.34045	137.57	384.33	0.7515	1.8557
-44	99.24	69.51	1382.4	3.2470	0.00072338	0.30798	140.19	385.52	0.7629	1.8509
-42	109.19	77.17	1376.3	3.5821	0.00072659	0.27917	142.80	386.70	0.7743	1.8463
-40	119.91	85.49	1370.1	3.9440	0.00072987	0.25355	145.43	387.88	0.7856	1.8419
-38	131.45	94.51	1363.9	4.3344	0.00073319	0.23071	148.07	389.06	0.7968	1.8376
-36	143.84	104.26	1357.7	4.7547	0.00073654	0.21032	150.71	390.23	0.8079	1.8334
-34	157.13	114.80	1351.4	5.2066	0.00073997	0.19206	153.36	391.39	0.8190	1.9294
-32	171.36	126.17	1345.1	5.6919	0.00074344	0.17569	156.02	392.54	0.8301	1.8255
-30	186.58	138.41	1338.7	6.2122	0.00074699	0.16097	158.69	393.69	0.8410	1.8218
-28	202.84	151.56	1332.3	6.7694	0.00075058	0.14773	161.37	394.83	0.8520	1.8182
-26	220.17	165.67	1325.9	7.3653	0.00075420	0.13577	164.06	395.96	0.8628	1.8146
-24	238.63	180.79	1319.4	8.0020	0.00075792	0.12497	166.76	397.08	0.8737	1.8112
-22	258.27	196.97	1312.8	8.6814	0.00076173	0.11519	169.47	398.19	0.8844	1.8079
-20	279.13	214.26	1306.2	9.4057	0.00076558	0.10632	172.19	399.30	0.9851	1.8047
-18	301.26	232.71	1299.6	10.177	0.00076947	0.098261	174.92	400.39	0.9058	1.8016
-16	324.72	252.37	1292.9	10.998	0.00077346	0.090926	177.66	401.47	0.9164	1.7985
-14	349.55	273.30	1286.1	11.870	0.00077754	0.084246	180.41	402.54	0.9270	1.7956
-12	375.81	295.55	1279.2	12.796	0.00078174	0.078149	183.17	403.60	0.9376	1.7927
-10	403.54	319.16	1272.3	13.780	0.00078598	0.072569	185.94	404.65	0.9481	1.7899
-8	432.82	344.21	1265.4	14.822	0.00079026	0.067467	188.73	405.69	0.9585	1.7872
-6	463.67	370.75	1258.3	15.927	0.00079472	0.062786	191.53	406.71	0.9689	1.7846
-4	496.17	398.83	1251.2	17.097	0.00079923	0.058490	194.34	407.72	0.9793	1.7820
-2	530.36	428.51	1244.1	18.335	0.00080380	0.054540	197.16	408.71	0.9897	1.7795
0	566.31	459.86	1236.8	19.645	0.00080854	0.050904	200.00	409.69	1.0000	1.7770
2	604.06	492.94	1229.5	21.029	0.00081334	0.047553	202.85	410.65	1.0103	1.7746
4	643.68	527.80	1222.1	22.492	0.00081263	0.044460	205.72	411.60	1.0206	1.7722
6	685.22	564.51	1214.5	24.037	0.00082338	0.041603	208.60	412.53	1.0308	1.7699
8	728.74	603.14	1207.0	25.668	0.00082850	0.038959	211.50	413.44	1.0410	1.7676
10	774.30	643.75	1199.3	27.390	0.00083382	0.036510	214.41	414.33	1.0512	1.7653
12	821.96	686.40	1191.5	29.207	0.00083928	0.034238	217.34	415.21	1.0614	1.7631
14	871.78	731.18	1183.6	31.123	0.00084488	0.032131	220.28	416.06	1.0715	1.7609
16	923.82	778.13	1175.6	33.144	0.00085063	0.030171	223.25	416.90	1.0816	1.7587
18	978.14	827.34	1167.4	35.275	0.00085660	0.028349	226.23	417.71	1.0918	1.7565
20	1034.8	878.87	1159.2	37.522	0.00086266	0.026651	229.23	418.49	1.1019	1.7544
22	1093.9	932.80	1150.8	39.892	0.00086896	0.025068	232.25	419.25	1.1120	1.7522
24	1155.4	989.21	1142.3	42.390	0.00087543	0.023590	235.29	419.99	1.1220	1.7501
26	1219.5	1048.2	1133.7	45.025	0.00088207	0.022210	238.36	420.70	1.1321	1.7479
28	1286.1	1109.7	1124.9	47.804	0.00088897	0.020919	241.44	421.38	1.1422	1.7458
30	1355.5	1174.0	1115.9	50.735	0.00089614	0.019710	244.55	422.03	1.1523	1.7436
32	1427.5	1241.1	1106.8	53.828	0.00090351	0.018578	247.69	422.64	1.1624	1.7414
34	1502.4	1311.1	1097.5	57.093	0.00091116	0.017515	250.85	423.23	1.1725	1.7392
36	1580.1	1384.0	1088.0	60.541	0.00091912	0.016518	254.04	423.77	1.1826	1.7369
38	1660.7	1459.9	1078.3	64.185	0.00092739	0.015580	257.26	424.28	1.1928	1.7347
40	1744.4	1539.0	1068.4	68.037	0.00093598	0.014698	260.50	424.75	1.2029	1.7323
42	1831.1	1621.3	1058.2	72.114	0.00094500	0.013867	263.79	425.17	1.2131	1.7299
44	1921.0	1707.0	1047.8	76.431	0.00095438	0.013084	267.10	425.55	1.2233	1.7275
46	2014.1	1796.1	1037.2	81.008	0.00096413	0.012344	270.46	425.87	1.2336	1.7249
48	2110.5	1888.7	1026.2	85.865	0.00097447	0.011646	273.85	426.15	1.2439	1.7223
50	2210.3	1984.9	1014.9	91.028	0.00098532	0.010986	277.28	426.36	1.2542	1.7196
52	2313.5	2085.0	1003.2	96.523	0.00099681	0.010360	280.77	426.51	1.2647	1.7168
54	2420.3	2188.9	991.20	102.38	0.0010089	0.0097675	284.30	426.59	1.2752	1.7138
56	2530.7	2296.9	978.74	108.64	0.0010217	0.0092047	287.89	426.59	1.2858	1.7107
58	2644.8	2409.0	965.80	115.35	0.0010354	0.0086693	291.53	426.51	1.2965	1.7074
60	2762.6	2525.4	952.33	122.55	0.0010501	0.0081599	295.25	426.34	1.3073	1.7039
62	2884.4	2646.3	938.25	130.31	0.0010658	0.0076740	299.04	426.06	1.3182	1.7003
64	3010.0	2771.8	923.50	138.70	0.0010828	0.0072098	302.91	425.66	1.3293	1.6963
66	3139.8	2902.2	907.95	147.82	0.0011014	0.0067650	306.88	425.13	1.3407	1.6920
68	3273.6	3037.7	891.49	157.78	0.0011217	0.0063379	310.95	424.45	1.3522	1.6874
70	3411.7	3178.5	873.93	168.73	0.0011443	0.0059266	315.16	423.58	1.3640	1.6824
72	3554.1	3325.0	855.06	180.87	0.0011695	0.0055288	319.52	422.50	1.3762	1.6768
74	3700.9	3477.4	834.56	194.48	0.0011982	0.0051519	324.07	421.16	1.3889	1.6706

Note) P', p', v', h' and s' indicate the values at the boiling point, and P",p" v", h" and s" indicate the values at the dew point.

Fig.2-35 R407C P-h Chart (SI unit)

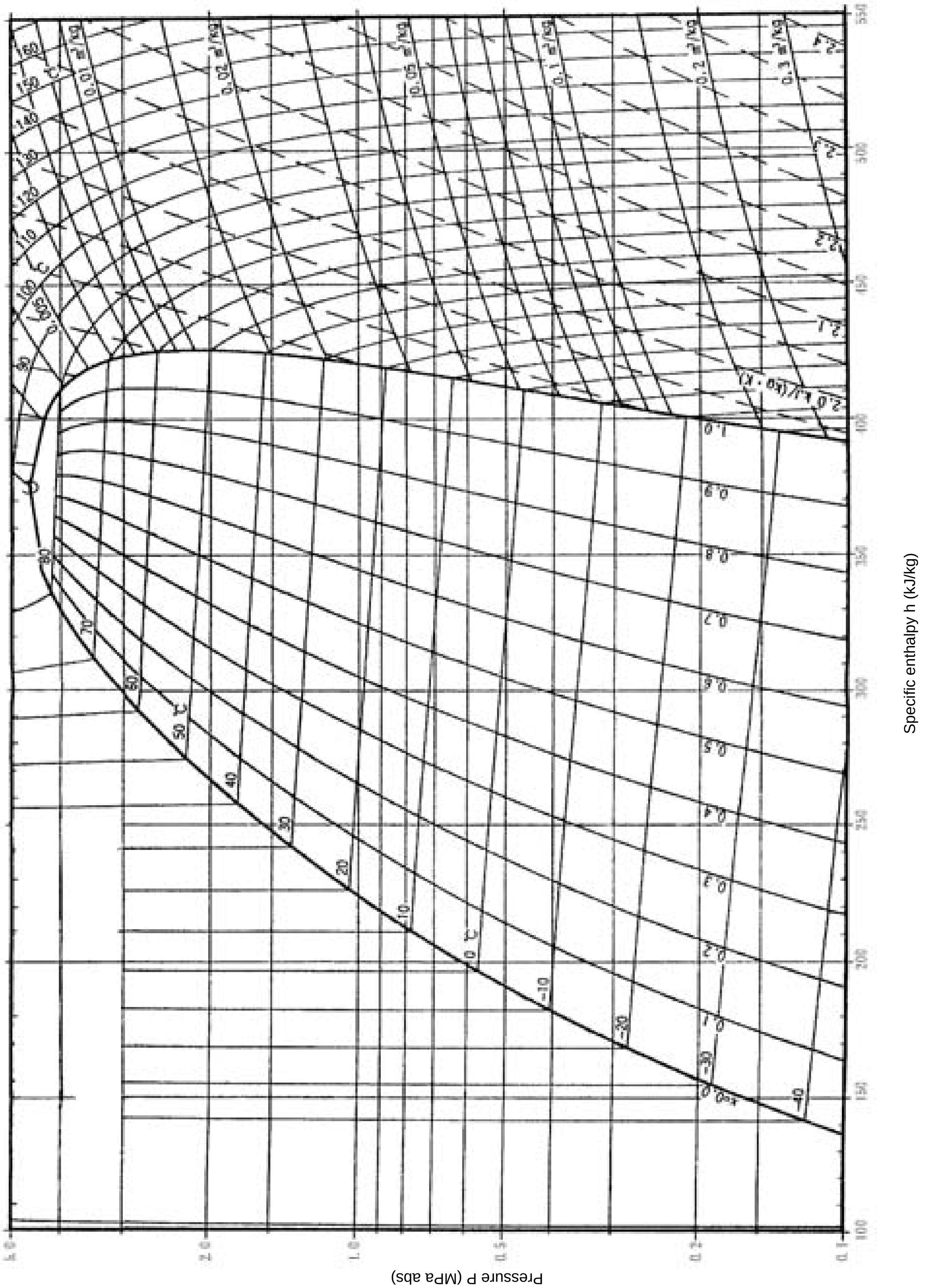
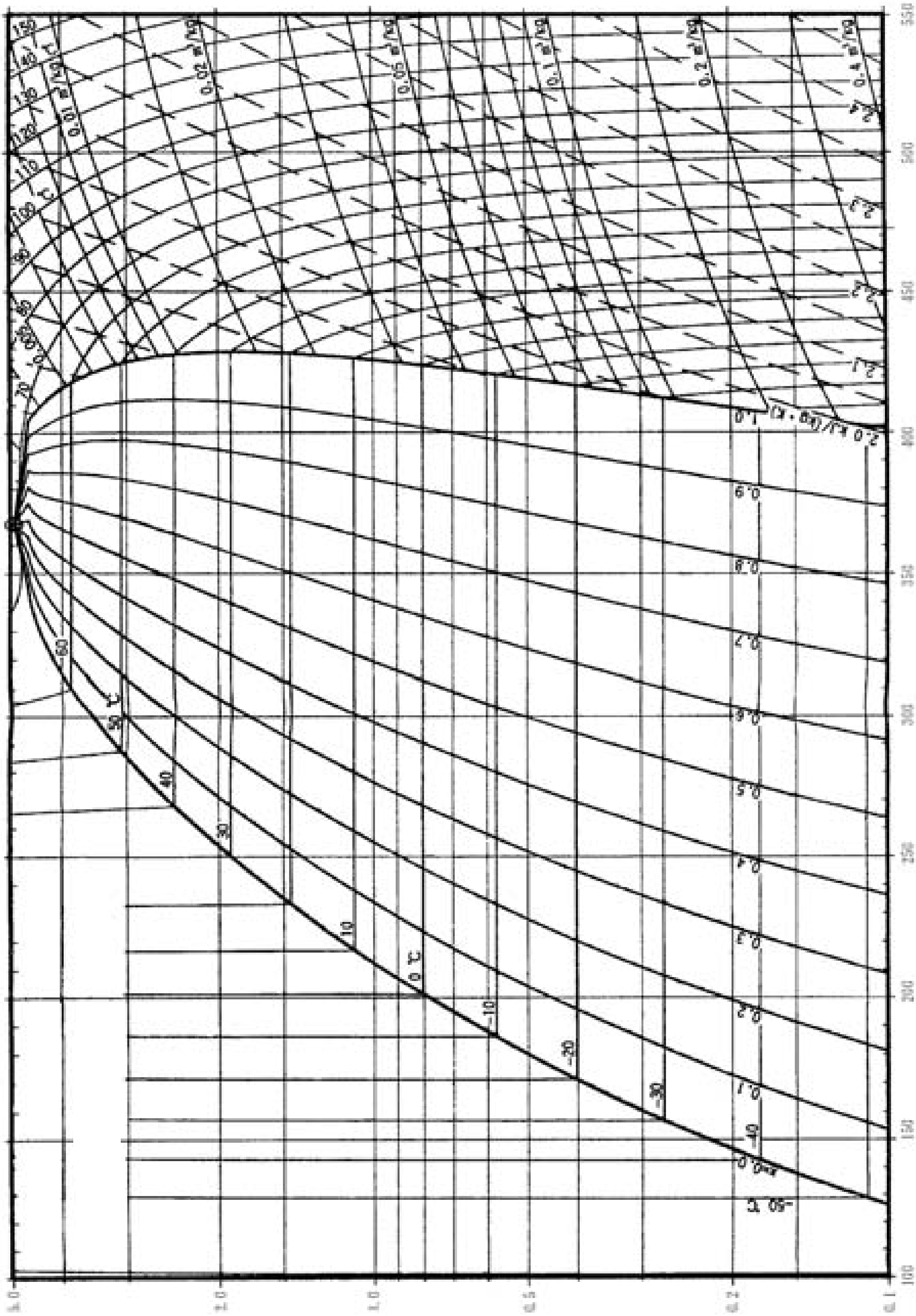


Table 2-9 R410A Thermodynamic properties
Composition ratio: R32 / R125 (50 / 50 / mass%)

Temperature	Pressure		Density		Specific volume		Specific enthalpy		Specific entropy	
C t	kPa Boiling point P'	Dew point P"	kg/ Liquid p'	Vapor p''	/kg Liquid v'	Vapor v''	kJ/kg Liquid h'	Vapor h''	kJ/(kg•K Liquid s'	Vapor s''
-58	71.84	71.48	1369.4	3.0053	0.00073025	0.33275	117.82	395.87	0.6650	1.9577
-56	80.01	79.61	1363.4	3.3254	0.00073346	0.30072	120.49	396.95	0.6773	1.9508
-54	88.90	88.48	1357.3	3.6720	0.00073676	0.27233	123.17	398.02	0.6896	1.9440
-52	98.57	98.11	1351.2	4.0467	0.00074008	0.24711	125.86	399.08	0.7018	1.9575
-50	109.06	108.57	1345.0	4.4511	0.00074349	0.22466	128.56	400.13	0.7139	1.9311
-48	120.42	119.89	1338.8	4.8869	0.00074694	0.20463	131.27	401.17	0.72590	1.9250
-46	132.69	132.12	1332.6	5.3558	0.00075041	0.18671	133.99	402.20	0.7379	1.9189
-44	145.94	145.32	1326.3	5.8597	0.00075398	0.17066	136.72	403.22	0.7499	1.9131
-42	160.20	159.53	1319.9	6.4002	0.00075763	0.15625	139.46	404.22	0.7617	1.9074
-40	175.53	174.82	1313.5	6.9795	0.00076132	0.14328	142.22	405.21	0.7735	1.9018
-38	192.00	191.23	1307.0	7.5995	0.00076511	0.13159	144.98	406.19	0.7853	1.8964
-36	209.65	208.82	1300.5	8.2622	0.00076894	0.12103	147.76	407.16	0.7970	1.8910
-34	228.53	227.65	1293.9	8.9699	0.00077286	0.11148	150.55	408.12	0.8086	1.8859
-32	248.72	247.77	1287.3	9.7247	0.00077682	0.10283	153.35	409.06	0.8202	1.8808
-30	270.27	269.25	1280.6	10.529	0.00078088	0.094976	156.16	409.98	0.8318	1.8759
-28	293.23	292.14	1273.9	11.385	0.00078499	0.087835	158.98	410.89	0.8433	1.8711
-26	317.68	316.51	1267.0	12.296	0.00078927	0.081327	161.82	411.79	0.8547	1.8663
-24	343.66	342.41	1260.2	13.263	0.00079352	0.075398	164.67	412.67	0.8661	1.8617
-22	371.26	369.92	1253.2	14.291	0.00079796	0.069974	167.53	413.53	0.8775	1.8572
-20	400.52	399.09	1246.2	15.381	0.00080244	0.065015	170.41	414.38	0.8888	1.8527
-18	431.53	430.00	1239.1	16.536	0.00080704	0.060474	173.30	415.20	0.9001	1.8483
-16	464.33	462.70	1231.9	17.761	0.00081175	0.056303	176.20	416.01	0.9113	1.8441
-14	499.01	497.27	1224.7	19.057	0.00081653	0.052474	179.12	416.80	0.9225	1.8398
-12	535.62	533.77	1217.3	20.430	0.00082149	0.048948	182.06	417.57	0.9337	1.8357
-10	574.25	572.28	1209.9	21.881	0.00082651	0.045702	185.01	418.32	0.9448	1.8316
-8	614.95	612.86	1202.4	23.415	0.00083167	0.042708	187.97	419.05	0.9559	1.8276
-6	657.81	655.58	1194.8	25.037	0.00083696	0.039941	190.95	419.75	0.9670	1.9236
-4	702.89	700.52	1187.1	26.750	0.00084239	0.037383	193.95	420.44	0.9780	1.8196
-2	750.27	747.76	1179.4	28.559	0.00084789	0.035015	196.97	421.09	0.9890	1.8158
0	800.02	794.36	1171.5	30.469	0.00085361	0.032820	200.00	421.72	1.0000	1.8119
2	852.22	849.40	1163.5	32.485	0.00085948	0.030783	203.05	422.33	1.0110	1.8081
4	906.95	903.96	1155.4	34.613	0.00086550	0.028891	206.12	422.90	1.0219	1.8043
6	964.28	961.11	1147.1	36.859	0.00087176	0.027130	209.22	423.45	1.0329	1.8005
8	1024.2	1020.9	1138.8	39.228	0.00087812	0.025492	212.33	423.97	1.0438	1.7967
10	1087.0	1083.5	1130.3	41.729	0.00088472	0.023964	215.46	424.45	1.0547	1.7929
12	1152.6	1148.9	1121.7	44.367	0.00089150	0.022539	218.62	424.90	1.0656	1.7892
14	1221.2	1217.3	1112.9	47.152	0.00089855	0.021208	221.80	425.32	1.0765	1.7854
16	1292.7	1288.6	1104.0	50.092	0.00090580	0.019963	225.01	425.70	1.0874	1.7816
18	1367.4	1363.1	1094.9	53.197	0.00091333	0.018798	228.24	426.04	1.0983	1.7778
20	1445.2	1440.7	1085.6	56.476	0.00092115	0.017707	231.50	426.34	1.1092	1.7740
22	1526.3	1521.6	1076.2	59.941	0.00092920	0.016683	234.79	426.59	1.1202	1.7701
24	1610.8	1605.8	1066.5	63.606	0.00093765	0.015708	238.12	426.80	1.1311	1.7662
26	1698.8	1693.5	1056.7	67.483	0.00094634	0.014819	241.47	426.95	1.1421	1.7623
28	1790.2	1784.8	1046.6	71.588	0.00095547	0.013969	244.86	427.06	1.1531	1.7582
30	1885.4	1879.7	1036.2	75.938	0.00096506	0.013169	248.29	427.11	1.1641	1.7541
32	1984.3	2087.0	1025.6	80.553	0.00097503	0.012414	251.75	431.01	1.1752	1.7500
34	2087.0	2080.9	1014.7	85.455	0.00098551	0.011702	255.26	427.02	1.1864	1.7457
36	2193.7	2187.3	1003.5	90.668	0.00099651	0.011029	258.82	426.87	1.1976	1.7413
38	2304.4	2297.9	991.97	96.220	0.0010081	0.010393	262.43	426.64	1.2088	1.7367
40	2419.4	2412.6	980.08	102.15	0.0010204	0.0097895	266.09	429.33	1.2202	1.7320
42	2538.6	2531.6	967.65	108.48	0.0010334	0.0092183	269.81	425.94	1.2316	1.7272
44	2662.3	2655.1	954.82	115.27	0.0010473	0.0086753	273.60	425.44	1.2432	1.7221
46	2790.4	2783.1	941.47	122.58	0.0010622	0.0081579	277.46	424.83	1.2549	1.7168
48	2923.3	2915.9	927.52	130.48	0.0010781	0.0076658	281.40	424.10	1.2668	1.7112
50	3061.0	3053.5	912.90	138.98	0.0010954	0.0071953	285.44	423.22	1.2789	1.7053
52	3203.7	3196.1	897.50	146.19	0.0011142	0.0067449	289.58	422.19	1.2912	1.6991
54	3351.5	3343.9	881.19	158.42	0.0011348	0.0063123	293.85	420.97	1.3037	1.6924
56	3504.6	3497.0	863.80	169.61	0.0011577	0.0058959	298.26	419.54	1.3166	1.6852
58	3663.3	3655.8	845.11	182.06	0.0011833	0.0054897	302.85	417.84	1.3300	1.6773
60	3827.7	3820.3	824.75	196.07	0.0012124	0.0051002	307.64	415.82	1.3438	1.6686
62	3998.0	3990.9	802.31	212.10	0.0012463	0.0047148	312.72	413.39	1.3584	1.6588
64	4174.7	4168.0	777.10	230.83	0.0012867	0.0043322	318.16	410.42	1.3739	1.6476
66	4358.0	4351.9	747.81	253.51	0.0013372	0.0039893	324.12	406.66	1.3908	1.6342
68	4548.4	4543.1	711.70	282.64	0.0014050	0.0035381	330.97	401.65	1.4102	1.6174
70	4746.8	4742.8	661.17	325.21	0.0015126	0.0030749	339.69	394.07	1.4348	1.5933
71.95	4948.3	4948.3	472.00	472.00	0.0021186	0.0021186	368.31	368.31	1.5169	1.5169

Note) P', p', v', h' and s' indicate the values at the boiling point, and P", p" v", h" and s" indicate the values at the dew point.

Fig.2-36 R410 P-h Chart (SI unit)



Specific enthalpy h (kJ/kg)

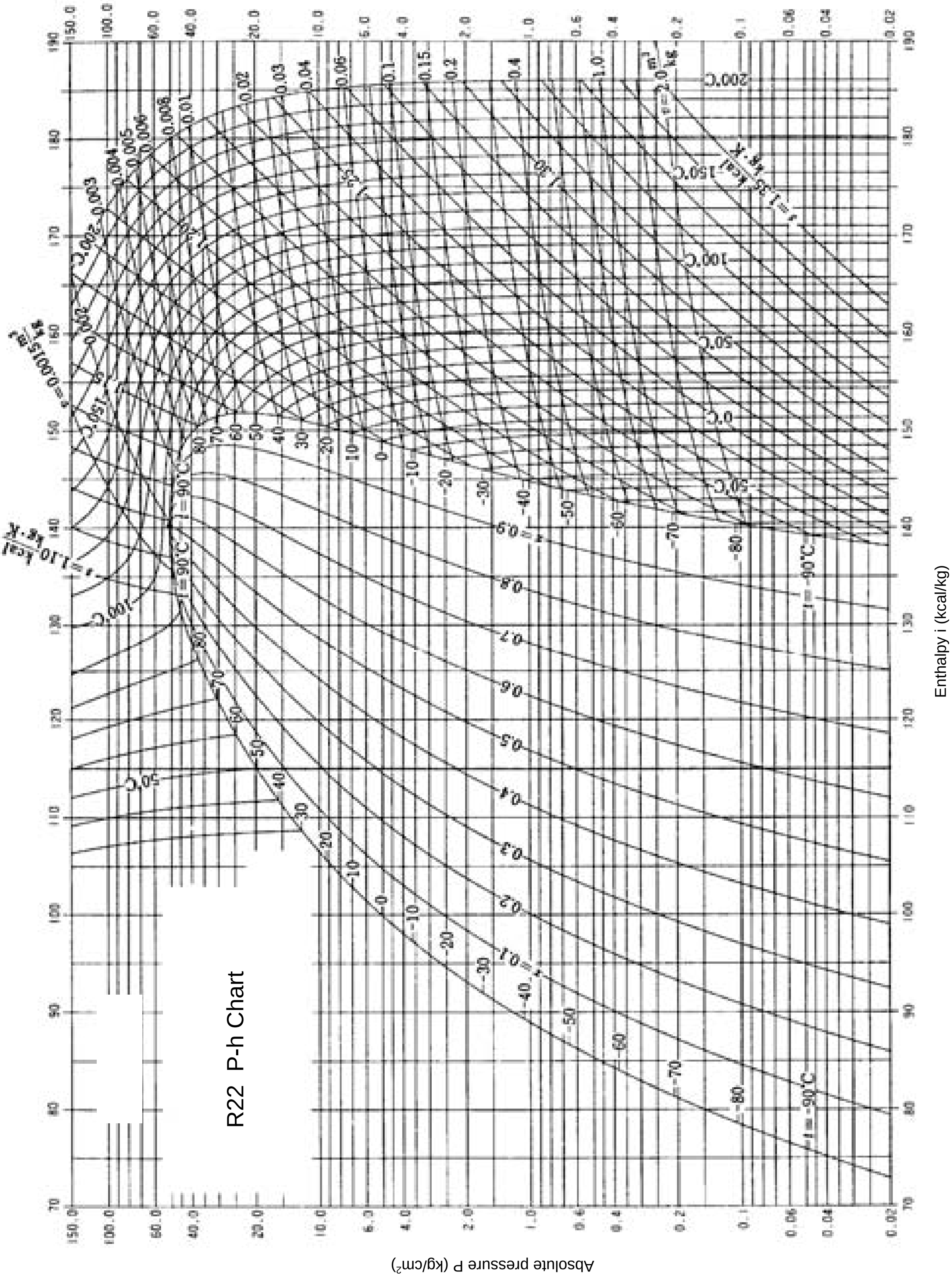
pressure P (MPa abs)

Table 2-10 R22 Thermodynamic properties (Previous unit)

Temperature	Pressure		Specific volume		Density		Specific enthalpy			Specific entropy	
C	kg/		/kg		g/		kcal/kg			kcal/(kg•K)	
	Absolute	Gauge	Liquid*	Vapor	Liquid	Vapor	Liquid	Vapor	Latent heat	Liquid	Vapor
t	P		v'	v"	p'	p"	h'	h"	h"-h'	s'	s"
-100	0.019957	14.680	0.00063765	8.4889	1.5683	0.00011780	72.83	138.09	65.26	0.8761	1.2530
-95	0.031561	23.215	0.00064284	5.5179	1.5556	0.00018123	74.31	138.67	64.36	0.8845	1.2458
-90	0.048412	35.610	0.00064818	3.6939	1.5428	0.00027072	75.76	139.25	63.49	0.8925	1.2392
-85	0.072238	53.135	0.00065365	2.5394	1.5299	0.00039379	77.19	139.83	62.64	0.9002	1.2331
-80	0.10512	77.320	0.00065928	1.7883	1.5168	0.00055920	78.59	140.41	61.82	0.9076	1.2276
-75	0.14951	109.972	0.00066507	1.2870	1.5036	0.00077699	79.97	140.99	61.02	0.9146	1.2226
-70	0.20826	153.190	0.00067103	0.94477	1.4902	0.0010585	81.34	141.57	60.23	0.9214	1.2179
-65	0.28464	209.369	0.00067717	0.70609	1.4767	0.0014162	82.69	142.14	59.45	0.9280	1.2136
-60	0.38230	281.207	0.00068349	0.53641	1.4631	0.0018642	84.03	142.72	58.69	0.9344	1.2097
-55	0.50533	371.703	0.00069003	0.41362	1.4492	0.0024177	85.36	143.28	57.92	0.9405	1.2060
-50	0.65821	484.155	0.00069677	0.32330	1.4352	0.0030931	86.68	143.84	57.16	0.9465	1.2027
-45	0.84582	622.153	0.00070375	0.25586	1.4210	0.0039084	87.99	144.40	56.41	0.9523	1.1995
-40	1.07342	0.04019	0.00071098	0.20480	1.4065	0.0048829	89.31	144.95	55.64	0.9580	1.1966
-35	1.34665	0.31342	0.00071847	0.16564	1.3918	0.0060373	90.62	145.48	54.86	0.9635	1.1939
-30	1.6715	0.6383	0.00072624	0.13524	1.3769	0.0073940	91.94	146.01	54.07	0.9690	1.1914
-25	2.0542	1.0210	0.00073433	0.11140	1.3618	0.0089770	93.26	146.53	53.28	0.9743	1.1890
-20	2.5014	1.4682	0.00074274	0.092487	1.3464	0.010812	94.58	147.03	52.45	0.9796	1.1868
-15	3.0201	1.9869	0.00075152	0.077352	1.3306	0.012928	95.92	147.52	51.60	0.9848	1.1847
-10	3.6173	2.5841	0.00076069	0.065128	1.3146	0.015354	97.26	148.00	50.74	0.9899	1.1827
-5	4.3005	3.2673	0.00077028	0.055173	1.2982	0.018125	98.62	148.46	49.84	0.9950	1.1808
0	5.0774	4.0442	0.00078035	0.047001	1.2815	0.021276	100.00	148.90	48.90	1.0000	1.1790
5	5.9556	4.9224	0.00079094	0.040244	1.2643	0.024848	101.39	149.32	47.93	1.0050	1.1773
10	6.9434	5.9102	0.00080211	0.034617	1.2467	0.028888	102.81	149.72	46.91	1.0100	1.1756
15	8.0488	7.0156	0.00081393	0.029900	1.2286	0.033444	104.24	150.09	45.85	1.0149	1.1740
20	9.2804	8.2472	0.00082646	0.025922	1.2100	0.038577	105.70	150.44	44.74	1.0199	1.1725
25	10.647	9.614	0.00083981	0.022547	1.1907	0.044353	107.18	150.76	43.58	1.0248	1.1709
30	12.156	11.123	0.00085410	0.019666	1.1708	0.050850	108.69	151.05	42.36	1.0297	1.1694
35	13.819	12.786	0.00086946	0.017193	1.1501	0.058162	110.23	151.30	41.07	1.0346	1.1679
40	15.643	14.610	0.00088606	0.015063	1.1286	0.066401	111.81	151.51	39.70	1.0396	1.1664
45	17.638	16.605	0.00090414	0.013209	1.1060	0.075706	113.42	151.67	38.25	1.0445	1.1648
50	19.815	18.782	0.00092397	0.011594	1.0823	0.086249	115.06	151.78	36.72	1.0495	1.1632
55	22.185	21.152	0.00094595	0.010178	1.0571	0.098254	116.76	151.82	35.06	1.0546	1.1614
60	24.758	23.725	0.00097060	0.0089272	1.0303	0.11202	118.50	151.79	33.29	1.0597	1.1596
65	27.547	26.514	0.00099866	0.0078156	1.0013	0.12795	120.31	151.66	31.35	1.0649	1.1576
70	30.566	29.533	0.0010313	0.0068192	0.96968	0.14664	122.20	151.42	29.22	1.0702	1.1554
75	33.829	32.796	0.0010702	0.0059165	0.93438	0.16902	124.19	151.02	26.83	1.0757	1.1528
80	37.356	36.323	0.0011187	0.0050858	0.89389	0.19663	126.34	150.40	24.06	1.0816	1.1497
85	41.166	40.133	0.0011832	0.0043009	0.84517	0.23251	128.72	149.45	20.73	1.0880	1.1459
90	45.289	44.256	0.0012811	0.0035166	0.78060	0.28437	131.54	147.87	16.33	1.0955	1.1405
95	49.770	48.737	0.0015130	0.0025467	0.66094	0.39266	135.84	144.20	8.36	1.1068	1.1296
96	50.719	49.686	0.0017053	0.0021531	0.58639	0.46446	138.04	141.77	3.73	1.1127	1.1228

Note) This value with "*" times 1000 is /kg. Pressure unit is mmHg (absolute).

Fig.2-37 R22 P-h Chart (Previous unit)



Chapter 3 Classification of air conditioners

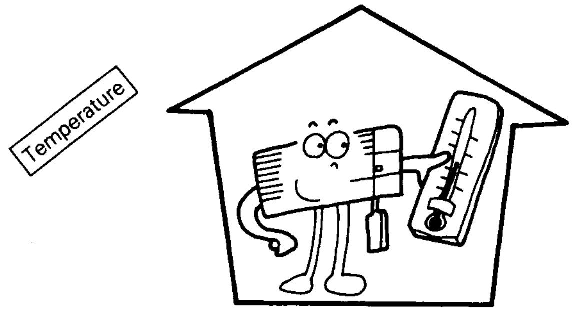
Chapter 3 Classification of air conditioners

3.1 Air conditioning

Air conditioning is defined as "the process of treating air so as to control simultaneously its temperature, humidity, cleanness and distribution to meet the requirements of the conditioned space". As indicated in the definition, the important actions involved in the operation of an air conditioning system are;

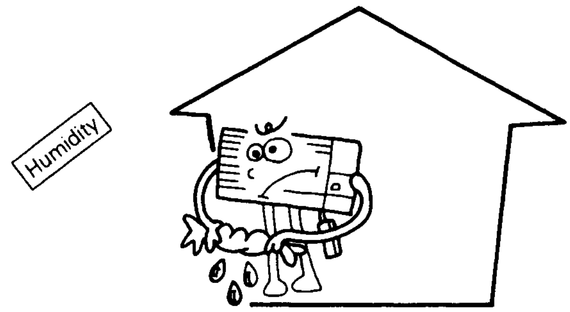
(1) Temperature control
Room temperature is controlled to the predesigned dry bulb temperature by cooling or heating room air.

Fig.3-1
1. Room air is cooled or heated



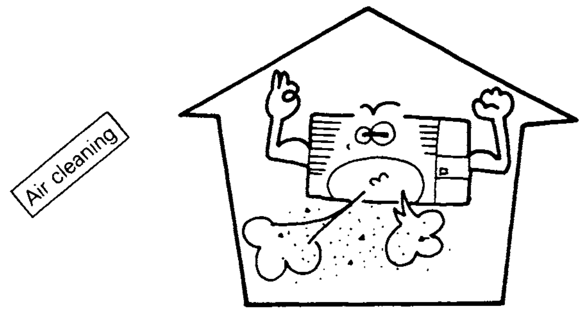
(2) Humidity control
Room air is controlled to the predesigned relative humidity by humidifying or dehumidifying room air.

Fig.3-2
2. Room air is humidified or dehumidified



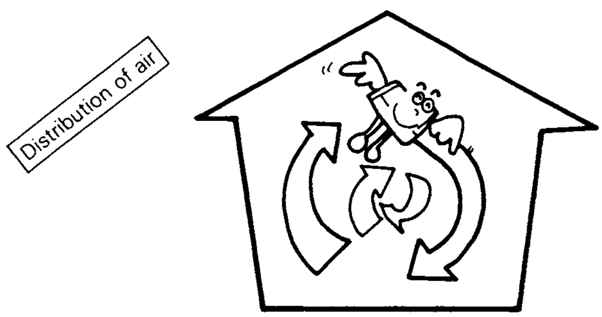
(3) Air filtering, cleaning and purification
Room air is cleaned by removing dust and dirt from the air.

Fig.3-3
3. Room air is cleaned by removing dust and dirt from it.



(4) Air movement and circulation
Air which is controlled in temperature and humidity and cleaned is distributed throughout a room. As a result, room air can be maintained evenly in temperature and humidity conditions.

Fig.3-4
4. Controlled air is distributed throughout a room

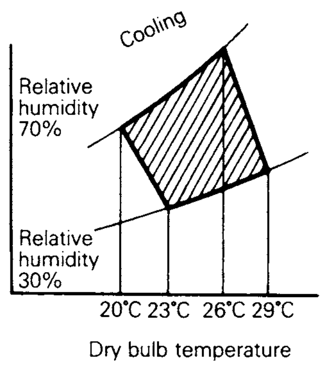


Temperature, humidity, cleanness and distribution of air are called "Four elements of air conditioning". By controlling these four elements, room air can be comfortably maintained regardless of outdoor temperature. Should these four elements be replaced with the works of the air conditioner, the room air is drawn in the air conditioner, where dust and dirt are removed from the air by the air filter(cleanness of air)and is sent to the evaporator, where temperature of the air is reduced by evaporation of the refrigerant(temperature), and at the same time, humidity in the air is removed as condensation(humidity). As a result, the air distributed from the air conditioner is cool and crisp and can be distributed throughout the room by the evaporator fan(distribution of air stream). Such works are repeated so as to perform air conditioning.

3.2 What is comfortable air?

The heat and coldness that the man feels depend not only on air temperature(dry bulb temperature), but also on humidity and distribution of air.
In addition, the general comfortable zone is within the range shown with oblique lines in Fig.3-5, although comfort differs with the distinction of sex, age and work.
In case of cooling, however, although room air conditions are within the comfortable zone, the room air is not always optimum. For example, if temperature difference between indoor and outdoor is nearly 10ºC because room air is controlled so as to be within this zone, one feels coolness and heat strongly when he enters in and out of a room, which makes him feel uncomfortable.
Such discomfort is called "cold shock". Consequently, it is important to control room air temperature so as not to feel "cold shock" during cooling by adjusting the thermostat. The optimum temperature difference between indoor and outdoor is from 3 to 6ºC in consideration with health and economy.

Fig.3-5



3.3 Classification of air conditioners

The main stream of air conditioners is packaged(Unitary) air conditioners, but they are gradually diversified in shapes and kinds owing to building utilities.
There are many kinds of classifications of air conditioners, but the representative classifications will be explained below.

3.3.1 Classification by expansion methods

Expansion methods are largely classified in two types; i.e. direct expansion and indirect expansion. The direct expansion method is that heat is directly exchanged between air to be conditioned and the refrigerant, and the air conditioners adopt this method. The indirect expansion method is that heat is exchanged indirectly between air to be conditioned and the refrigerant by means of water or brine. The systems combining the chillers or centrifugal water chillers with fan coil units adopt this method.

Expansion method ─┬─ Direct expansion
                  └─ Indirect expansion

Fig.3-6 Direct expansion

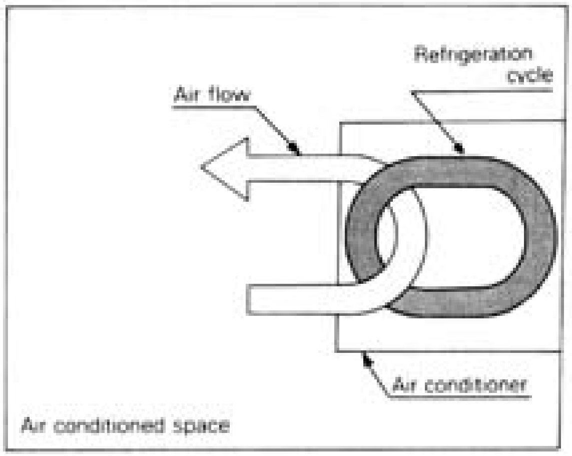
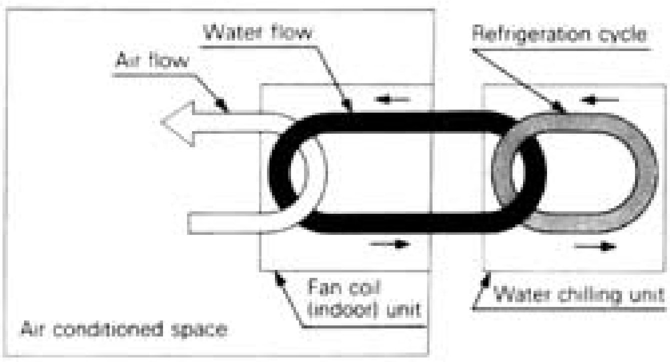


Fig.3-7 Indirect expansion



3.3.2 Classification by heat rejection methods

Heat rejection methods are largely classified in two types; i.e. water cooled type by means of water, and air cooled type by means of air.
(As the recent tendency, the air cooled type air conditioners which are free from maintenance work increase.)

Air conditioners
- Air cooled type
- Water cooled type

Table 3-1 Features of air cooled and water cooled types

Items	Air cooled type	Water cooled type
① Condensing medium	• Outdoor air	• Well water, city water • Cooling tower water
② Incidental works	• Power supply • Refrigerant piping (Split type only)	• Power supply, cooling water piping • Pump for well water or water circulating pump for cooling tower
③ Cooling capacity per 0.75kw	Approx.8,790~10,465 kJ/h(2100~2500kcal/h)	Approx.12,558kJ/h(3000kcal/h)
Noise	Comparatively high(Outdoor unit)	Low
Check points	• Conditions of outdoor air intake(chemicals, dust and dirt) • Short-circuit of distributed air • Outdoor air temp.	• Quantity and quality of cooling water • Position of a cooling tower

Fig.3-8 Water cooled type

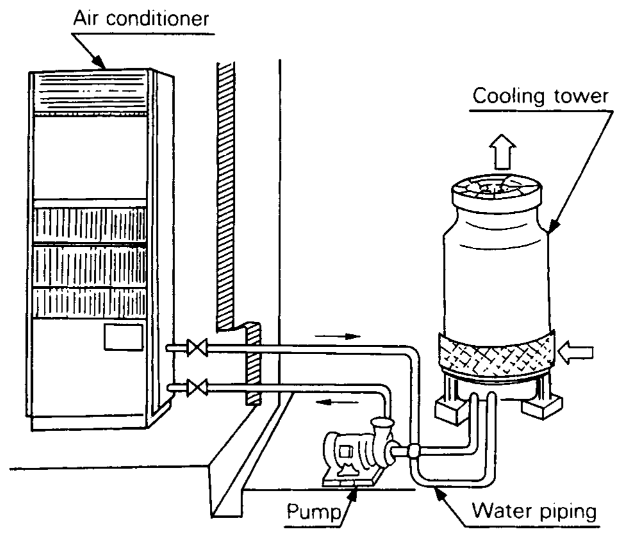
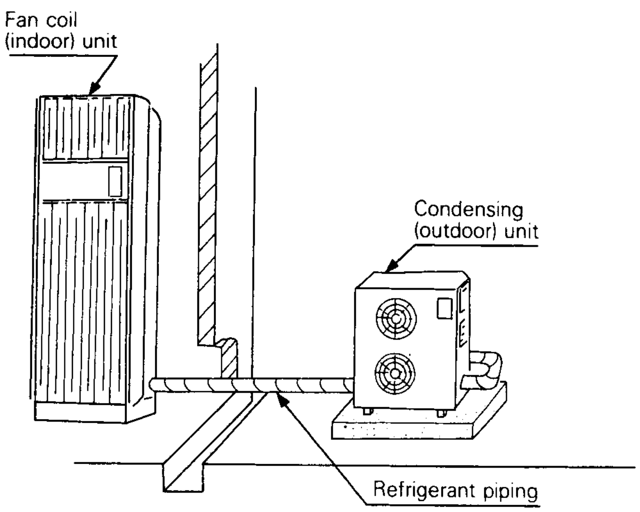


Fig.3-9 Air cooled type



3.3.3 Classification by structure

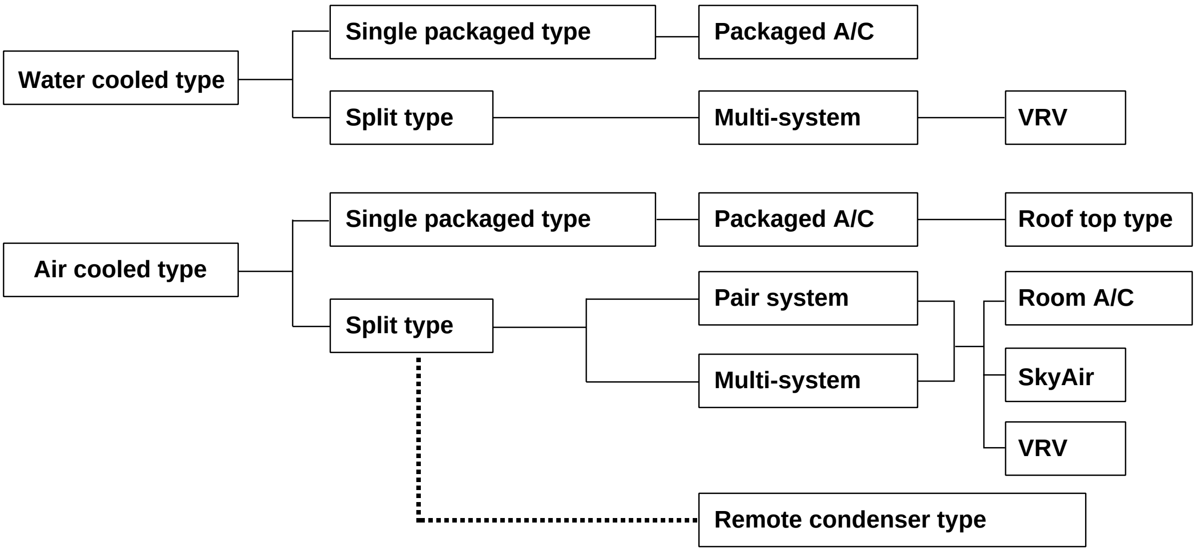


Table 3-2 Features of Single packaged type and Split type

Items	Single packaged type	Split type
Structure	One package type with all necessary components incorporated	Indoor units and outdoor units are manufactured independently.
Installation work	• Incorporation of all necessary components results in heavy weight per unit. • No piping work requires no skillful piping worker, while the Roof top type requires duct work.	• Piping work is required. • Through holes must be made in the wall.
Location of installation	• In the case of indoor installation, a large dead space is required due to the floor installation.	• The indoor unit is light in weight and requires a minimal floor space. • The outdoor unit has a large flexibility of the installation site.
Noise Problem	• The indoor installation requirement results in operation at a high noise level including the compressor. • By the central system, airflow sound is only heard in the room. Therefore, superb duct design enables low-noise operation.	• Except for remote condenser type, no compressor noises remain in the room. • On all types incorporating the expansion valve (or capillary tube) in indoor unit, refrigerant passing sound is heard.

Fig.3-10 Roof-top type (UAT)

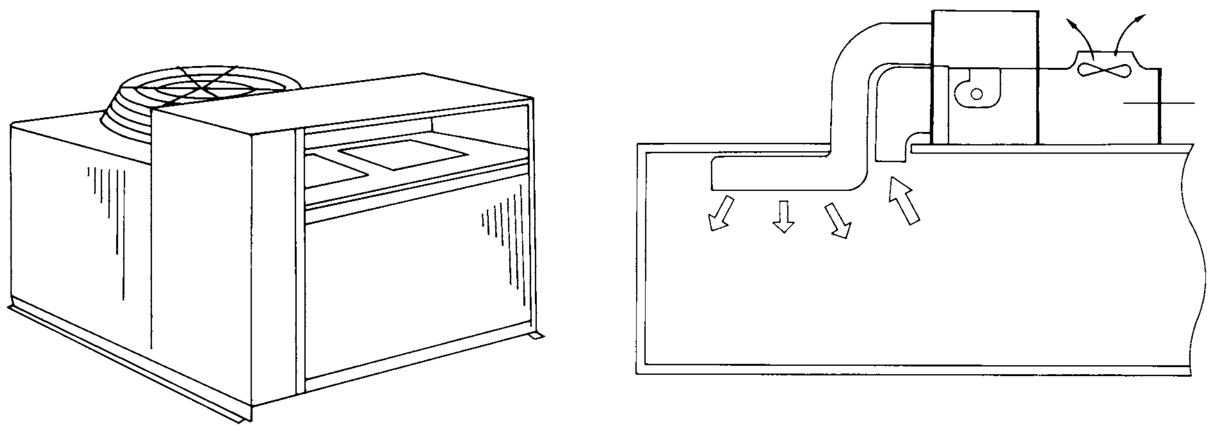


Table 3-3 Features of Split-pair and Multi-system

Items	Pair System	Multi-system
Installation Work	• Increasing the number of applicable rooms increases the number of outdoor units. As a result, the number of through holes in the distribution pipes increases. • The work itself is easier than that for Multi-system, thus required no skills of a high level.	• Even though there are a number of applicable rooms, one outdoor unit can cover. Therefore, the number of through holes in the pipes can be minimized. • The work itself becomes more complicated than that for Pair System due to additional work such as brazing.
Location of Installation	• In the case of a system of multiple outdoor units, larger space is required.	• Less number of outdoor units achieves less floor space required.
Control	• It is hard to perform the centralized control of a multiple of pair systems.	• There are a number of models, which enable the centralized control of a large number of indoor units
Noise problem	• The more outdoor units are provided, the noise source is dissipated.	• Since the noise source is concentrated on one place, it is convenient to take countermeasures such as the installation of noise insulation wall.

Fig.3-11 Split type (Pair system)

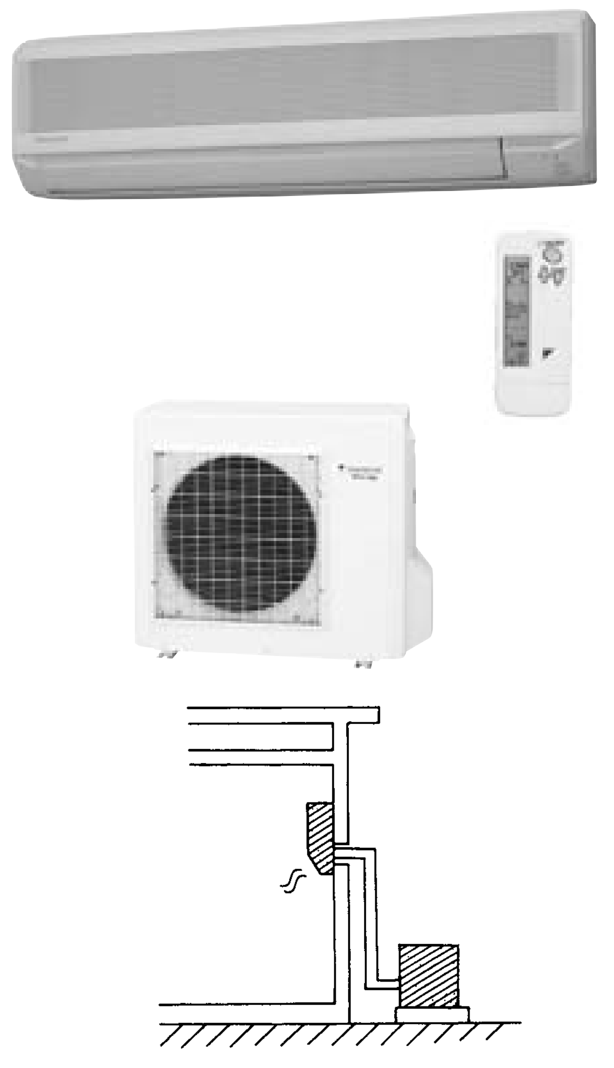
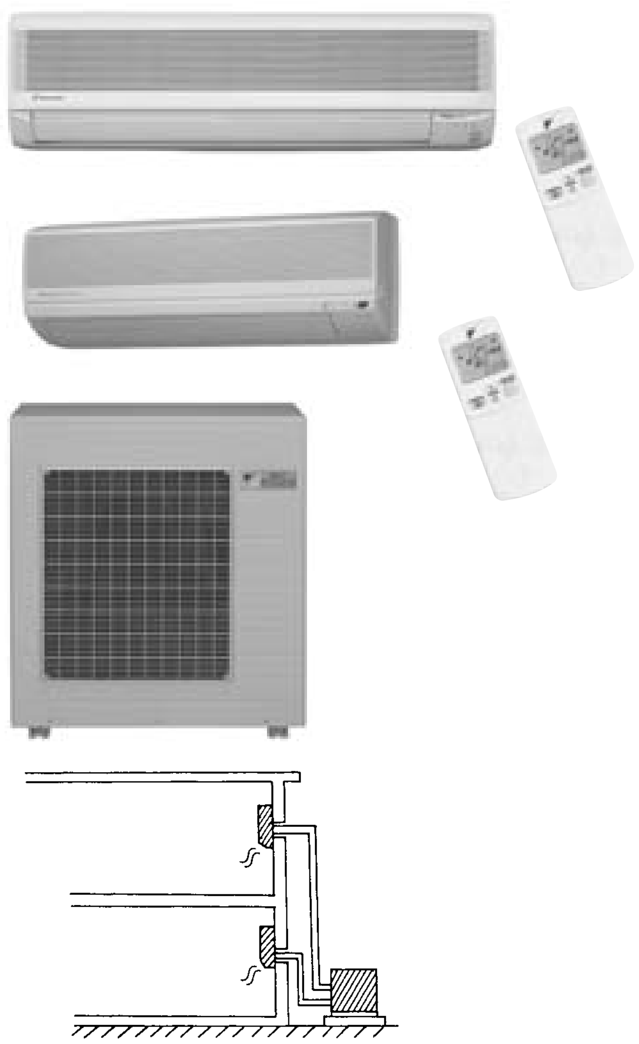


Fig.3-12 Split type (Multi-system)



3.3.4 Classification by locations of compressor (in case of the split type air conditioners)

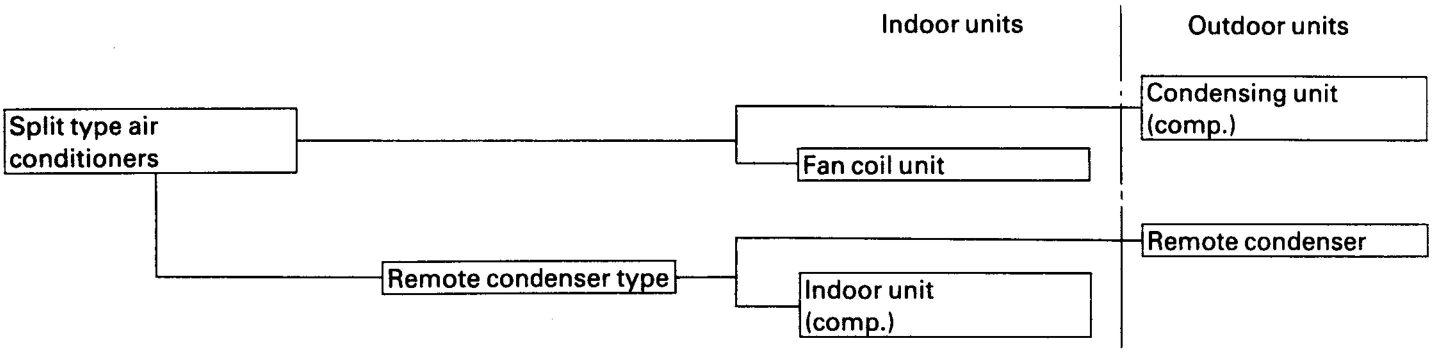


Fig.3-13 Split type

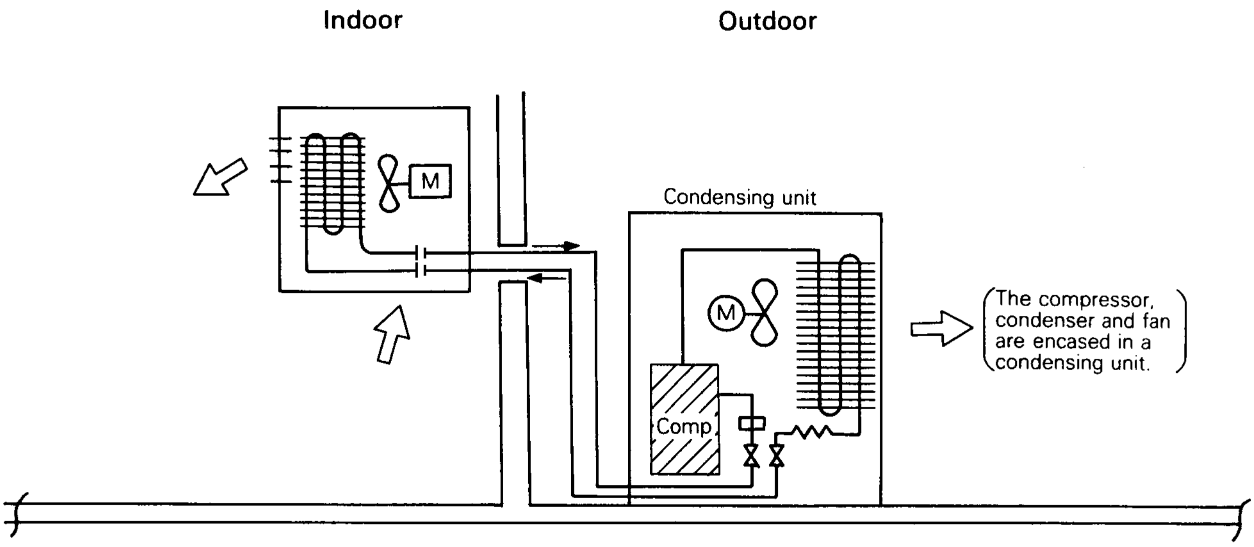
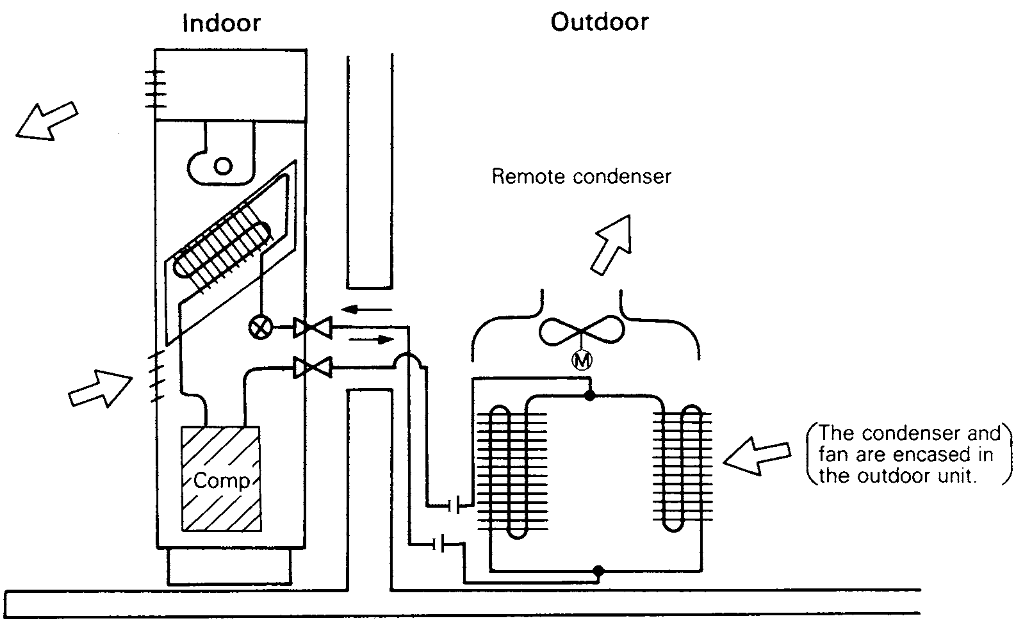
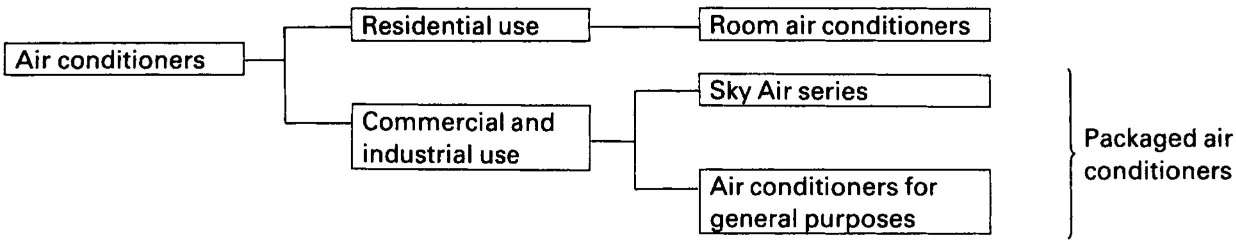


Fig.3-14 Remote condenser type



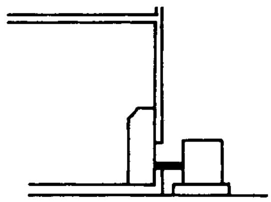
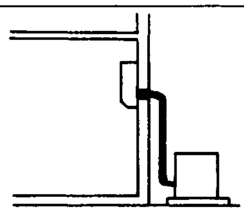
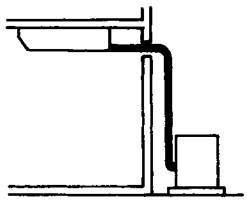
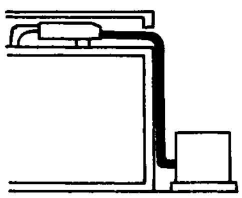
3.3.5 Classification by using positions

Air conditioners are largely classified in the residential use, commercial use and the industrial use.
In general, residential air conditioners are referred to as room air conditioners and commercial and industrial air conditioners as packaged air conditioners.

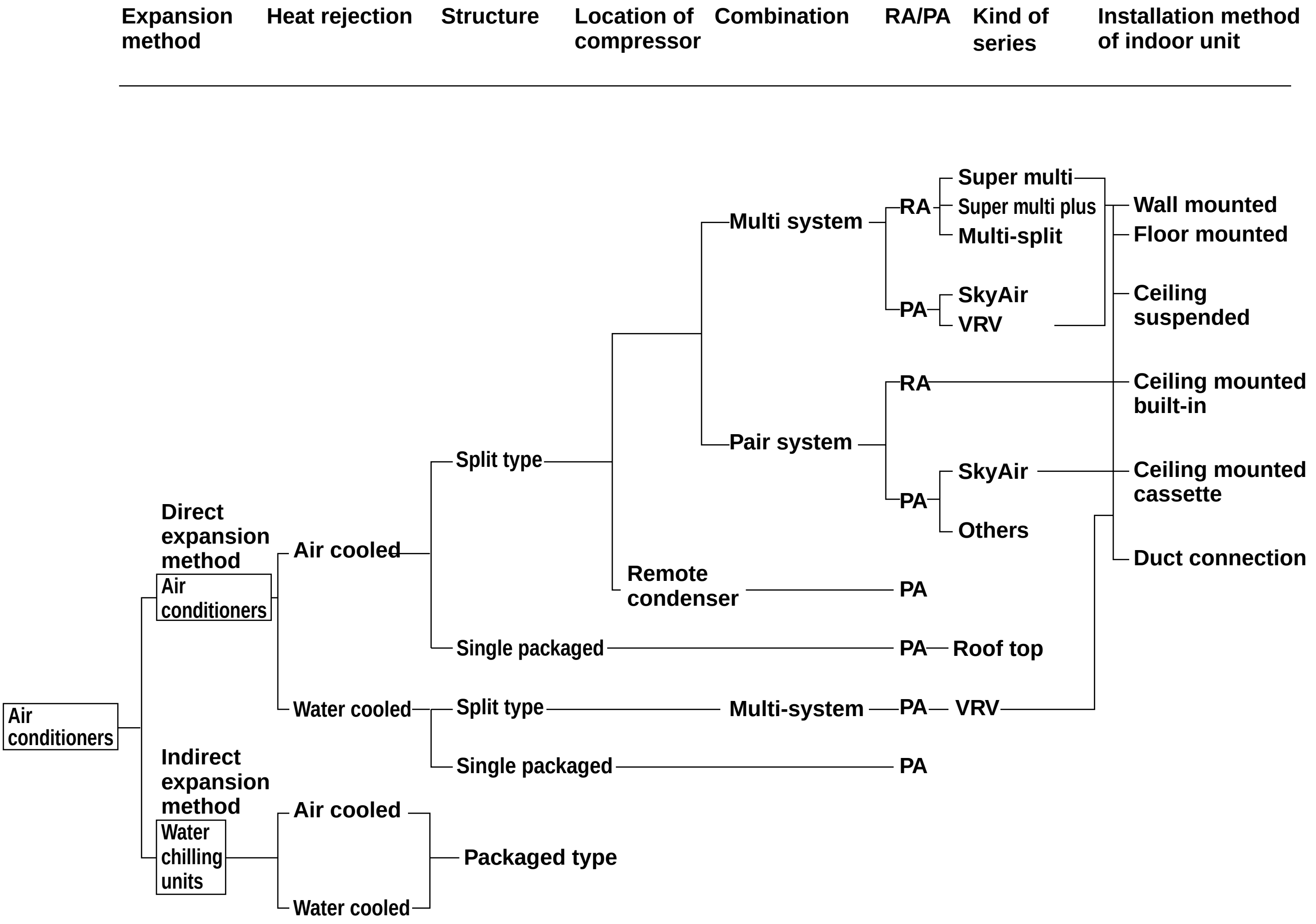


3.3.6 Classification by installation methods of fan coil (indoor) units

Fan coil (indoor units)

Kinds	Rough sketch	
Floor mounted type		The unit is installed on the floor and is capable of distributing the conditioned air widely.
Wall mounted type		The unit is installed at the middle of the wall. Since the unit is of the thin type, the room space can be used effectively.
Ceiling suspended type		The unit is suspended from the ceiling and distributes the conditioned air horizontally. Namely, not only the floor area, but also the wall face can be used effectively.
Ceiling mounted cassette type		The unit is installed in the ceiling, so room space can be fully used and is good from the interior designing point of view.

3.3.7 Table of classification of air conditioners



3.3.8 Classification of central air conditioning systems

There are several classification methods available for the air conditioning systems. This section describes the classification by decentralization degree and thermal transfer medium of air conditioners.

(1) Classification by decentralization degree of air conditioners

The decentralization degree methods are classified into centralized type (or central type) and individual type, and also into the in-between types such as each floor type and decentralized type.

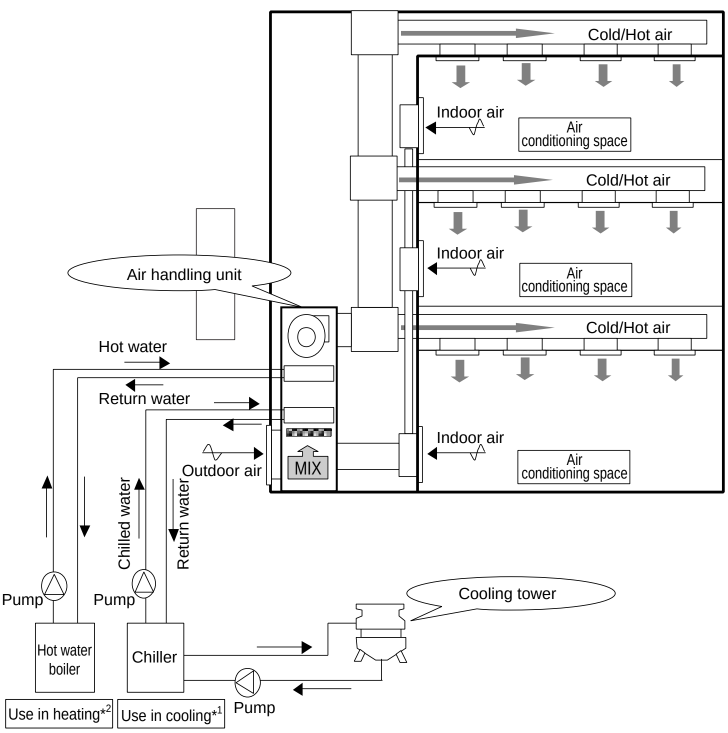
1. **Centralized type:** The central type is that air conditioning is performed over several floors through large-sized air conditioners and others, and used for air conditioning aimed at large area such as buildings.
2. **Each floor type:** The each floor type is that air conditioning is performed by floor and used when each floor has different intended use and time zone to be air-conditioned.
3. **Decentralized type:** The centralized type is that air conditioning is performed by partitioning a room into several air-conditioning zones and installing air conditioners in each zone in decentralized manner. This system is used to segment the indoor space.
4. **Individual type:** The individual type is that air conditioning is performed by installing individual air conditioner for each room and used for small-sized air conditioning system such as that for houses and stores.
   * Lately, in terms of operation control, inspection/ maintenance, energy saving, and others, the each floor type and the decentralized type have been increasingly introduced, compared to the centralized type.

(2) Classification by thermal transfer medium

1. **Total air method**
   The total air method is that conditioned air from the air conditioner is fed to each room through duct. Since heat is all transferred by means of air, this method is referred to as total air method.
   The total air method enables the intake of outdoor air, thus making it favorable in order to upgrade the indoor air cleanliness factor. However, air has a low heat capacity and requires larger ducts in size according to the airflow rate, thus resulting in increased number of restrictions in installation.
2. **Total water method**
   The total water method is that heat transport up to the inside of room is all performed by means of water. The fan coil unit type represents this method. It is a convenient method to perform air conditioning, while being behind other methods in terms of keeping the air cleanliness factor constant because indoor air is to be circulated for air conditioning.
3. **Water-air method**
   The water-air method is that indoor air-conditioning is performed in combination of conditioned air from the air conditioner and chilled water from chiller or else. This method performs air conditioning by means of both air and water, thus being referred to as water-air method. The typical example is that the fan coil unit type supports the perimeter area of room (perimeter zone) while the single duct type supports the central area of the room (interior zone).

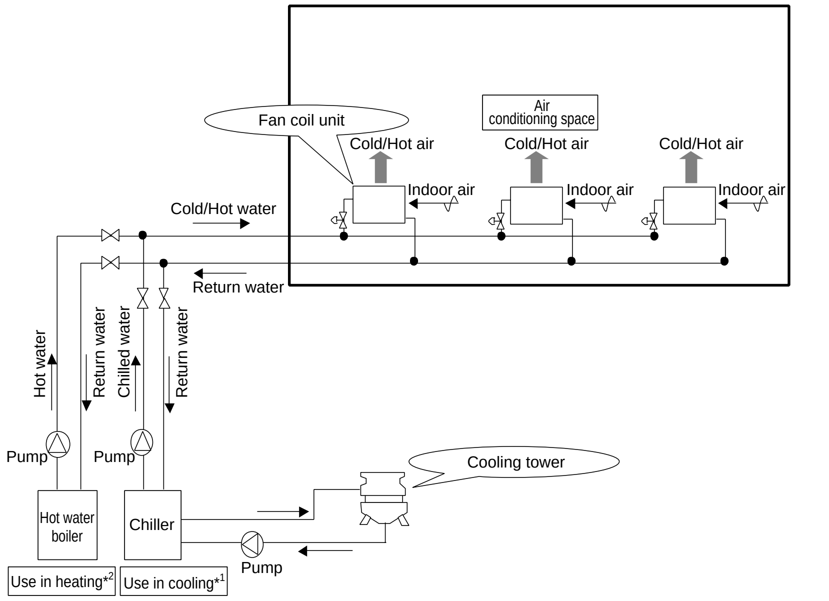
Total air method · Total water method · Water-air method

Fig.3-15 Total air method (Example of typical installation)



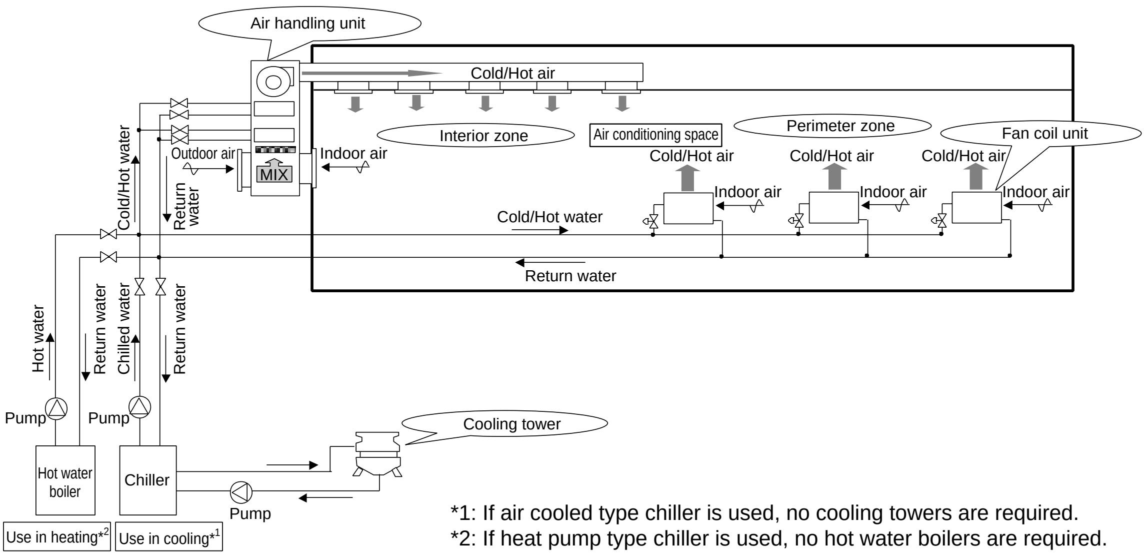
*1: If air cooled type chiller is used, no cooling towers are required.
*2: If heat pump type chiller is used, no hot water boilers are required.

Fig.3-16 Total water method (Example of typical installation)



*1: If air cooled type chiller is used, no cooling towers are required.
*2: If heat pump type chiller is used, no hot water boilers are required.

Fig.3-17 Water-air method (Example of typical installation)



*1: If air cooled type chiller is used, no cooling towers are required.
*2: If heat pump type chiller is used, no hot water boilers are required.

4. **Refrigerant method**

The refrigerant method is that indoor air-conditioning is performed through making use of evaporation and condensation effect of fluorocarbon gas (Flon gas).
According to the innovation of air conditioning technology in recent years, this method is widely used regardless of the sizes of buildings.
Compared to methods making use of water or air, this method will has advantages in equipment costs, energy consumption, installation space, maintenance costs, and others. The following figures show the examples of respective installations.

- **Room air conditioner**

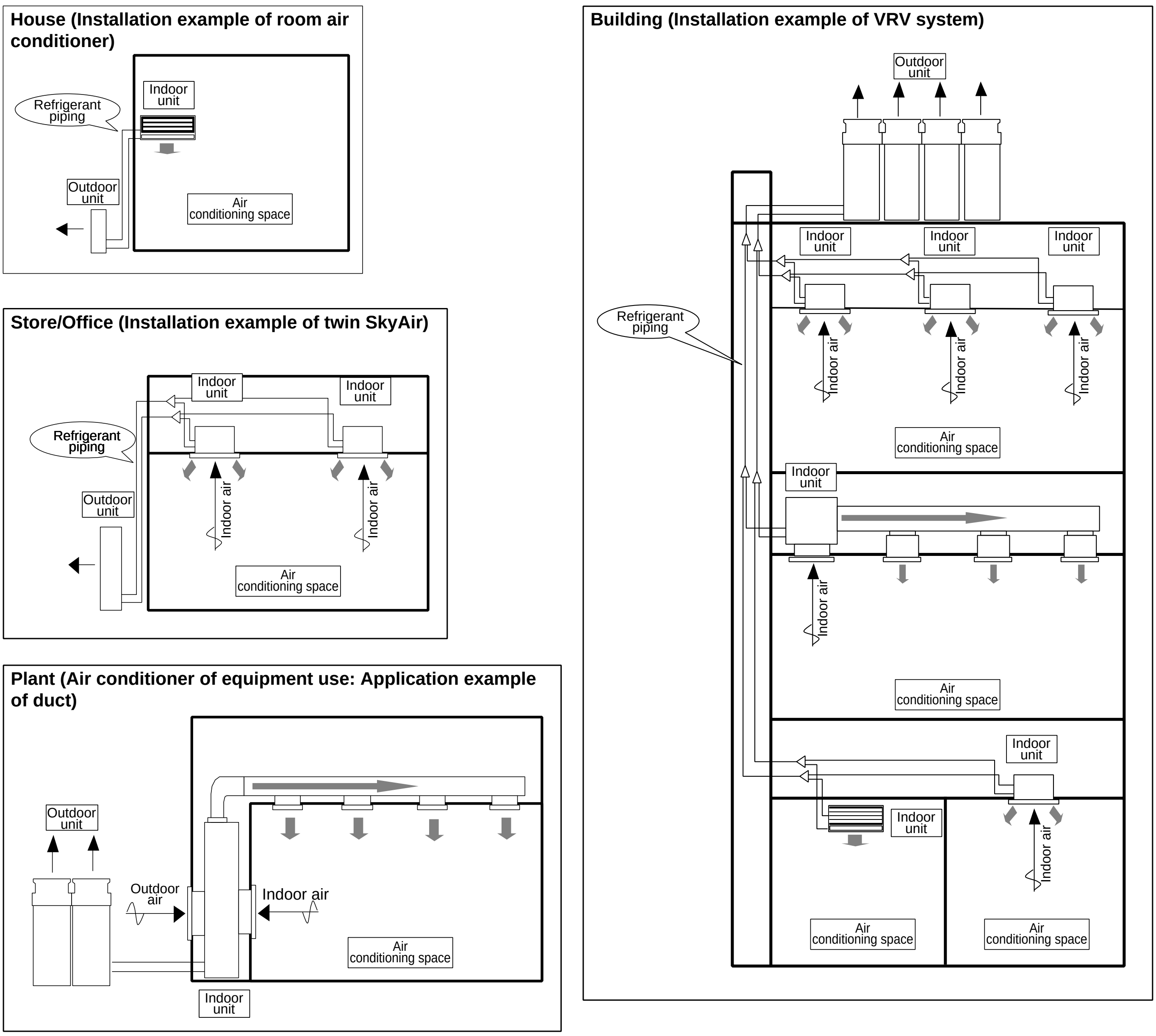
  The room air conditioner is an air conditioning system installed at home and the pair type of room air conditioners, which indoor unit and outdoor unit are installed in a pair, is currently the mainstream. Besides the pair type, the multi-type, which enables the installation of 2 to 3 indoor units in a system, is available.

- **Package air conditioner for business use**

  Generally, as the air conditioning system used at any other place than home, the package air conditioners are used in a variety of ways for diversified applications such as stores, offices, plants, and buildings. Besides those for plant use, there is a wide choice of variations available for indoor units. Currently, the ceiling mounted cassette types come into common use, and the support of optional accessories enables the incorporation with air cleaning and humidifying functions.

Refrigerant method (House, store, office, plant, building)

Fig.3-18



3.3.9 Configuration of Air Conditioning System

Numbers of sir conditioning systems, including the total air method, total water method, and water-air method, consist of the following equipment.

1. **Heat source unit**
   The heat source unit is used to produce chilled water, hot water or vapor required for air conditioners.
   This unit consists of heat source units such as chiller (e.g. turbo chiller and water chilling unit), absorption type chiller/ water heater, and boiler together with various equipment required to operate the heat source units such as pump, cooling tower, and oil tank.
2. **Air conditioner**
   The air conditioner consists of cooling coil, heating coil, humidifier, air filter, and others, which treats indoor heat loads to keep air clean.
   The air conditioner sometimes takes in outdoor air (referred to as fresh air as well) and mixes it in return air from rooms. This outdoor air replaces indoor air contaminated due to breathing, odor, or smoking of people in the rooms.
3. **Fan and duct**
   The fan serves as a power to transport air through transport path that is the duct.
   Air treated with the air conditioner is transported through the duct and fed into the room from the air outlet. Air, which has treated the indoor heat loads, is returned from the air inlet back to the air conditioner through the duct.
4. **Pump and piping**
   The pump serves as a power to transport the heating medium such as water through transport path that is the piping.
   Chilled water, hot water, or vapor, which is produced with the heat source unit, is transported to the air conditioner through the piping, where the heat loads are treated. After that, it is returned to the heat source unit. In order to discharge heat removed through chiller or absorption type chiller to the outside, the pump transports cooling water up to cooling tower through the piping.
5. **Automatic control unit**
   On air conditioners, the chilled and hot water flow rates are adjusted and the discharge temperature and relative humidity are controlled.
   Furthermore, the airflow rate of the discharge air may be controlled. The intake amount of outdoor air is controlled as well.
   On heat source units, the chilled and hot water temperatures are kept constant and, at the same time, the number of operating units and their capacities are controlled according to the load capacities. On pumps, the number of units and the capacities are controlled.
   Thus, the automatic control unit is a unit to operate the entire air conditioning system so that it can keep the indoor temperature and relative humidity under the most favorable conditions and economical running conditions.

Chapter 4 Components

4

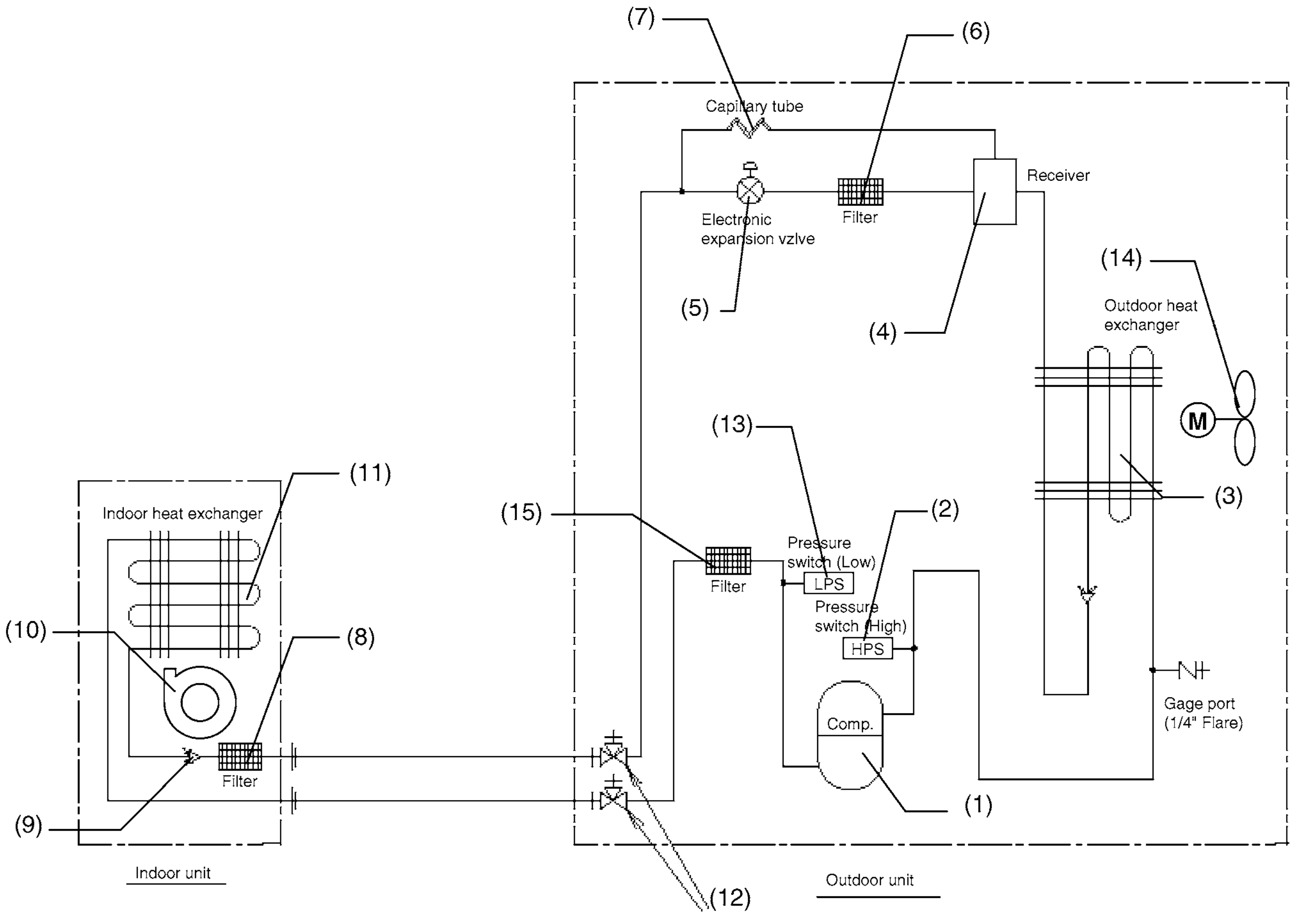
Chapter 4 Components

4.1 General description

The air conditioners consist of various parts and components. It is very important for servicemen to understand the structure and functions of each part and component well and to diagnose troubles with the air conditioners.
In this chapter, the parts and components used mainly in the room air conditioners and packaged air conditioners in recent years are explained.

In order to support the reading exercise of piping diagram, this Chapter picks up a product of simple design out of the SkyAir Series prevailing as air conditioners for business use, thus explaining typical components. Referring to the actual single view drawing on the following page of parts with the number corresponding to that shown in the circuit diagram below, get at the outline image of the parts.

Fig.4-1 R71KU



Components name

(1) Compressor
(2) High pressure switch
(3) Condenser (Outdoor unit heat exchanger)
(4) Receiver
(5) Electronic expansion valve
(6) Filter (Refrigerant)
(7) Capillary tube
(8) Filter (Refrigerant)
(9) Distributor
(10) Indoor unit fan (Centrifugal)
(11) Evaporator (Indoor unit heat exchanger)
(12) Stop valve (Service vale)
(13) Low pressure switch
(14) Outdoor fan (Propeller)
(15) Filter (Refrigerant)

SkyAir (Cooling only)

Fig.4-2 FVY71L

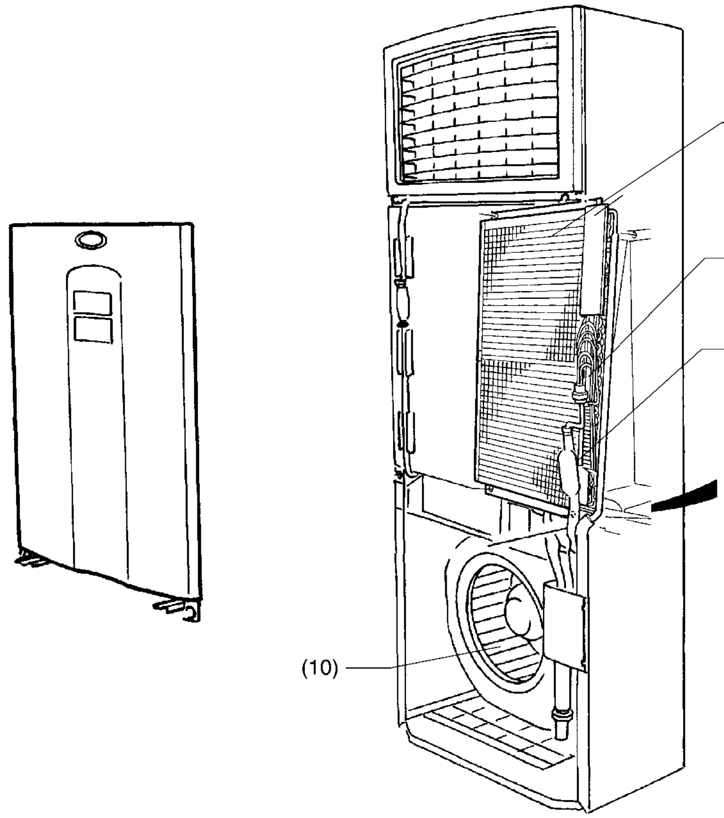
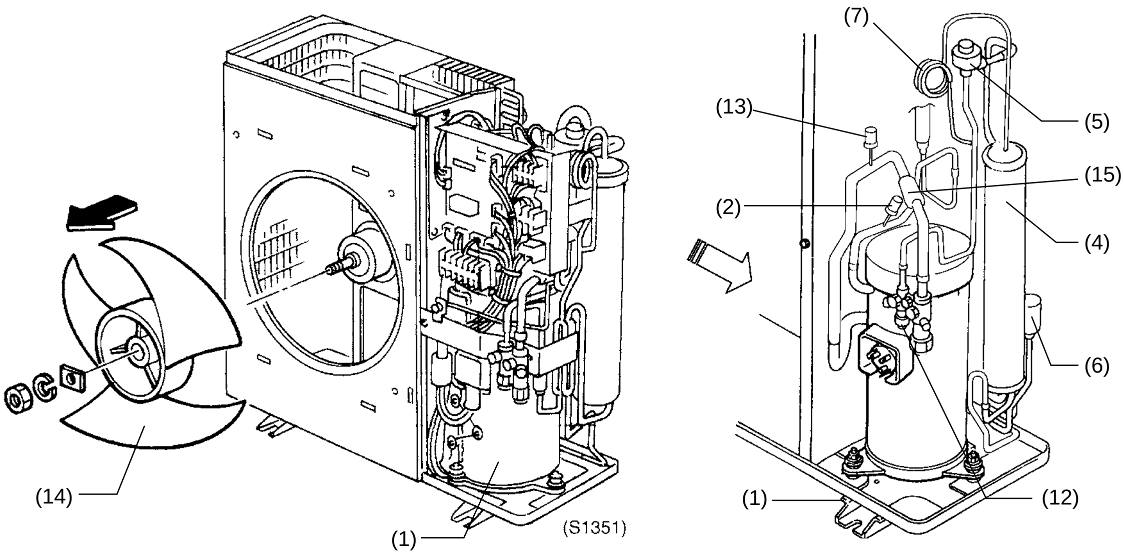


Fig.4-3 R71KU



Air conditioners have a variety of functional parts except for four components such as compressor, condenser, expansion valve, and evaporator. It is certainly practical for you to understand the structure and functions of the parts when you do many different types of services.

This Chapter explains on the basis of actual piping circuit diagram the structure, types, and functions of the components used in the piping. At present, the Split-type air conditioners are prevailing, among which the Daikin SkyAir Series is the most popular in the field. Therefore, a simple circuit diagram in the SkyAir Series is illustrated below.

■ Cooling only

Fig.4-4 R35~60G

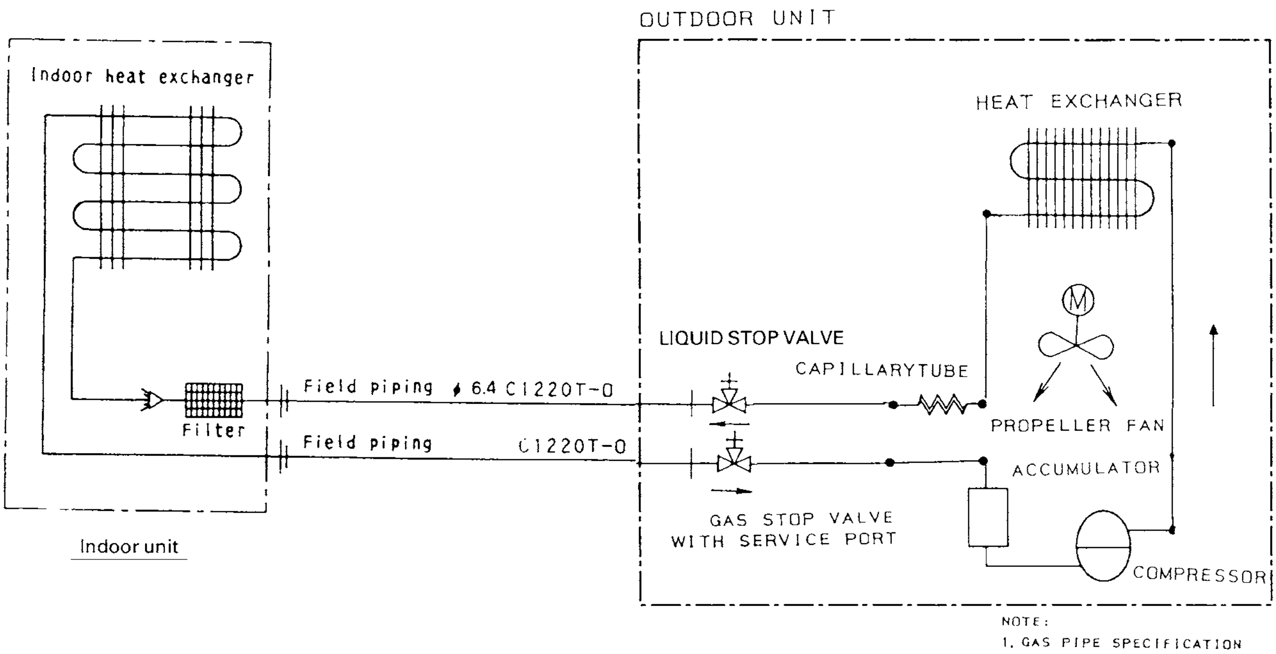
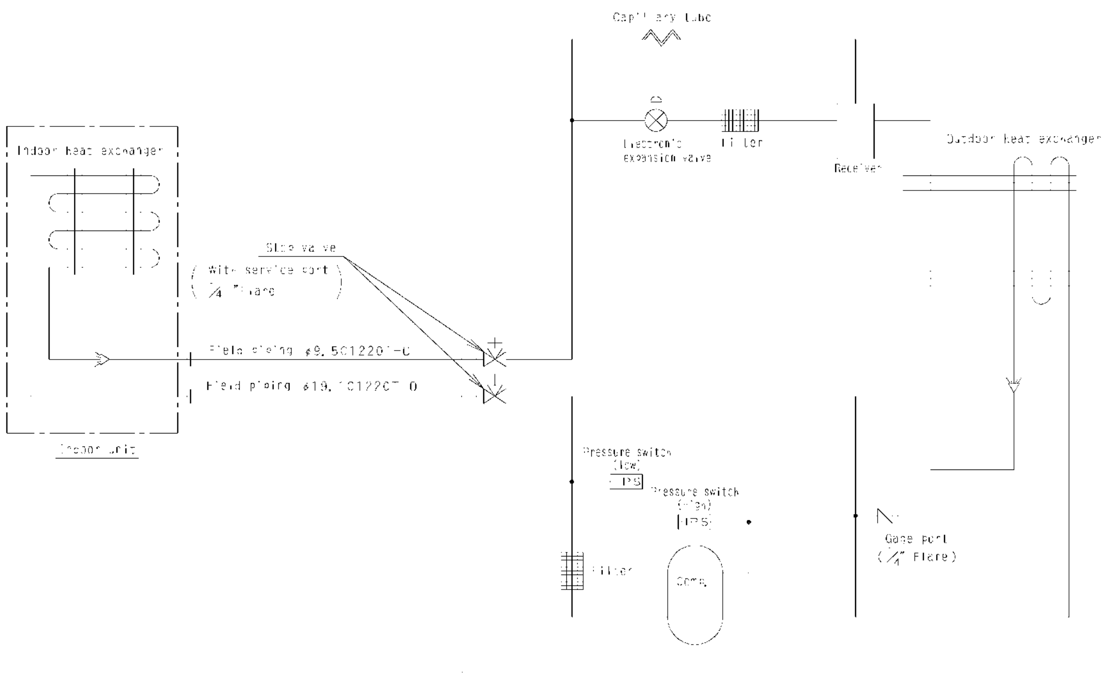


Fig.4-5 R71KU



3D039741

■ Heat pump

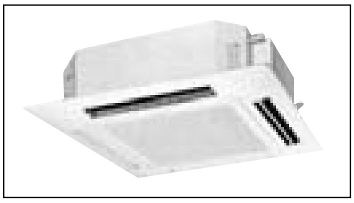


Fig.4-6 RY50GAV1A

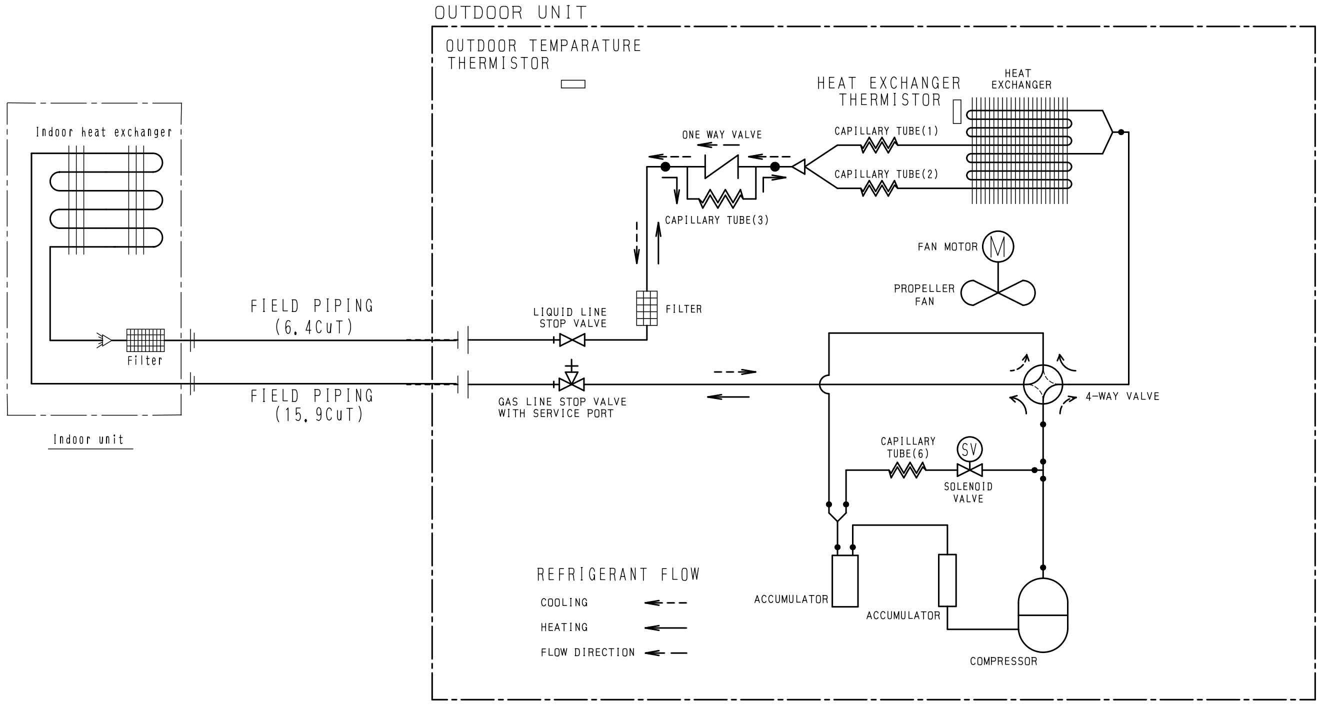


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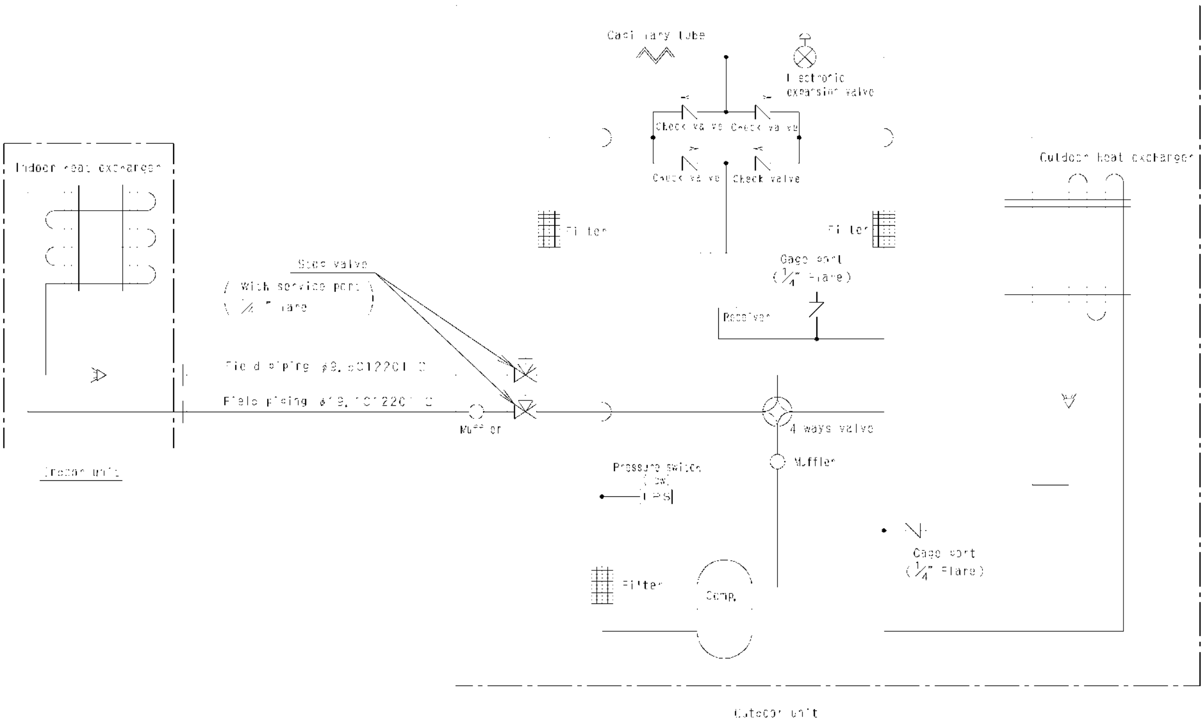
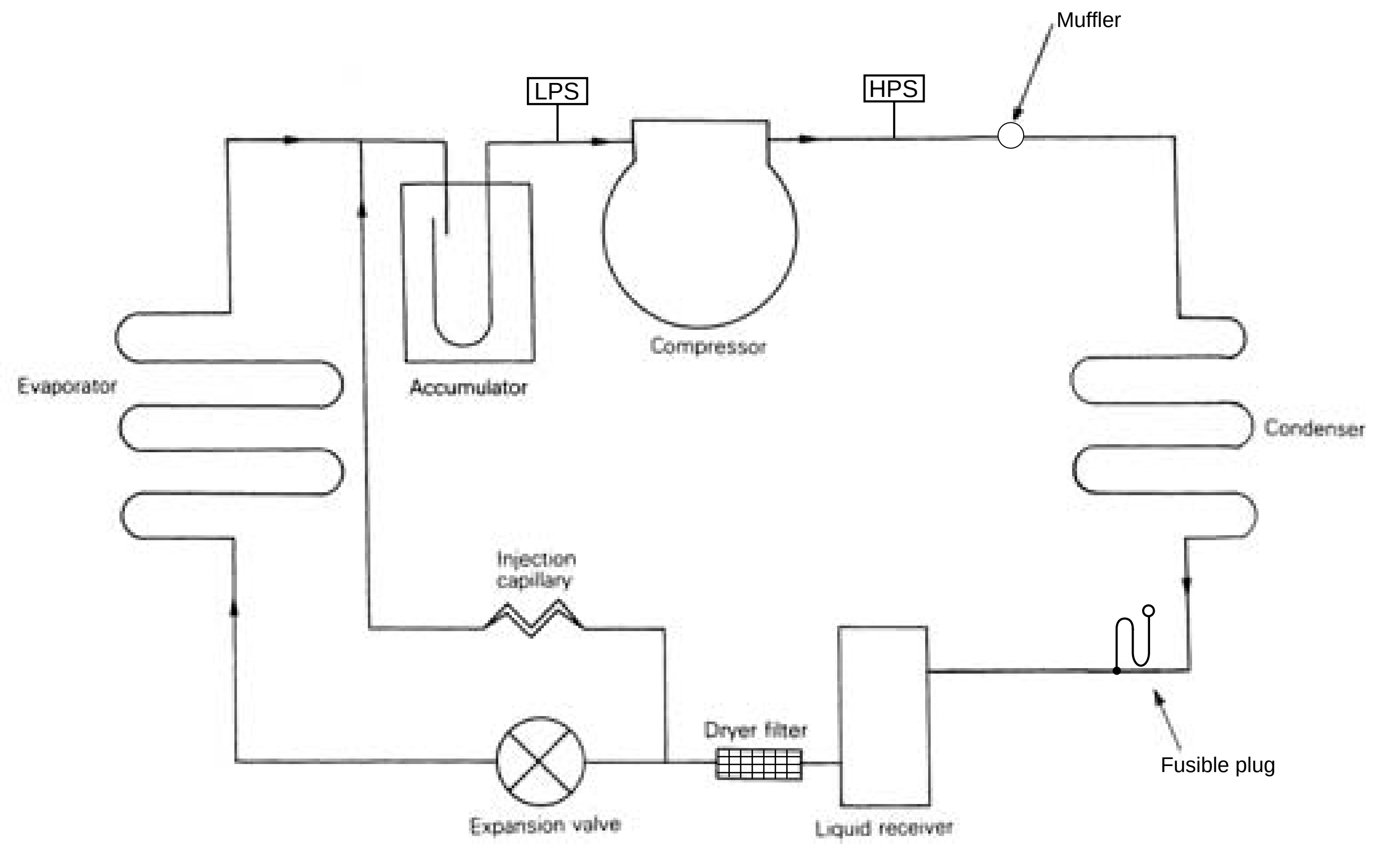
Fig.4-7 RY100KU



3D039735

Here, main components are schematically illustrated for better comprehension. In the succeeding pages, this schematic figure sometimes can be seen on the booth explaining each component or equipment. This figure effectively affects to let you notice the location of the component in relation to the other component's locations.

Fig.4-8



4.2 Main components

All of the unitally air conditioners consist of four main components, a compressor, a condenser, an evaporator and a refrigerant controller.
Firstly functions and kinds of four main components will be explained below.

4.2.1 Compressor

The compressor performs as a pump to circulate the refrigerant in the refrigeration circuit. The low temperature and low pressure refrigerant vapor evaporates through the evaporator and is compressed to the pressure at which the refrigerant vapor can be easily liquefied in the condenser.

(1) Classifications by compression methods

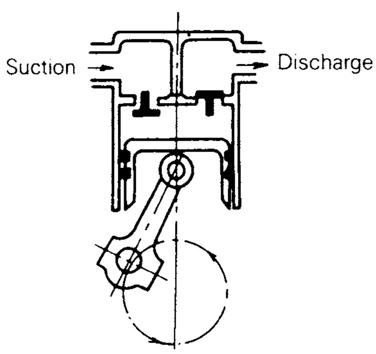
Compressors are largely classified by compression methods;i.e., volumetric compression and centrifugal compression, and when these types are classified furthermore, they are as shown below.

- Volumetric compression
  - Reciprocating type
    - Single stage compression
    - Two stage compression
  - Rotary type
    - Rolling piston
    - Sliding vane
    - Swing
  - Scroll type
  - Screw type
- Centrifugal compression
  - Single stage compression
  - Multi-stage compression

1) Reciprocating compressors

The reciprocating compressors consist of cylinders, pistons and valves.
Compression is performed by reciprocating movements of the piston in the cylinder. The valve controls gas in and out of the cylinder. (See Fig.4-9)

Fig.4-9 Reciprocating type



2) Rotary compressors

The rotary compressors are available in two types, rolling piston and sliding vane types.
The compression theory of the rolling piston type is that the rotating piston which is also called rotor rotates in contact with the contour of the cylinder and a fixed blade compresses the refrigerant. (See Fig.4-10)
Compression method of the sliding vane type is that several blades rotate with the rotary piston in contact with the contour of the cylinder, compressing the refrigerant. (See Fig.4-11)
Compared with the reciprocating compressors, the rotary compressors are compact, simple in construction and consist of fewer parts. In addition, the rotary compressors excell in coefficient of performance and efficiency.
However, accuracy and antiabrasion are required for machining the contacting parts. For the time being, the rolling piston type has been a major type of rotary, but in recent year, new rotary of swing type has been developed and gradually expands the share of rotary comps.

Fig.4-10 Rolling piston type

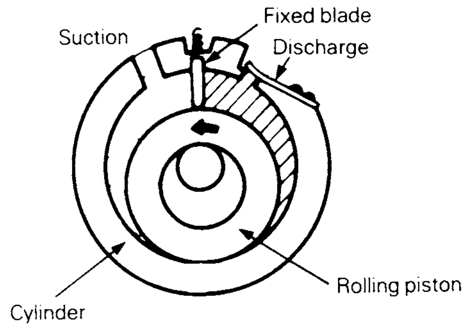


Fig.4-11 Sliding vane type

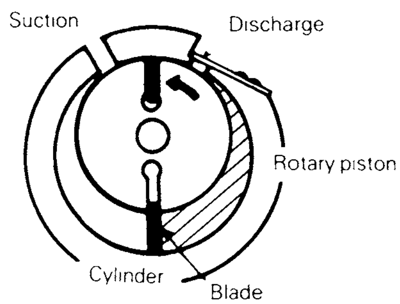
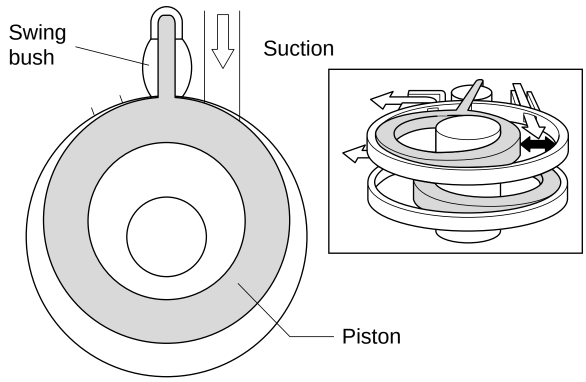
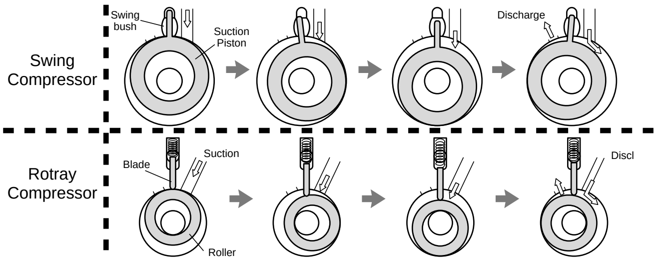


Fig.4-12 Swing type



The Swing Rotary Compressor has an integrated blade and piston, thus producing no blowing-through loss from high pressure to low pressure and standing the high-pressure compression ratio. (See Fig. 4-12, 4-13)

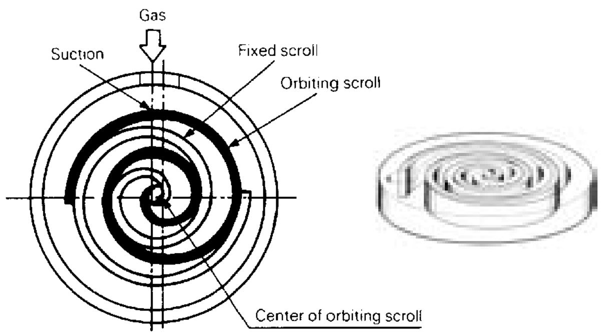
Fig.4-13



3) Scroll compressors

As shown in Fig.4-14, the scroll compressors consist of two scrolls, and one is fixed and the other revolves in orbit. The gaseous refrigerant is drawn in from the circumference of the scrolls and compressed in the space reduced by the surrounded scrolls and discharged from the discharge port at the center.

Fig.4-14 Scroll type

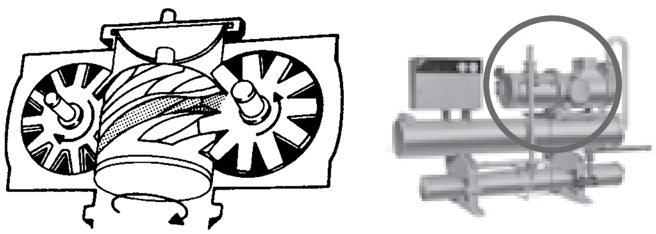


4) Single screw compressors

The screw compressors consist of rotors having male and female gears and compresses the refrigerant by engaging one screw rotor and two gate rotors. Like the reciprocating compressors, the compression process of the screw compressors has three steps, suction, compression and discharge.

To minimize gas flow resistance, the gas is sucked toward the shaft direction, compressed and discharged.(See Fig. 4-15)

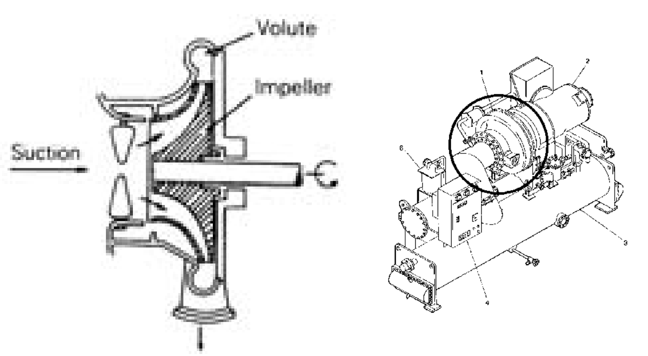
Fig.4-15 Screw type



5) Centrifugal compressors

The centrifugal compressors consist of impeller and volute. The impeller is rotated approximately at 10,000rpm. Such centrifugal force changes the gaseous refrigerant into speed energy, which is converted into pressure energy for compression. (See Fig. 4-16)

Fig.4-16 Centrifugal type



(2) Classifications of compressors by structure

When the compressors are classified by structure, they are as shown below.

- Open type
  - • Single stage
  - • Two stage
- Hermetic type
  - • Semi-hermetic type
    - • Single stage
    - • Two stage
  - • Hermetic type

1) Open type compressors (Fig.4-17)

The open type compressors are driven by external power by means of V belts or direct connection couplings. Therefore, one end of the drive shaft sticks out of the compressor housing. To prevent gas from leaking through gap between the compressor housing and the drive shaft, specific part called shaft seal is equipped.
Furthermore, they are easily dismantled for inspection and services, and worn or damaged parts can be replaced easily. The are mainly used for low temperature applications.

Fig.4-17 Open type

2) Semi-hermetic type compressors (Fig.4-18)

The compressor and the motor are connected and housed in the same housing. The cover of each part is tightened by bolts. No shaft seal is required, because no gas leakage occurs.

Fig.4-18 Semi-hermetic type

Reciprocating

Screw

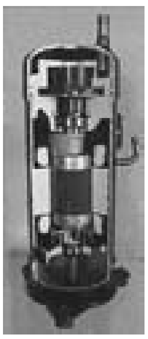
3) Hermetic type compressors (Fig.4-19)

The compressor and the motor are connected and housed in the same housing, which is hermetically sealed by welding. Compared with the semi-hermetic compressors, the hermetic type compressors excell in air tightness. Comparatively small size reciprocating compressors and rotary compressors are in most cases of the hermetic type. In this type, however, if the compressors are out of order, it is necessary to replace whole compressors.

Fig.4-19 Hermetic type

Reciprocating

Scroll



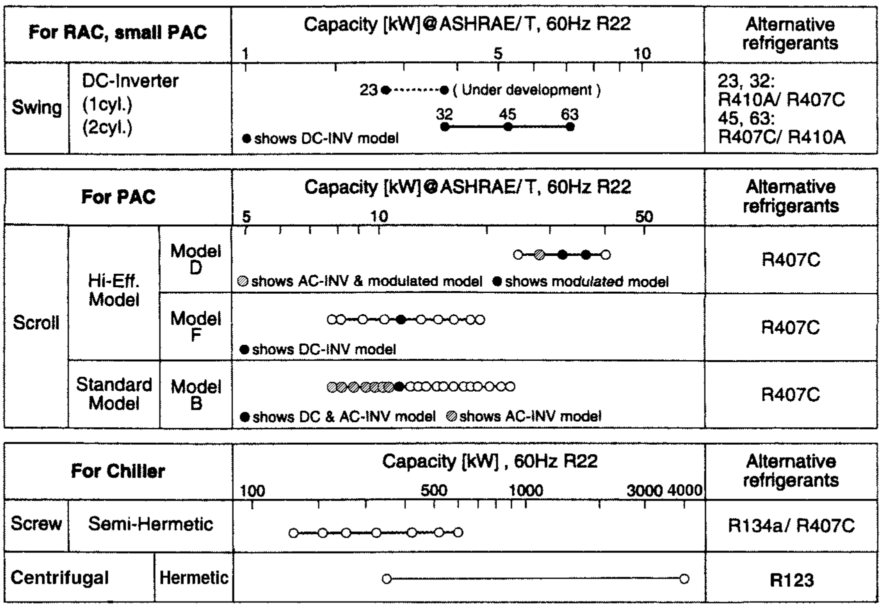
4) Compound type compressors

The compound type compressors have the high pressure stage and the low pressure stage in a single compressor. Compared with the two stage compression method in which separate compressors are used for high and low pressure stages respectively, they are simple in structure, light, and require small installation area and low initial costs.
They are used for low temperature applications.

Table 4-1 Reciprocating compressors

	Advantages	Disadvantages
Open type	(1) Dismantling and inspection are possible. (2) Revolving speed is variable. (3) Engine drive is possible.	(1) Dimensions of units are larger than that of other compressors having the same horsepower. (2) Shaft seal is necessary and there is possibility of gas leakage.
Semi-hermetic type	(1) Dismantling and inspection are possible. (2) No gas leaks from shaft seal (3) Moving parts are not exposed. (4) Running noise is smaller than that of the open type.	(1) Revolving speed is fixed (2) Motor is free from any moisture or dust.
Hermetic type	(1) Compact and light (2) No gas leaks. (3) Moving parts are not exposed. (4) Running noise is low.	(1) Dismantling is impossible when damaged. A whole compressor should be replaced. (2) Motor is free from moisture or dust.

Table 4-2 Lineup of Daikin Compressors



4.2.2 Condenser

The condenser functions to change the state of the refrigerant discharged by the compressor from gas to liquid.

Since the refrigerant vapor discharged by the compressor is high in temperature and pressure, the refrigerant can be condensed easily by outdoor air or water. The heat gained through the evaporator is discharged into outdoors or water by the condenser.

The heat discharged by the condenser is larger than evaporation heat, since the compression heat in the compressor is added to it.

The condenser can be classified into two types according to its cooling method; i.e. water cooled type and air cooled type. Each type is further classified into two types.

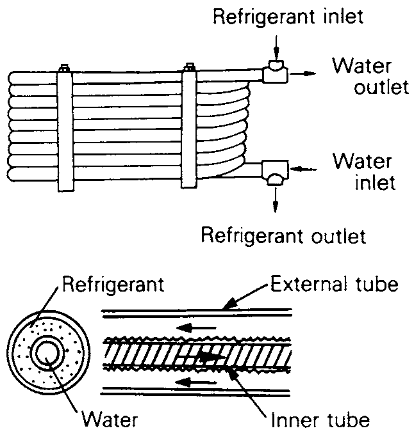
- Water cooled
  - Double tube type................ (1)
  - Shell and tube type .... (2)
- Air cooled
  - Cross fin coil type .... (3)
  - Wind fin type .... (4)

(1) Double tube type (Tube-within-a-tube type)

This type is adopted in smaller capacity models of water cooled packaged water chillers and air conditioners. Water flows through the inner tube and the refrigerant flows in the opposite direction between the inner and outer tubes.

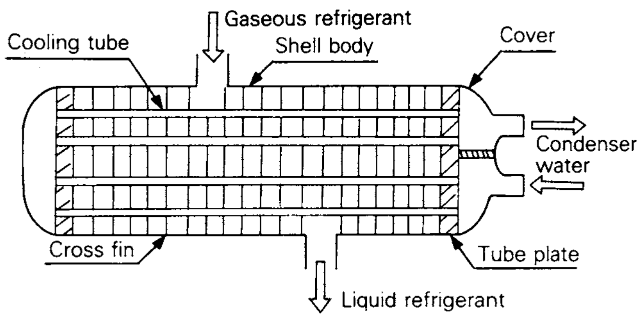
The external surface of the inner tube is formed with a spiral groove flute to increase heat exchange coefficient.

Fig.4-20 Double tube type



(2) Shell and tube type
This type is adopted in larger capacity models of water cooled packaged water chillers and air conditioners. The condensers are composed of many copper cooling tubes with aluminium cross fins around them, which are fixed to the end plates at both ends by enlarging the tube ends and encased neatly in a steel body as shown on the right.
Condenser water is circulated in the tubes so that the refrigerant vapor can be condensed on the surface of the cooling tubes with cross fins.

Fig.4-21 Shell and tube type



(3) Cross fin coil type
This type is adopted in nearly all sizes of air cooled air conditioners and water chillers.
The cross fin coil type condenser consists of U shaped copper tubes inserted in aluminum fins to have larger heat transferring area. Some recent condensers have waffle louver fins or multi-slit fins and Hi-X tubes, the internal surface of which is modified by serration. They increase the heat exchange coefficient and reduce the size of the unit.

Fig.4-22 Cross fin coil type

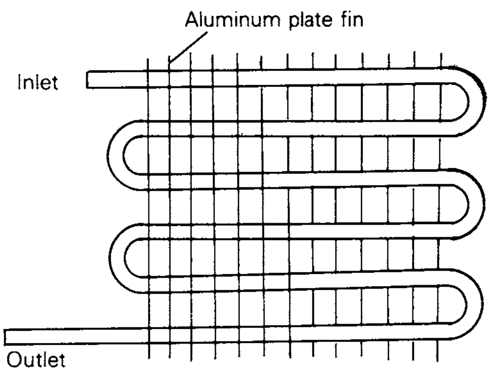


Figure on the right shows an example of this type of coil designed to suit with outdoor units of cooling only room air conditioners, which is usually used in such double-coil configuration as shown in the figure. The fin pattern has been improved to upgrade the thermal efficiency.

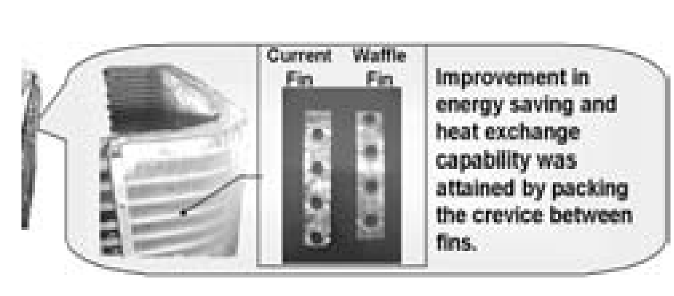
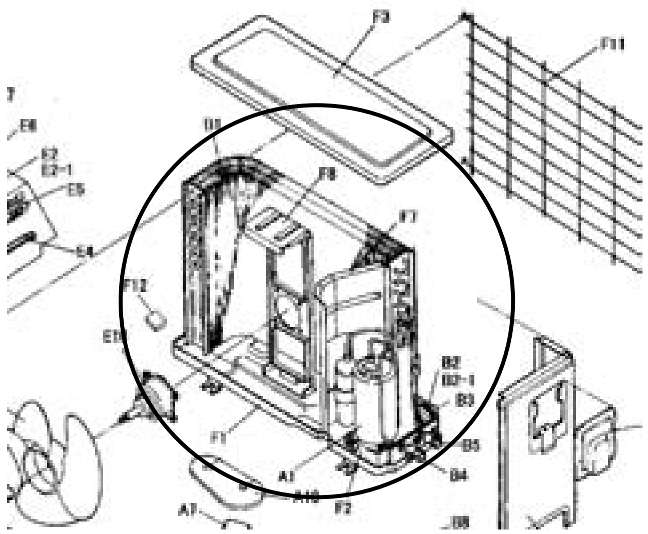
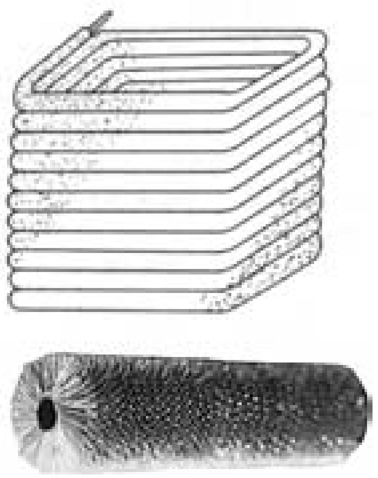


Fig.4-23



(4) Wind fin type
This type is adopted in the Sky Air Series(air cooled split system air conditioners). (R4L, 5L)
The spinelike aluminum fins are wound around a copper tube and they shape like rectangular spiral.

Fig.4-24 Wind fin type



4.2.3 Evaporator
The evaporator cools the air or water by evaporation of the refrigerant. The liquid refrigerant which is released in pressure

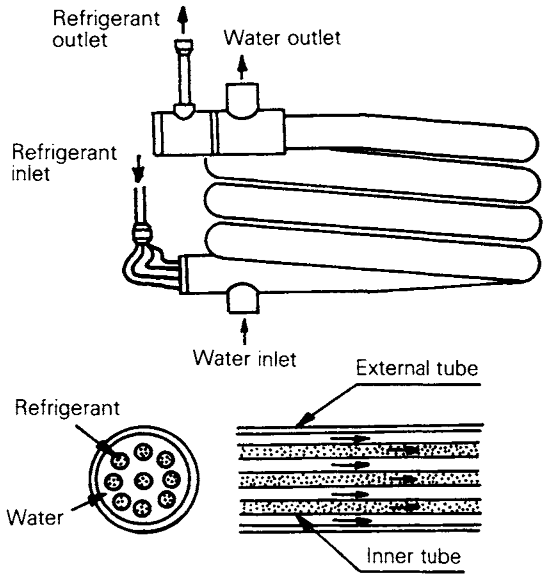
through the expansion valve (or the capillary tube) evaporates in the evaporator, taking heat from the air or water while passing through the evaporator. The refrigerant becomes low temperature and low pressure vapor.
Both the evaporator and the condenser are called"heat exchanger".
The evaporator can be classified into two types according to its cooling methods, water cooling type and air cooling type. Water cooling type is further classified into several types.

- Water cooling
  - Multiple tube-within-a-tube type ....(1)
  - Shell and tube type
    - Dry expansion shell and tube type ....(2)
    - Flood shell and tube type ....(3)
  - Plate type.......................................(4)
- Air cooling — Cross fin coil type............................(5)

(1) Multiple tube-within-a-tube-type

This type is adopted in smaller capacity models of water chillers. Several tubes are inserted within a single tube.
The refrigerant flows through the inner tubes and water flows outside the inner tubes in the opposite direction. (See Fig.4-25)

Fig.4-25 Multiple tube-within-a-tube type



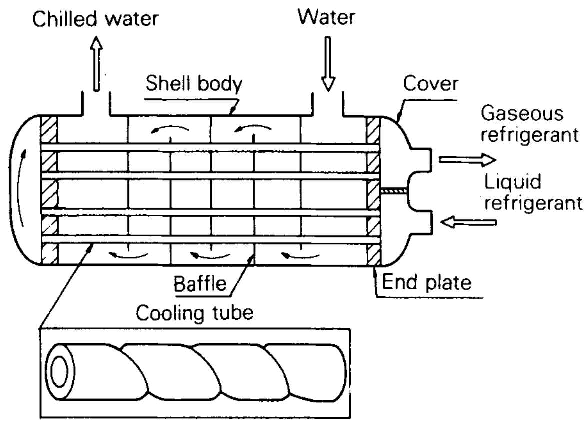
(2) Dry expansion shell and tube type

The following types are adopted in middle and larger capacity models of water chillers.

(1) Dry expansion shell and corrugated tube type

Corrugated copper cooling tubes are fixed to the end plates at both ends by enlarging the tube ends, and are neatly encased in a steel shell body as shown in Fig.4-26.
The liquid refrigerant is circulated in the cooling tubes, taking heat from water which flows in contact with the cooling tubes, and evaporates.

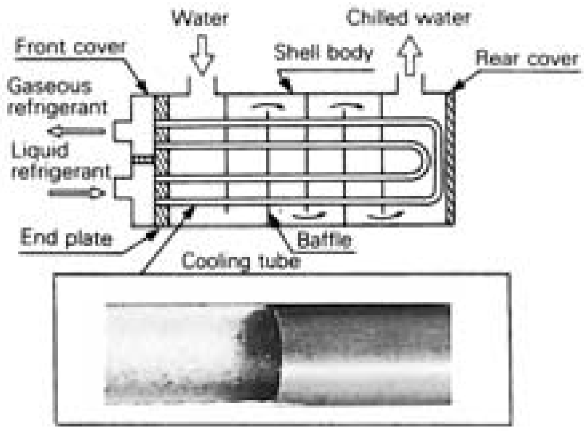
Fig.4-26 Dry expansion shell and corrugated tube type



(2) Dry expansion shell and Hi-X tube type

The dry expansion shell and Hi-X tube type is almost the same as the dry expansion shell and corrugated tube type except that Hi-X copper cooling tubes are used instead of corrugated copper cooling tubes.

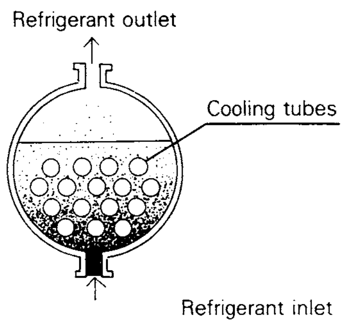
Fig.4-27 Dry expansion shell and Hi-X tube type



(3) Flooded shell and tube type

This type is adopted in centrifugal water chillers.
In contrast with the dry expansion shell and tube type condenser, water flows through the tubes and the refrigerant flows outside the tube.

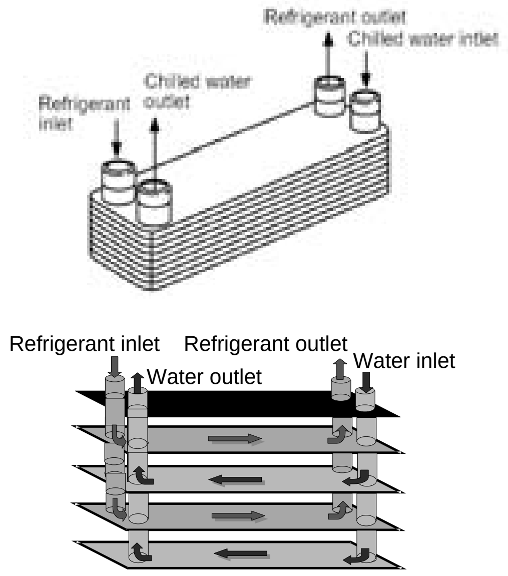
Fig.4-28 Flooded shell and tube type



(4) Plate type

This plate type of condenser is used for small-sized chillers, which have a compact structure and a high level of heat exchanging efficiency compared to other water-cooled-type heat exchangers. It consists of numbers of hollow aluminum plates, through which water and refrigerant flows alternately.

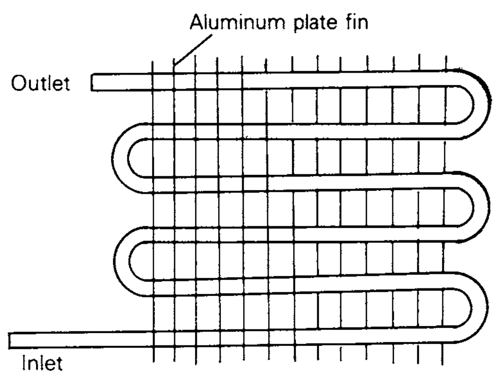
Fig.4-29 Plate type



(5) Cross fin coil type

This type is adopted in air conditioners of nearly all sizes.
The cross fin coil type evaporator consists of U shaped copper tubes inserted in aluminium fins to have large heat transferring area. Some recent evaporators have waffle louver fins or multi-slit fins and Hi-X tubes, the internal surface of which is modified by serration.
They increase the heat exchange coefficient and reduce the size of unit.

Fig.4-30 Cross fin coil type



The cross fin coil type of evaporator has a wide variety of applications corresponding to the shape of indoor unit. Fig. 4-31 shows a coil incorporated in the ceiling recessed cassette type of indoor unit, which is configured in the manner to enclose the turbo fan.

Fig.4-31

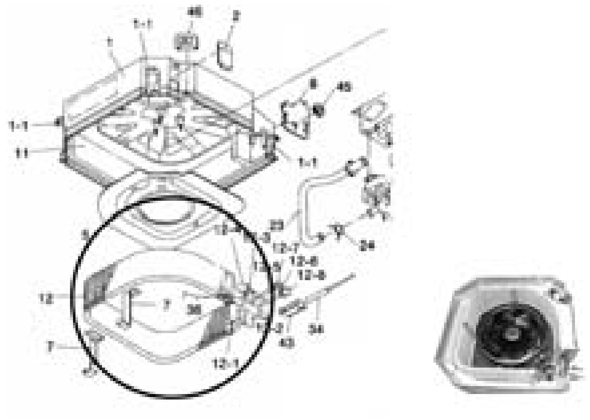
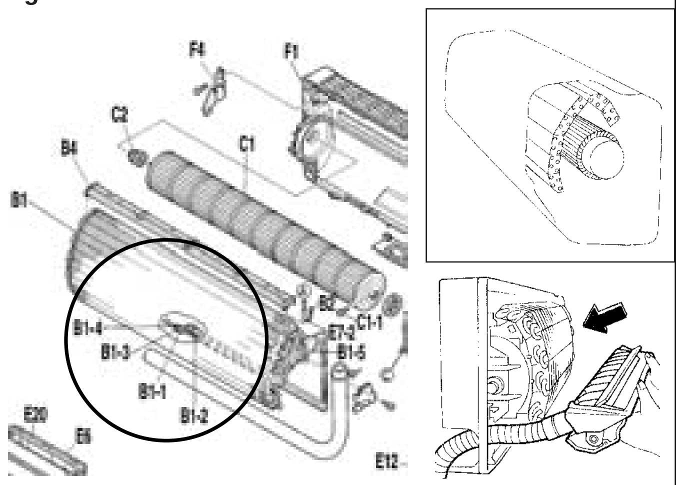


Figure 4-32 shows a cross fin coil incorporated in the wall-mounted type of indoor unit. It is in the shape of segment and configured in the manner to enclose the cross flow fan.

Fig.4-32

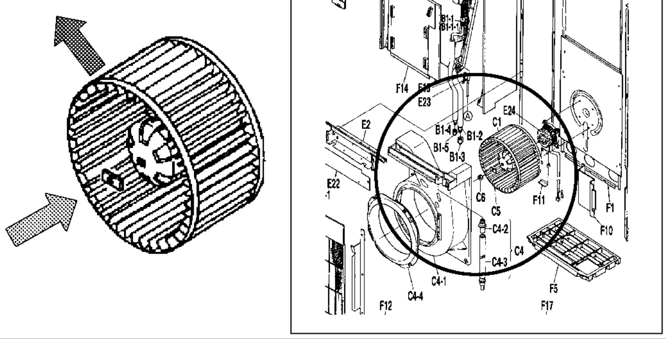


4.2.4 Fan

(1) Sirocco fans

Indoor units make most use of the multi-blade fans, which offers a large static pressure. Therefore, this type of fans is suited for units with high airflow resistance or of duct connection type. Air is sucked in from one side and discharges in the rotating direction. The fans are completely enclosed in the fan housing for use.

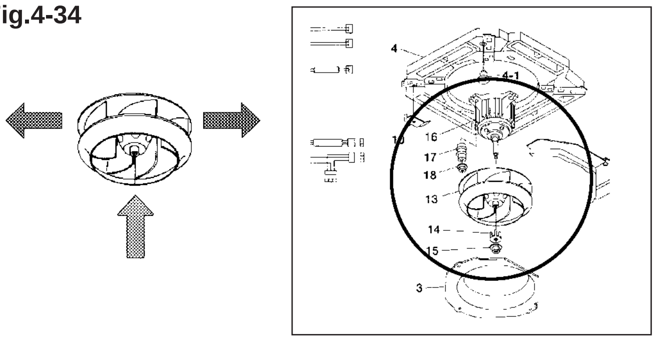
Fig.4-33



(2) Turbo fans

The turbo fans are used for the ceiling recessed cassette type of multi-flow units, which suck air from the bottom and discharge to the periphery. This type of fans requires no particular housing and is configured with heat exchanger coil around.

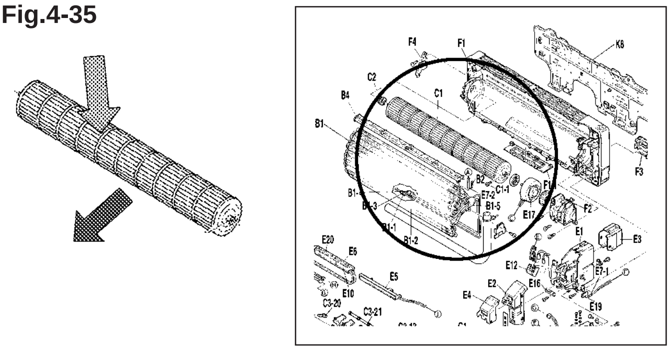
Fig.4-34



(3) Cross flow fans

The cross flow fans are dedicated for wall-mounted type of indoor units and have a long, narrow structure. Air is sucked in from one side with higher resistance and discharged to the other side with lower resistance. This type of fans cannot provide a large static pressure, thus disabling the duct connection.

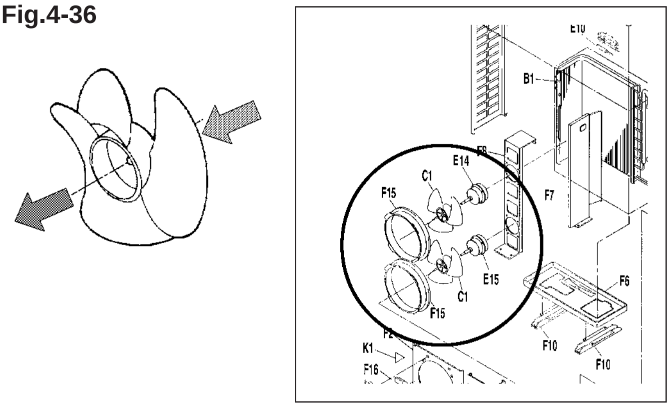
Fig.4-35



(4) Propeller fans

The propeller fans are in the most common use for outdoor units and called axial flow fans as well. Air is sucked in and discharged in the direction of the rotary shaft. This type of fans provide a small static pressure, while enables the connection of simple ducts when outdoor units are installed in the balcony.

Fig.4-36



4.2.5 Metering devices

The functions of the metering devices are to regulate the flow of high-pressure liquid refrigerant from the liquid line into the evaporator and to maintain a pressure differential between the high and low pressure sides of the system in order to permit the refrigerant to vaporize under the desired low pressure in the evaporator and at the same time to be condensed at a high pressure in the condenser.
There are six basic types of refrigerant flow controls as shown below. Almost all recent room air conditioners and packaged air conditioners adopt the capillary tube or the thermostatic expansion valve. So these types are explained below.

- Hand expansion valve
- Automatic expansion valve
- Thermostatic expansion valve
- Capillary tube
- Low pressure float
- High pressure float

(1) Capillary tube

The simplest one of all metering devices is the capillary tube, which is shown in Fig.4-37. This is nothing more than a deliberate restriction in the liquid line. Because of its small tube size, it creates a considerable pressure drop. The diameter and length of the capillary tube are determined experimentally by capacity of the refrigeration unit, operation conditions and refrigerant charged volume.
This type of the metering device is generally used only in small equipment with fairly constant loads, such as room air conditioners and small sized packaged air conditioners.
The advantages and disadvantages of the capillary tube are as follows:

1. Low cost compared with expansion valve
2. Simple structure...difficult to be damaged
3. When the compressor stops, high and low pressure are equalized soon.

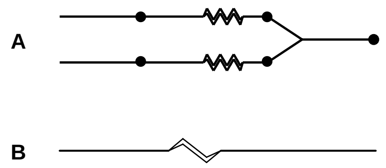
Disadvantages
1. Difficult to determine the length and the diameter
2. Difficult to control the refrigerant volume depending on cooling load

*The amount of refrigerant in the system must be carefully calibrated, since all of the liquid refrigerant will move into the low-side during the off-cycle as the pressure is balanced.

Fig.4-37

The capillary tube is represented in the piping circuit diagram as shown in the figures on the right. Even though the symbol A or B is sometimes used, both of the symbols are the same, and the substance itself remains unchanged due to the choice of the symbols.

Fig.4-38



(2) Thermostatic expansion valves

Whereas the operation of the automatic expansion valve is based on maintaining a constant pressure in the evaporator, the operation of the thermostatic expansion valve is based on maintaining a constant degree of suction superheat at the evaporator outlet.
There are two kinds of thermostatic expansion valves, internal equalizing type and external equalizing type.

Thermostatic expansion valves
- Internal equalizing type
- External equalizing type

Fig.4-39

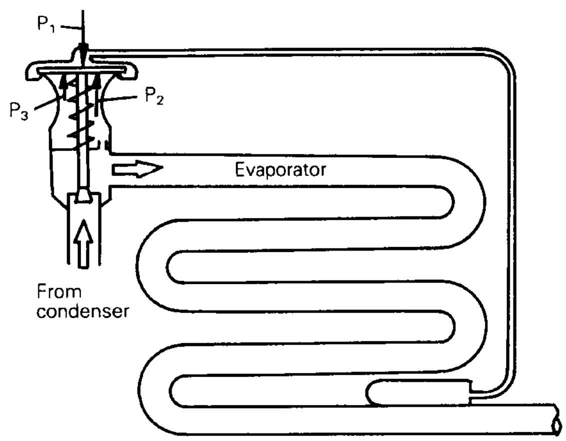
1) Internal equalizing thermostatic expansion valve

Fig.4-40 shows the structure of the internal equalizing thermostatic expansion valve.
Opening degree of the valve automatically changes according to the load fluctuations, adjusting the amount of refrigerant supplied so that neither wet compression nor superheated compression occur. Valve opening degree is determined by the state of equilibrium of the following three forces.

P_1: Force exerted upon the diaphragm by the gas pressure sealed in the sensor tube
P_2: Refrigerant evaporation pressure by the evaporator
P_3: Force of the superheat adjustment spring

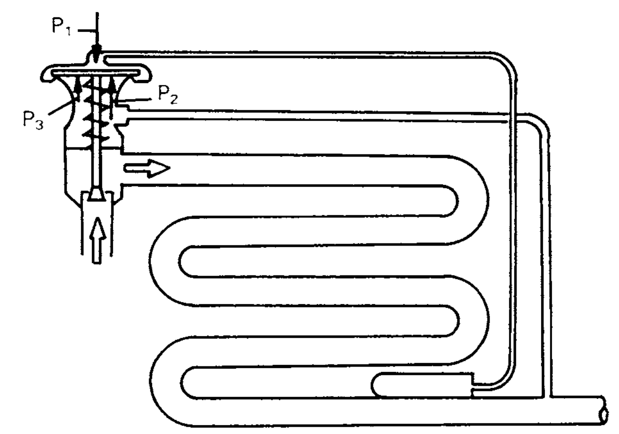
When $P_1 = P_2 + P_3$, the valve controls the refrigerant flow under stable conditions. If load increases, the feeler bulb detects such increase, the temperature within the feeler bulb rises, and $P_1 > P_2 + P_3$ condition occurs. At this time, the diaphragm is pressed downward, and the valve begins to open.
Flow rate of the refrigerant increases in order to prevent super-heated compression (capacity insufficiency). On the contrary, if load decreases, the pressure in the feeler bulb reduces, and $P_1 < P_2 + P_3$ condition occurs. The valve then closes, the flow rate of refrigerant decreases, and a degree of superheating which prevents wet compression is constantly maintained.

Fig.4-40 Internal equalizing thermostatic expansion



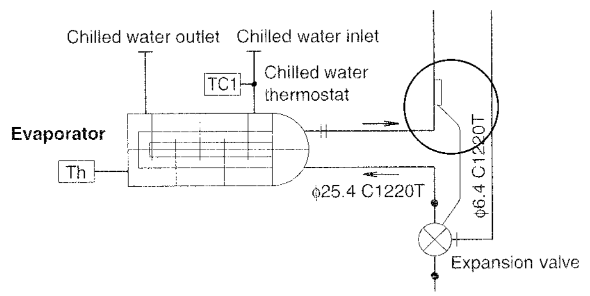
2) **External equalizing thermostatic expansion valve**
When the refrigerant passes through the evaporator, the pressure drops by a certain degree.
In case of an internal equalizing thermostatic expansion valve, if pressure drops greatly, degree of super-heat increases and super-heated compression occurs. To compensate for pressure drop in the evaporator, the external equalizing expansion valve (Fig.4-41) is used. In this valve, the internal equalizing port is eliminated and the pressure under the diaphragm is being taken from the end of the coil.

Fig.4-41 Internal equalizing thermostatic expansion valve



Thermostatic expansion valve has been substituted by electronic expansion valve in recent years, resulting in few models using it. In order to differentiate the valve in the piping circuit diagram, probing the presence of the feeler bulb as shown in the figure on the right locates the thermostatic expansion valve. (See Fig. 4-42)

Fig.4-42



4.2.6 Electronic expansion valve

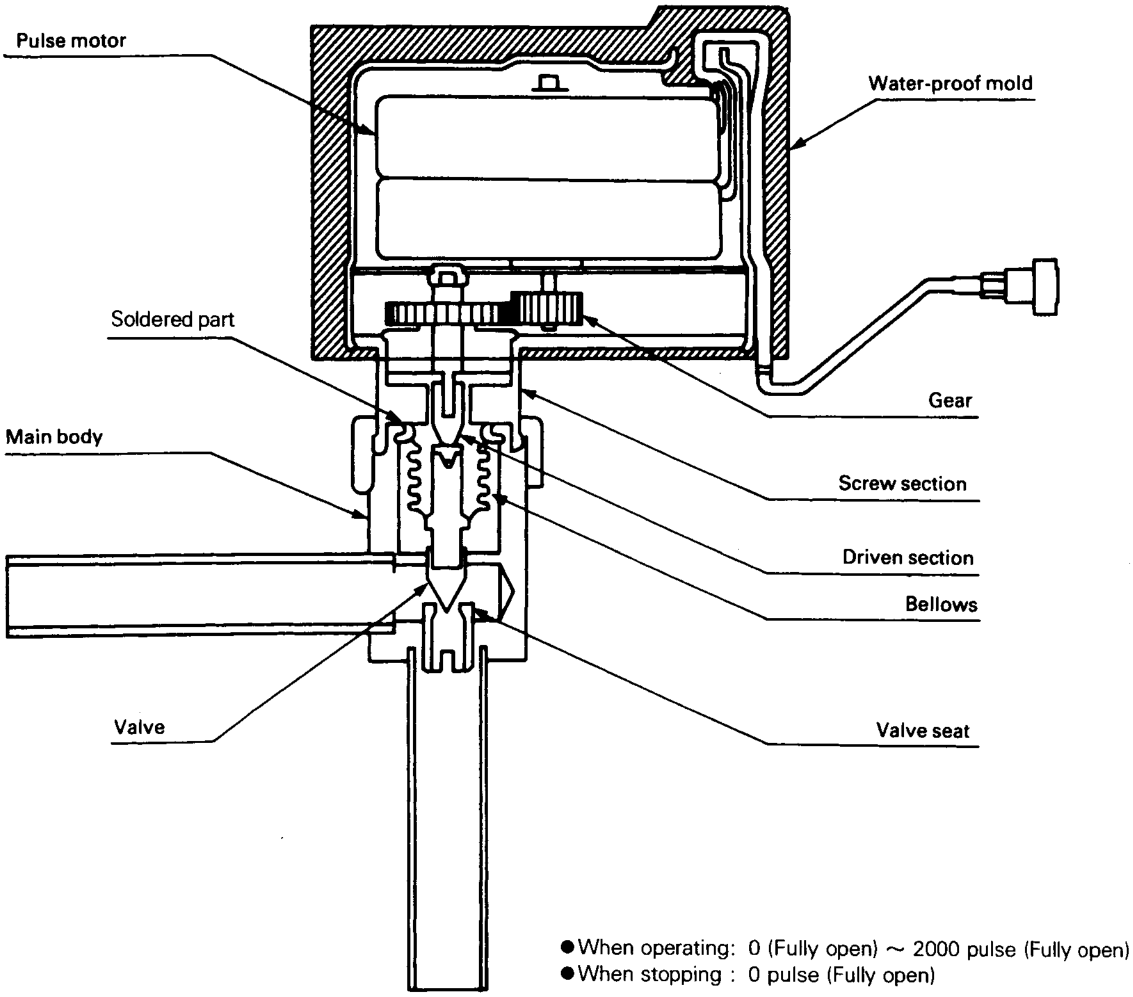
With the progress of mechanization and electronic technology, frequency in use of electronic expansion valve becomes high. This is used for various system air conditioners and especially for the finer control.
The function of electronic expansion valve is the same as that of mechanical one. It can be electrically operated using a certain software. From now on, it must be used more and more.
Both of them, EBM type linear control valves are used.

(1) Replacement of motor section

When the motor section is removed from the main body of the valve, the power source must be turned off, or the connector must be removed beforehand.

- When they are removed with the electricity is turned on, the screwdriver may jump out.

Fig.4-43



Structure of electronic expansion valve ··· its main body and motor section

(2) Disposition when electronic expansion valve will not open

In service working, when the screwdriver (portion to stop the valve)of the motor section jumps out, the repair procedure is as follows.

(3) Work Procedure

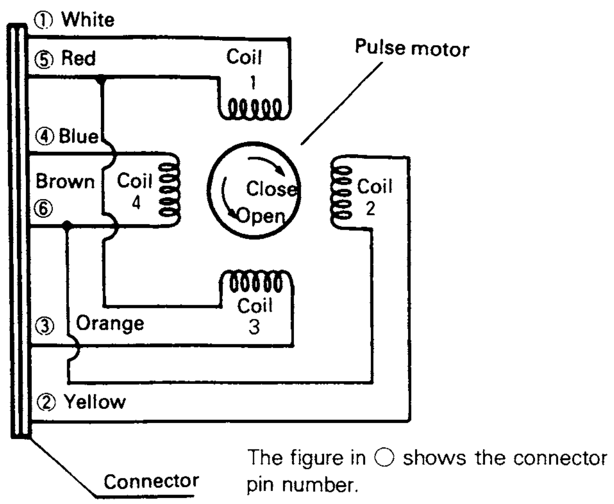
1) Turn off the power of indoor unit.
2) Pull the connector of electronic expansion valve out of the P-board.
3) Remove the motor section of electronic expansion valve from the valve-seat.
4) Replace (4) P (blue) with (2) P (yellow) connector pulled out.
5) Put the connector into the P-board.
6) Repeat several times on-off controls of the power of indoor unit — application of the theory of reversal. (At this time, confirm that the tip of screwdriver is sunk deeply than that of screw mechanism section.)
7) Turn off the power of indoor unit, and put the connectors (2) P and (4) P back in their places.
8) Attach the motor section of the electronic expansion valve to the valve section, securely.
9) Put the connector into the P-board, and repeat three times on-off controls of the power of indoor unit. (Detection of totally-enclosed state)
   With this, when the indoor unit becomes thermostat ON, the electronic expansion valve opens and returns to the normal operation.

Note: When the screwdriver is sunk too deeply with the operation (6), although the order of 2200 pulse "Close " is given from the P-board, it does not become totally-enclosed state. The operation (9) is necessary for once making the totally-enclosed state. Be sure to do this.

(4) Theory of reversal

In the electronic expansion valve, a pulse motor of two-phase exciting drive is used.

Fig.4-44



The figure mentioned above is a typification of the motor valve which is used practically.
The order of excitation at the time of valve opening is as follows.
→ mode 4 → mode 3 → mode 2 → mode 1
And that of valve closing is as follows.
→ mode 1 → mode 2 → mode 3 → mode 4
More, the mode 1~4 are shown in the following table.

Phase of ● mark:Electrical continuity

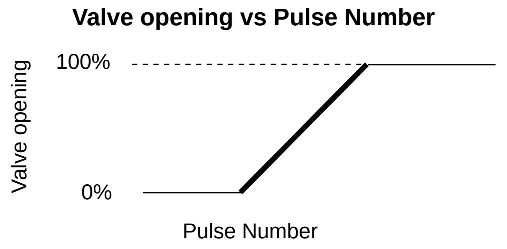
Mode \ Coil	1 (White-Red)	2 (Yellow-Brown)	3 (Orange-Red)	4 (Blue-Brown)
Mode1	●	●		
Mode2		●	●	
Mode3			●	●
Mode4	●			●

Therefore, by replacing (2) P (yellow) with (4) P (blue), the order of excitation at the time of valve opening is utterly reversed. By this way, when the order from the P-board is "Open", the motor functions by "Close" and when "Close", it functions by "Open".
This electronic expansion valve, when complete closing, becomes full opening by receiving the order of 2000 pulse "Open". Therefore, basically, the control is usually performed in the state of complete closing.
For this reason, it is necessary to start usually from the complete closing when the electrovalve is loaded, and the order of 2200 pulse "Close" is performed from the P-board.
By the use of these data, the reversal also can be performed.
(For instance, how to dispose in the case of a power is loaded as the motor section remains removed.)

(5) Relationship between valve opening degree and control pulse

The electronic expansion valve varies the opening degree in the range of 0 to 100% with the pulse signal. The number of pulses until the valve fully opens varies with the specifications of the valve.

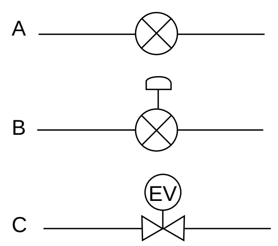
Fig.4-45



(6) Symbols in piping circuit diagram

The symbols A through C in the figure below are available, which vary with the manufacturing work or time of making the drawing.

Fig.4-46



4.3 Control devices

The four main components explained previously exhibit the sufficient effect in the refrigeration unit and air conditioner. In actual cases, however, the systems are operated under various conditions. In order to operate the system safely and effectively, the following control devices are mounted in the systems.

(1) Four-way valve

1 Outline

A four way valve is a representative one used in the heat pump type air conditioning system. This valve aims at the passage connection of the super heated refrigerant discharged from the compressor, to the indoor heat exchanger in case of heating operation, and to the outdoor heat exchanger in case of defrosting and cooling operation.

2 Structure and operating principle

This section discusses the structural drawing of the four way change-over valve. They are, a four way solenoid valve which operates as a pilot by electrical on-off signals, and the main body(slide valve)which operates by the pressure difference obtained with this pilot operation. The four way valve is made up of these two valves.

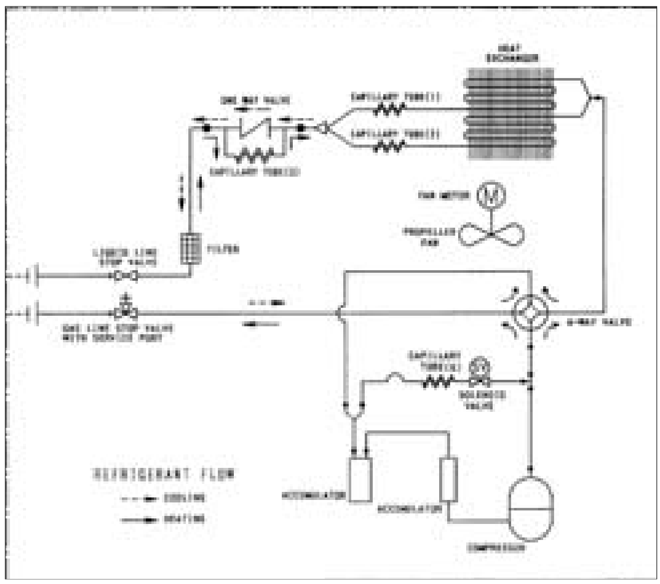
1) In case of cooling and constituting defrosting passage (solenoid valve: off-time)

The pilot (1) and (2) are connected, and high pressure gas is discharged from the compressor to enter Room (5). On the other hand, the pressure of Room (6) which passes through (3) and (4) already connected, is pulled into the compressor to become low pressure. At this time, pressure difference between high-pressure Room (5) and low-pressure Room (6) is produced. Owing to this pressure difference, the piston moves to the left and the slide valve connected together moves, too. That is the flow circuit of refrigerant mentioned as follows.

Compressor → Four way valve D → C → Outdoor heat exchanger → Indoor heat exchanger → Four way valve E → S → Compressor

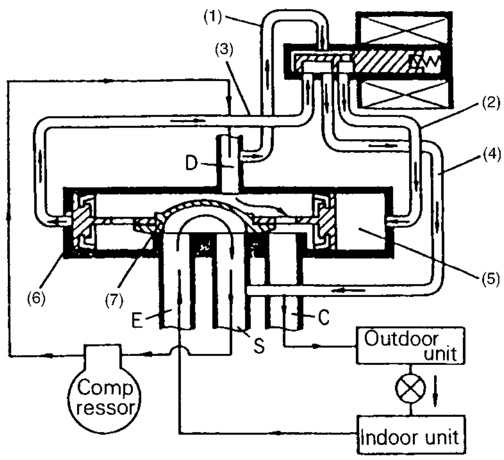
Fig.4-47

OUTDOOR UNIT



3D004866

Fig.4-48

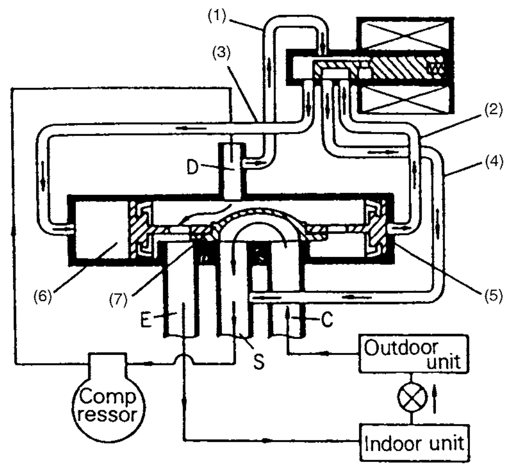


Off-time constituting of refrigerant passage

2) In case of constituting heating passage (Solenoid valve: on-time)

The pilot (1) and (3) are connected, and high pressure gas is discharged from the compressor to enter Room (6). On the other hand, the pressure of Room (5) which passes through (2) and (4) already connected, is pulled into the compressor to become low pressure, thus the slide valve functions in reverse of cooling time and the flow circuit of refrigerant in the heating is constituted.
(There is constitution of refrigerant passage at off-time heating or on-time cooling, too.)

Fig.4-49

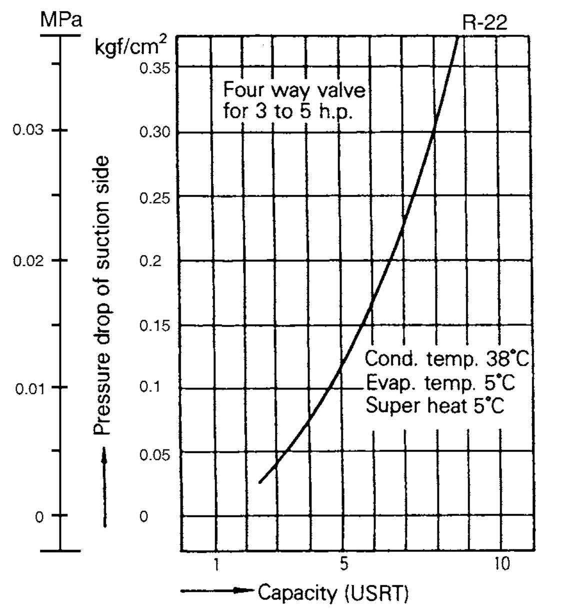


On-time constituting of refrigerant passage

3 Function and specification

1) This is a circuit changing valve which functions by electric signal, and there is no middle position, therefore the direction changing by fully open is possible.
2) This is generally used in the range of +10% to -15% of the constant passage voltage AC 100V or 200V.
3) Function pressure difference means the pressure difference between the high pressure of the suction side of the compressor. The function pressure difference is expressed by the maximum and the minimum.
4) Distinction of the size:It is necessary to choose the size which conforms to the to the system capacity to ensure the normal function by (1) to (3) in the standard value. Generally, a manufacturer's indicated conditions (pressure drop of the low pressure circuit, the capacity at the condensation temperature or at the evaporation temperature) are mentioned on the catalog. Therefore, more than the minimum requirement must be secured.
5) Test pressure: Generally, the maximum pressure which can be used is 3.0 MPa (30kg/cm^2) abs and airtight test pressure is 3.6 MPa (36kgf/cm^2) abs or so.
6) Fluid temperature: This limit is -20˚C to +120˚C or so, so that the fluid sufficiently withstand the winter evaporation temperature or the summer discharging gas temperature.

Fig.4-50



Tendency of capacity & pressure drop

4 Caution on handing

1) Installation position

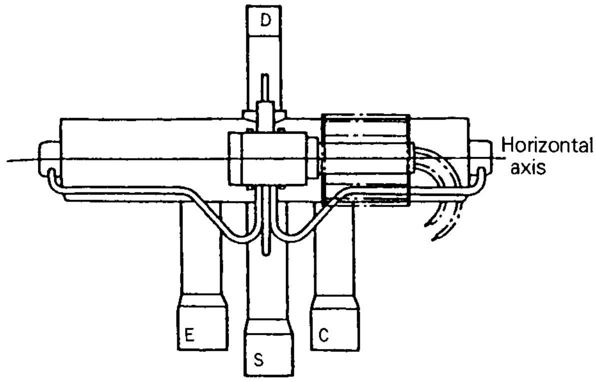
In the piping, refrigerating machine oil or the other flows besides the refrigerant. For this reason, it is necessary to be careful so that these substances should not exert bad influences upon the pilot solenoid valve or the main body. More, there is a case where the installation position is structurally limited. Be careful, please.

The axis of the main body should be installed horizontally, and the axis of the solenoid valve section should be set above the axis of the main body.

2) Heat-resistance temperature at the time of brazing

It is necessary to follow the heat-resistance temperature indicated by the manufacturer to prevent the carbonization of the oil in the main body and the heat influence. As a means, the main body must be covered by moist cloth and the temperature must be secured not exceeding +120˚C.

Fig.4-51



Installation position

(2) Liquid receiver

The liquid receiver is installed between the condenser and the metering device and temporarily holds the refrigerant which has been liquefied by the condenser before being sent to the expansion valve. As a result, only the refrigerant completely liquefied can be supplied to the metering device. The liquid receiver is also used as a container in which surplus refrigerant is stored since amount of the refrigerant circulated differs with the following conditions.

- Length of the connection piping between the condensing (outdoor unit) and the fan coil (indoor) unit.
- Changes in operating conditions

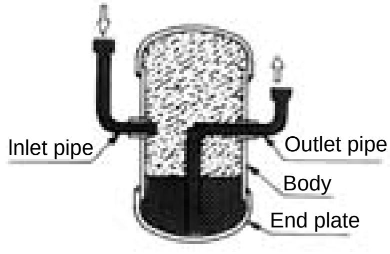
Note:

The receiver must not be used in the capillary tube system, because during off-cycle, liquid flows to the evaporator through the capillary tube and when the compressor starts again, there is a fear of liquid compression.

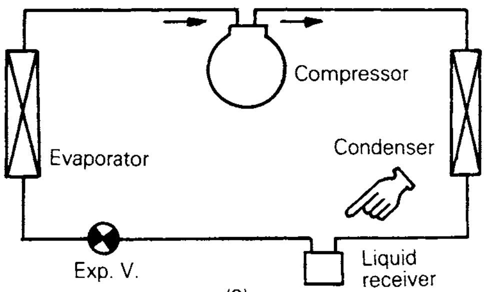
The configuration as shown in the figure on the right, which frequently appears in the piping circuit diagram, is a circuit used for liquid sealing prevention, which bypasses high-pressure gas through the direct receipt of resistance with the capillary from the liquid receiver. This circuit unites the function of fusible plug with pressure equalization at the time of stopping the operation.

Fig.4-52

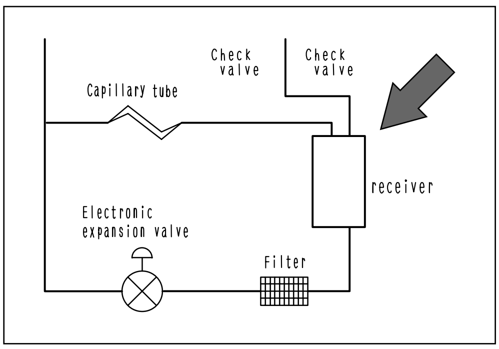
(1)



(2)



(3)



(3) Dryer filter (Filter)

The dryer filter removes moisture and minuite particles of foreign objects from the refrigerant during operation. It is a copper cylinder containing desiccating agent and is installed between the condenser and the metering device.
Moistre contained in the refrigerant causes the following troubles.

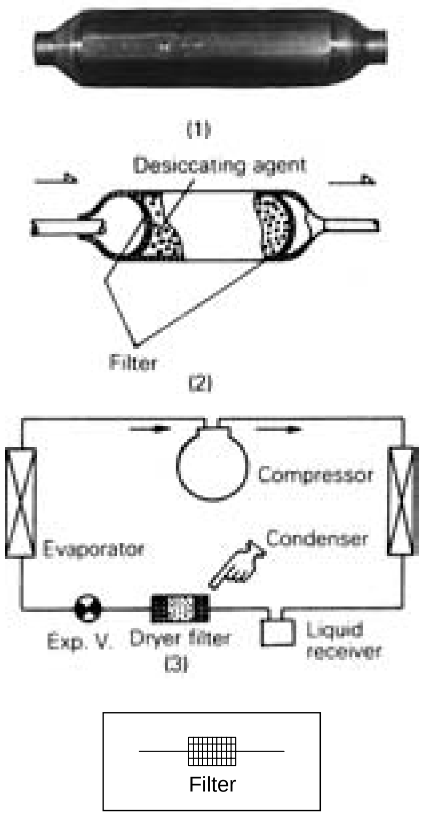
1. The expansion valve or capillary tube is stopped up with ice.
2. Hydrochloric acid is created, which corrodes metals.
3. Copper plating takes place.

As desiccating agent, Molecularseeve is used, because its absorption capacity does not decrease by high temperature or low partial pressure.
Molecularseeve is reclaimable by heating it from 150˚C to 300˚C.

Filter

Even though dryer filter stuffed with drying agent was previously used, since recently broken mesh of filter causes the drying agent to move through the circuit, thus resulting in clogging of narrow parts such as expansion valve. Therefore, the filters are only used in many cases.

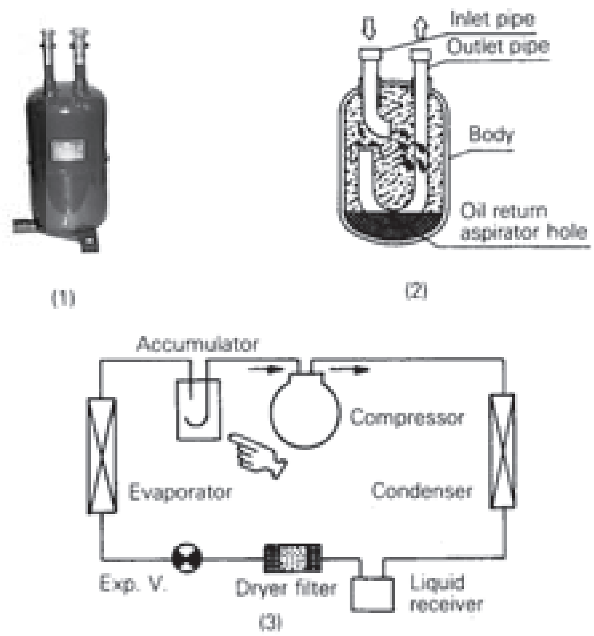
Fig.4-53



(4) Accumulator

The accumulator is installed between the evaporator and the compressor and functions to prevent the liquid refrigerant from entering the compressor.
The accumulator contains the liquid refrigerant and returns only the gaseous refrigerant to the compressor.
The oil admixed in the liquid refrigerant is separated from the refrigerant at the bottom of the accumulator, and returns to the compressor together with the suction gas, through a small hole in the suction pipe.

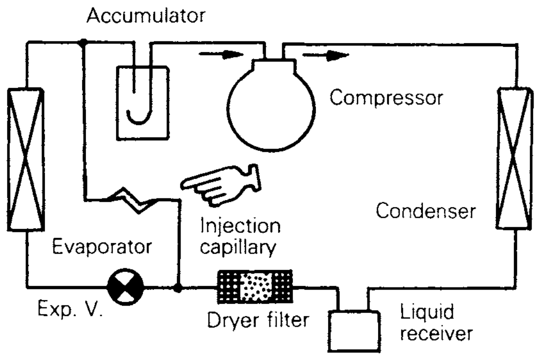
Fig.4-54



(5) Injection capillary

When cooling load increases and the discharge pressure rises, the discharge gas temperature rises and the compressor motor is over-heated.
The injection capillary is used for preventing the compressor motor from over-heating.
The structure of the injection capillary is the same with that of the capillary tube, and it is connected to the compressor or the suction pipe.
A certain constant volume of the liquid refrigerant passes through the injection capillary, where the refrigerant is changed to the low temperature liquid refrigerant, and cools the compressor motor.

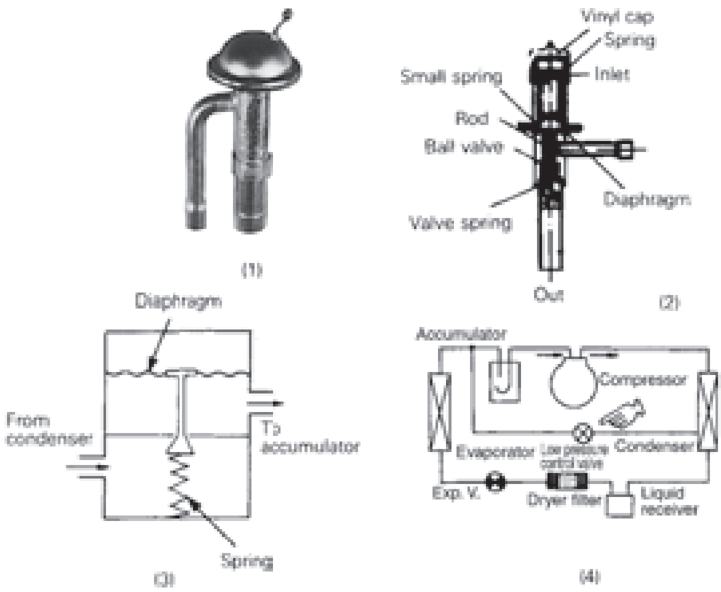
Fig.4-55



(6) Low pressure control valve

The low pressure control valve controls cooling operation.
The low pressure control valve senses the low pressure which is about 4kgf/cm^{2}G or less (the pressure of the fan coil unit) and bypasses the discharge gas from the compressor to the accumulator.

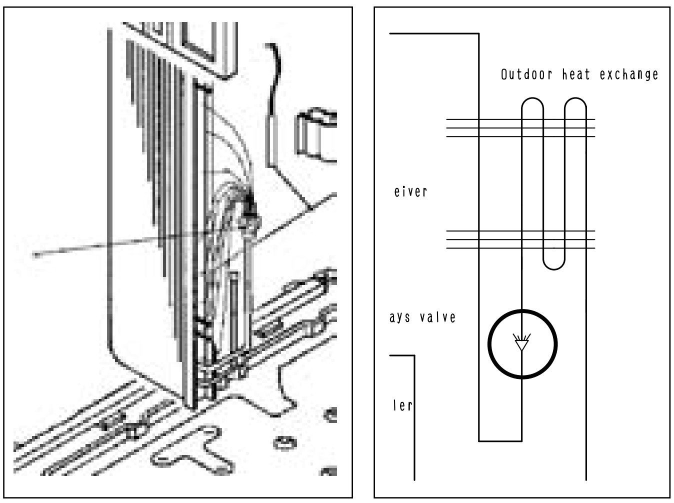
Fig.4-56



(7) Distributor

Heat exchanger with a cross fin coil is not designed so that a single coil passes all through the heat exchanger and consists of two or more circuits. Therefore, a distributor is used to distribute the refrigerant.

Fig.4-57



(8) Gas/liquid heat exchanger

The gas/liquid heat exchanger is used in the multi system. During operation, the high temperature liquid refrigerant (before it is sent to the expansion valve) and the low temperature gaseous refrigerant (before it is sent to the compressor) are exchanged in heat in this heat exchanger. The function of this heat exchanger is shown with broken line on the Mollier chart. [See Fig.4-58 (3)]

- Amount of subcooling becomes high so that liquid refrigerant (before it is sent to the expansion valve) does not become the flash gas easily.
- The cooling capacity increases.
- The low temperature gas is heated to a suitable superheated degree so as to prevent wet compression.

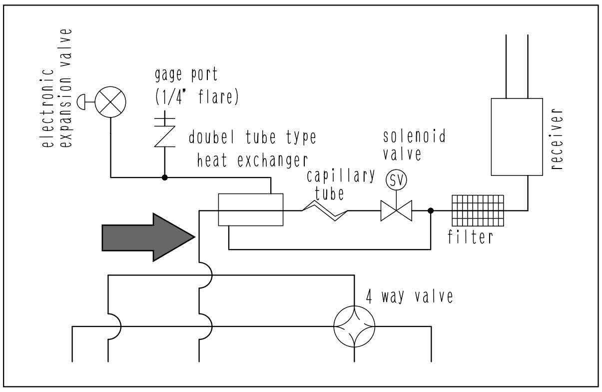
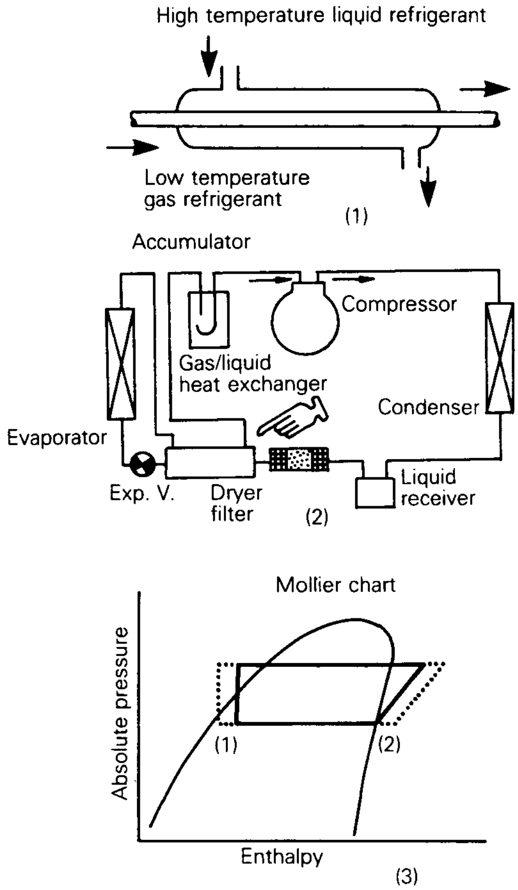


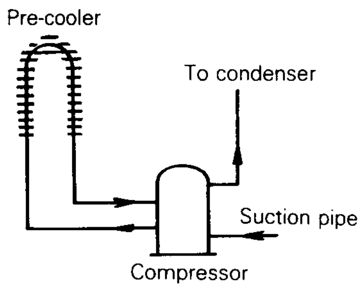
Fig.4-58



(9) Pre-cooler

There are two types of pre-cooler, one constructed as a U-shaped copper pipe with aluminium fins, and the other using part of the cooling piping of the condenser. Either type functions to cool the compressor discharge gas and to return it to the compressor. This protects against overheating of the compressor motor and reduces power consumption.

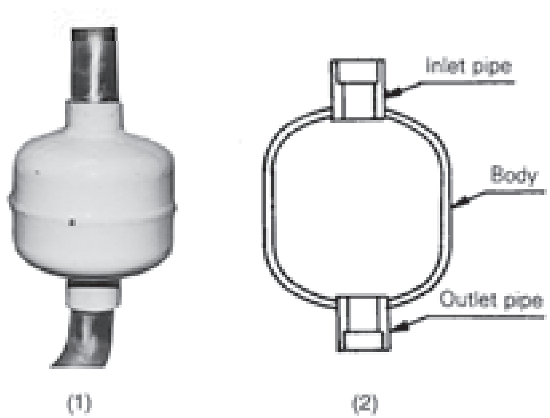
Fig.4-59



(10)Muffler

Some air conditioner provides a muffler to break up the pressure pulses which create noise. The muffler is usually located between the compressor discharge and the condenser and installed vertically to provide efficient oil movement.

Fig.4-60

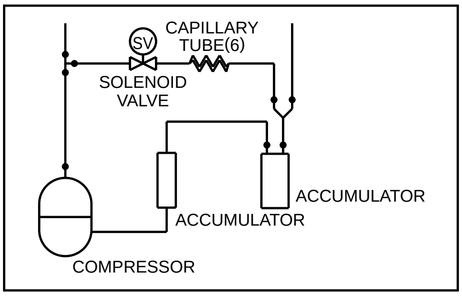


(11)Solenoid valve

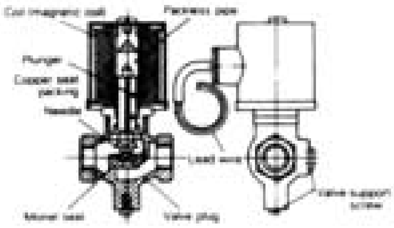
In case of the multi system, the refrigerant flow for the fan coil units stopped during cooling operation should be blocked. The solenoid valve is used to open or close the refrigerant circuit by energizing it on and off.

The solenoid valve resembles the electronic expansion valve in the piping circuit diagram. Therefore, do not confuse with it. The illustrated piping circuit is used for pressure equalization of high and low pressures while the unit stops running in order to reduce the torque for restarting the compressor.

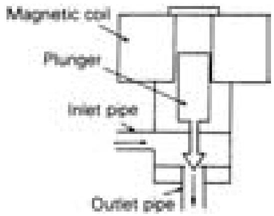
Fig.4-61



(1)



(2)



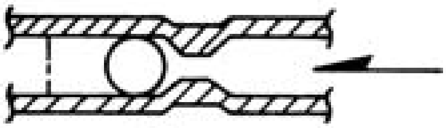
(3)

(12)Check valve

This valve allows the refrigerant to flow in one direction only. As shown in figure on the right, the structure is quite simple, but care must be taken to install it in the correct direction. In this reason, an arrow on its surface indicates the direction of refrigerant flow.

Fig.4-62

(1)



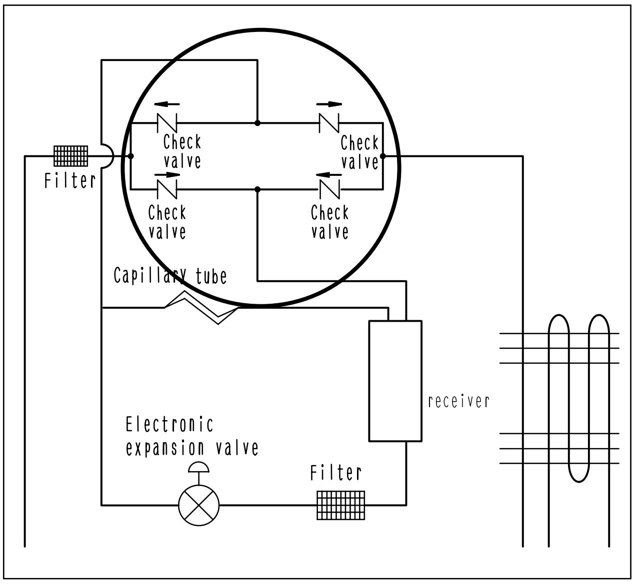
(2)

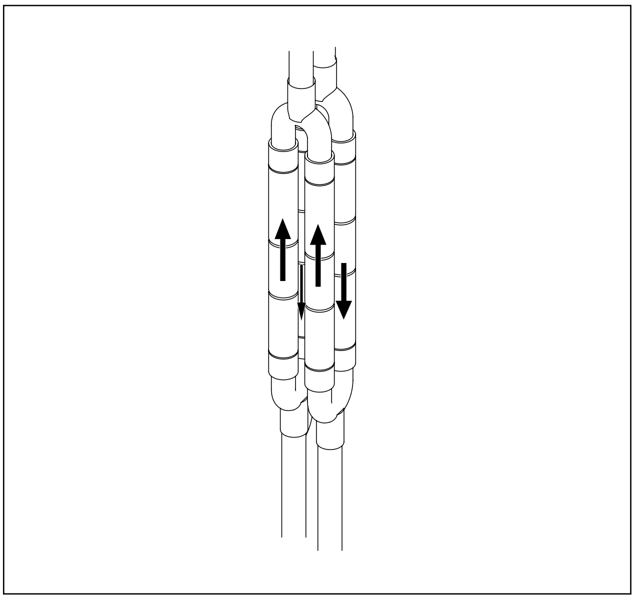
(13)Bridge circuit

The bridge circuit is made in combination of four check valves in order to use the components downstream from this circuit in common even though the refrigerant flows in the opposite direction in cooling and heating, which is frequently introduced the recent SkyAir Series.

As shown in the figure on the right, capillary tube for liquid sealing prevention use as well as liquid receiver, filer, and electronic expansion valve can be used as common parts.

Fig.4-63



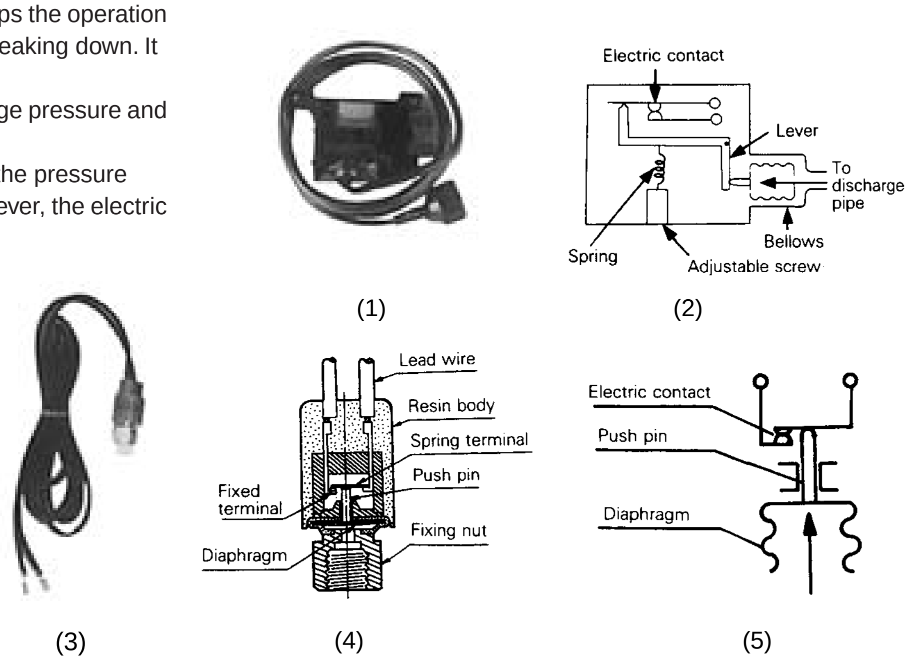


4.4 Safety devices

(1) High pressure switch (HPS)

If the refrigerant pressure of the high pressure side becomes abnormally high, the high pressure switch stops the operation of the unit automatically, preventing it from breaking down. It is installed on the discharge pipe.
The bellows of the switch accepts the discharge pressure and translates the force to the lever.
When the discharge pressure is higher than the pressure setting, the bellows of the switch pushes the lever, the electric contact opens and the compressor stops.

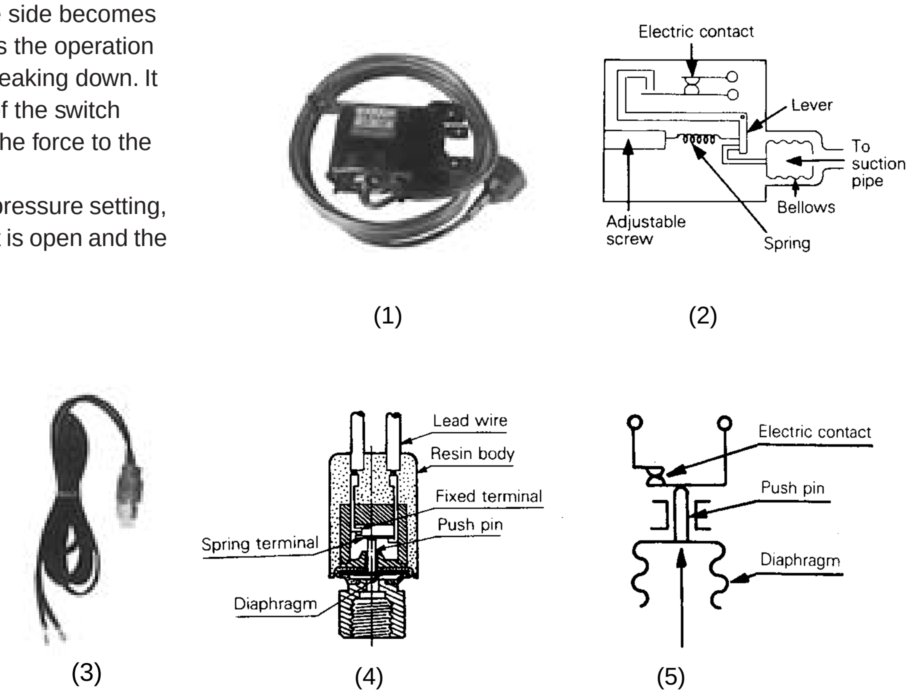
Fig.4-64



(2) Low pressure switch (LPS)

If the refrigerant pressure of the low pressure side becomes abnormally low, the low pressure switch stops the operation of the unit automatically, preventing it from breaking down. It is installed on the suction pipe. The bellows of the switch accepts the suction pressure and translates the force to the lever.
When the suction pressure is lower than the pressure setting, the bellows pulls the lever, the electric contact is open and the compressor stops.

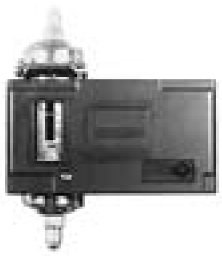
Fig.4-65



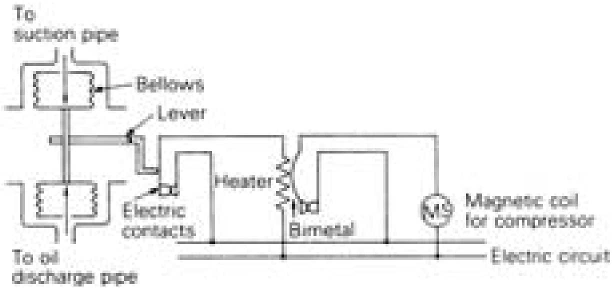
(3) Oil pressure switch (OPS)

The oil pressure switch is used in the large size unit having the semi-hermetic compressor to prevent the compressor metal from burning. It is installed on the discharge pipe. When the oil pressure does not rise to the required level within the predesigned period (approx.45 seconds after starting the compressor), this switch will automatically come into operation to stop the compressor and protect it from burning out.

Fig.4-66



(1)

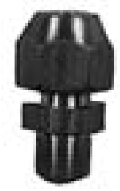


(2)

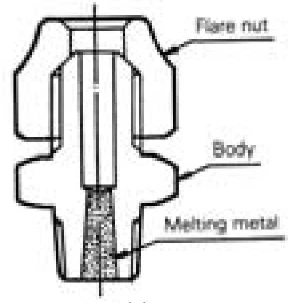
(4) Fusible plug

In case fire takes place or the high pressure switch does not work properly, the fusible plug or the safety valve (which is stated next) prevents the unit from accident. The fusible plug is used in the small unit and is installed in the condenser or the liquid pipe between the condenser and the metering device.
When the condensing temperature becomes higher than the temperature setting (approx.70~75˚C), the fusible metal melts and the refrigerant is blown out.

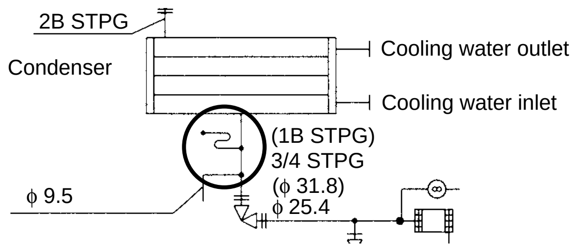
Fig.4-67



(1)



(2)



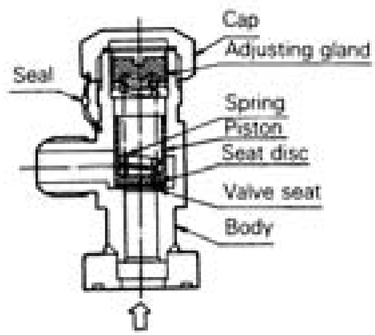
(3)

(5) Safety valve (relief valve)

The function of the safety valve is the same with that of the fusible plug.
The safety valve is used in the large units and is installed in the condenser.
When the condensing pressure becomes higher than the pressure setting, such pressure pushes open the sheet valve and the refrigerant is blown out.

Fig.4-68

(1)



(2)

(6) Pressure regulating value

This valve opens at a certain pressure difference for prevention of pressure increase, thus resulting in no damage of functional parts due to the increase of pressure in transportation or storage.

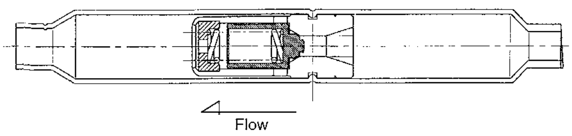
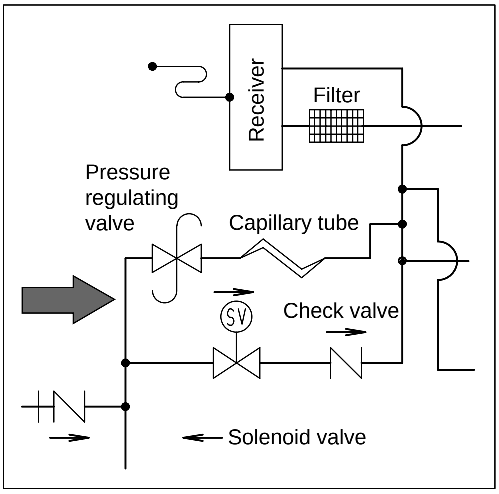


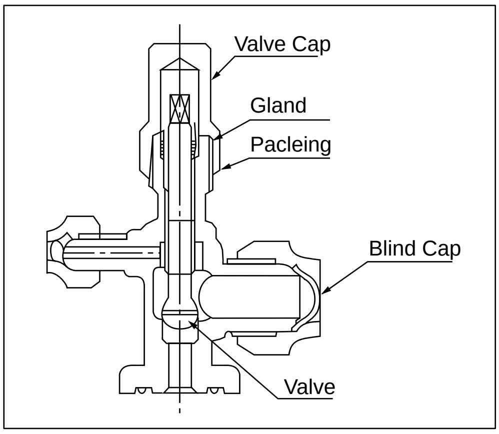
Fig.4-69

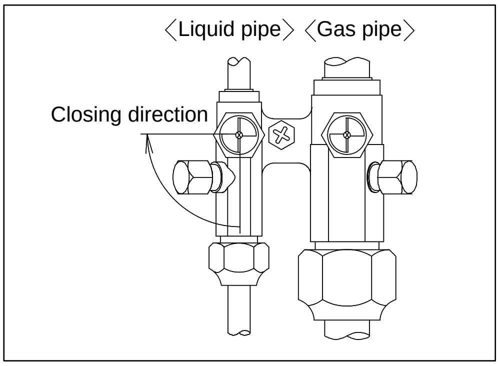


(7) Stop valve

This valve is used for closing or opening the refrigerant circuit and normally located on an outdoor unit. It does normally located on an outdoor unit. It does not regulate the flow rate of refrigerant, because full-close or full-open style is normal. Typical two types of stop valve are shown on the right.

Fig.4-70





Chapter 5 Electrical wiring

Chapter 5 Electrical wiring

It is very important for service technicians to read (understand) electrical wiring diagrams in order to diagnoze troubles.
In this chart, the rules how to read electrical wiring diagrams, the structures and functions of the electric devices used in the air conditioners and graphic symbols on the diagrams are explained so as to read actual wiring diagrams.

5.1 Fundamentals

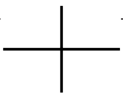
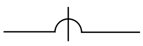
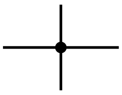
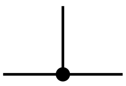
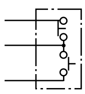
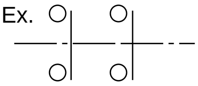
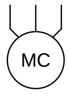
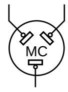
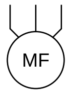
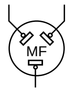
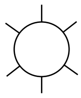
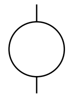
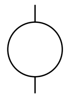
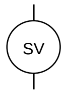
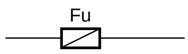
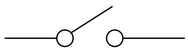
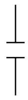
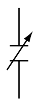
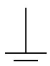
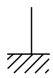
5.1.1 Rules for use of graphic symbols

All graphic symbols show the resting states of all electric devices or electric circuits and that they are disconnected from the power supply; i.e.

- All power supplies are disconnected.
- The electric devices to be controlled and electric circuits are at the resting state.
- The electric devices and electric circuits are left at the released state.
- The electric devices and electric circuits are at the reset state.

However, devices which are not impeded in their functions at whatever states they are located such as change-over contacts are indicated in desired state. (For example. change-over switch for COOL/HEAT)

5.1.2 Basic graphic symbols

Meaning	Symbol	Notes
Conductors (Factory wired)		
Conductors (Field wired)		
Crossover lead wires (not connected)		Do not indicate it as shown below. 
Crossover lead wires (connected)		Place ● at the intersecting point clearly.
Branch of lead wires		Place ● at the branched point clearly.
Terminal		Write terminal No. and symbol if any together with this symbol.
Varistor		
Encircle for things in the same device.		Ex. 
Linking		Ex. 
Compressor motor (3 phase)		
Compressor motor (single phase)		
Fan motor (3 phase)		
Fan motor (single phase)		
Light		or 
Coils		Coils for relay, timers etc.
Solenoid		
Fuse (Tube type or plug type)		In case of open type (naked) 
Switch		
General capacitor		
Electrolytic capacitor		
Variable capacitor		
Resistor		
Rectifier		
Ground connection		 Not allowed.

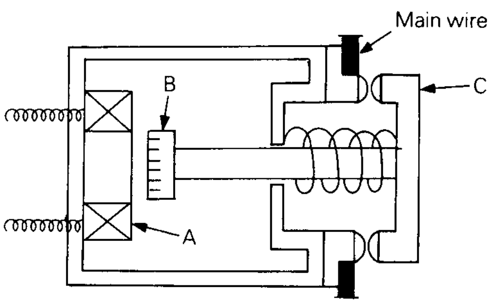
5.1.3 Contacts

(1) Magnetic contactor

Fig.5-1

- Structure
  The magnetic contactor consists of the magnet, the main contacts, auxiliary contacts and the parts for their attachment.
  The magnet is an iron core wound by a coil.
  By applying voltage to both ends of the coil, the shaft is shifted by means of a spring and opens and closes the contacts. The contacts are made of silver-nickel alloy in order to withstand large electric current, and can open and close several tens of thousand times.

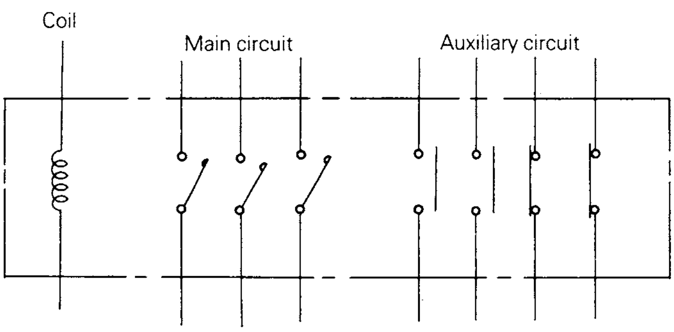
Fig.5-2 Structure of magnetic contactor



- Function
  When coil A is energized, the coil changes to a magnet. This magnet draws iron core B. The contact C closes and current flows.
  The magnetic contactor is used for starting a compressor motor or a fan motor.

- Symbol

Fig.5-3



(2) **a**-contact and **b**-contact
The symbols for the relay contacts which are normally open or normally closed are shown as below.

Table 5-1

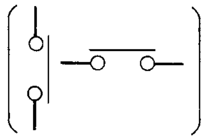
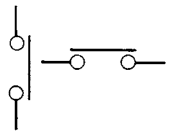
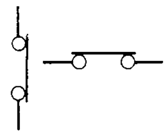
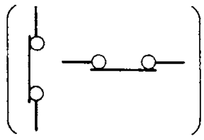
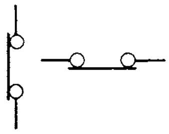
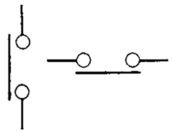
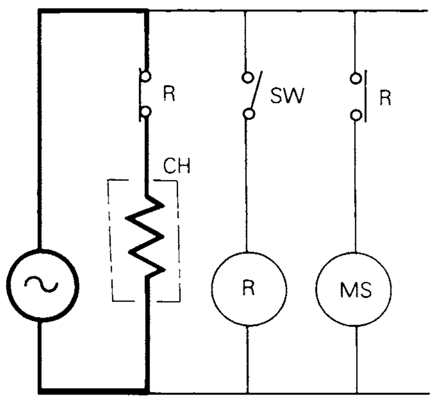
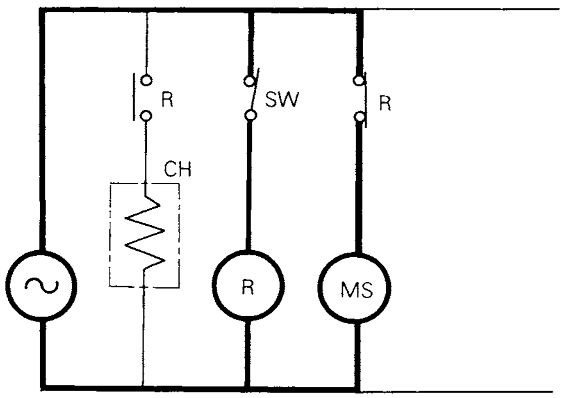
	coil	
	De-energized (Normal condition)	Energized
a-contact 	Open 	Closed 
b-contact 	Closed 	Open 

Fig.5-4



When coil Ⓡ is de-energized (when the SW is open),
a-contact opens (therefore, Ⓜ︎Ⓢ is de-energized),
and **b**-contact closes (therefore, CH is energized.)

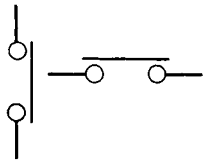
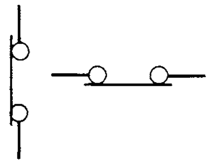
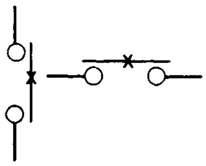
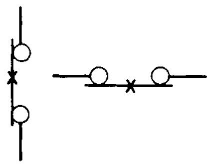
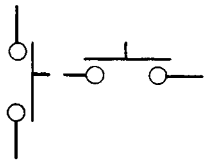
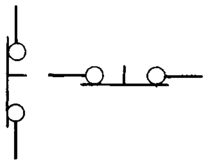
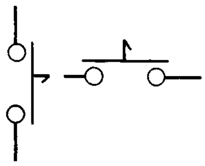
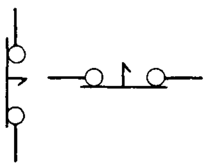
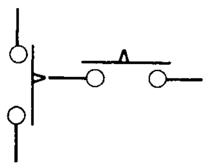
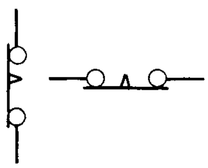
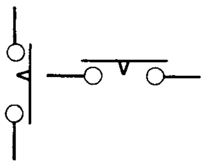
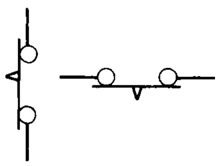
Fig.5-5



When coil Ⓡ is energized (when the SW is closed),
a-contact closes (therefore, Ⓜ︎Ⓢ is energized),
and **b**-contact opens (therefore, CH is de-energized).

(3) Kinds of contacts
The kinds of contacts are shown below.

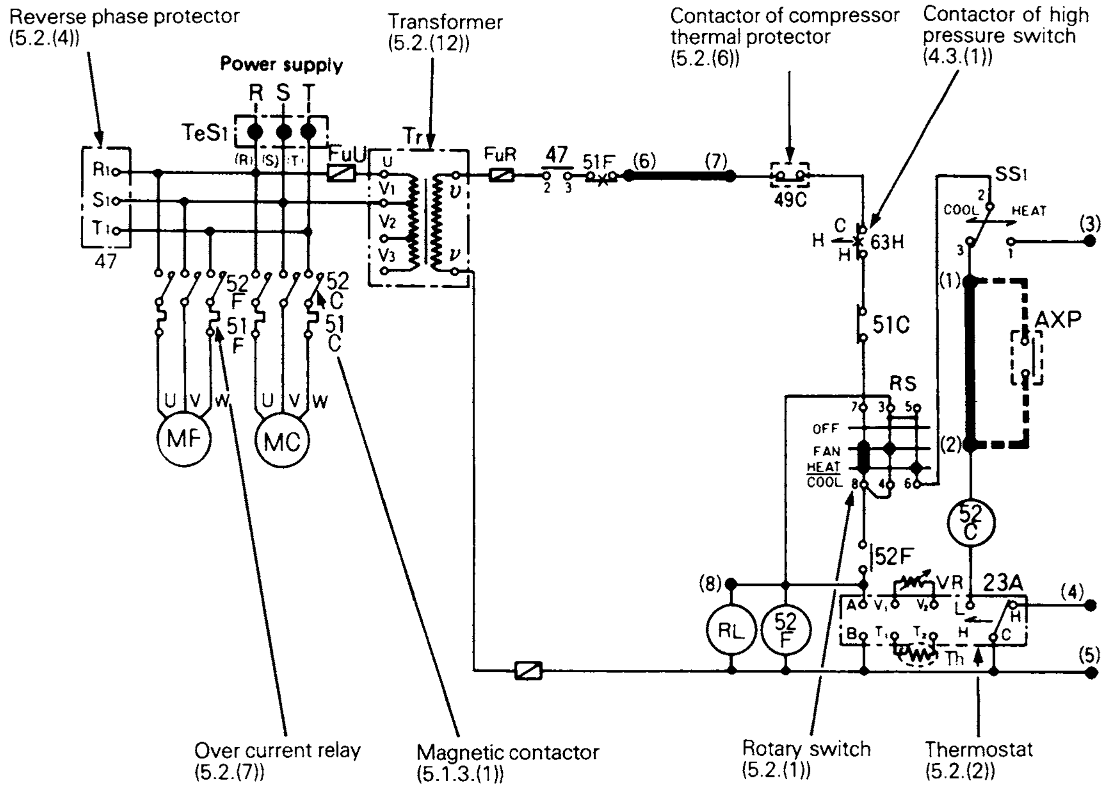
Table 5-2

No.	**a**-contact	**b**-contact	Note
1. Contact			The contact for a relay, etc.
2. Contact			When the coil is energized, **a**-contact closes or **b**-contact opens. Once this contact opens or closes, its reset button should be pressed to restore it. (Manual reset)
3. Switch			When this is pressed, **a**-contact closes or **b**-contact opens. If released, **a**-contact opens or **b**-contact closes.
4. Switch			When this is pressed, **a**-contact closes or **b**-contact opens. Even though it is released, **a**-contact remains closed or **b**-contact remains open.
5. Timer-contact			When the timer coil is energized, **a**-contact closes or **b**-contact opens after a predetermined lapse of time. This contact is remade immediately after its coil is de-energized.
6. Timer-contact			When the timer coil is energized, **a**-contact closes or **b**-contact opens immediately. After a predetermined lapse of time since the coil was de-energized, this contact is remade.

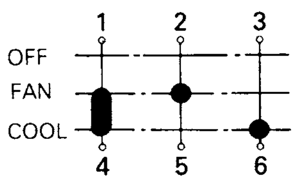
5.2 Electric parts

As shown in Fig.5-6, various electric parts are used in the electric circuit. The main electric parts used in the air conditioners are shown below.

Fig.5-6 Example of wiring diagram

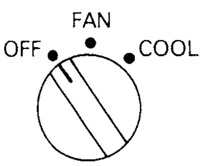
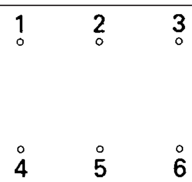
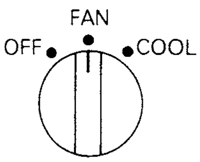
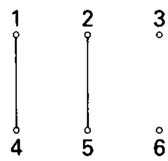
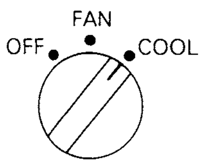
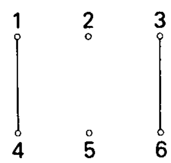


(1) Rotary switch



A black dot (●) means that the contact is closed.

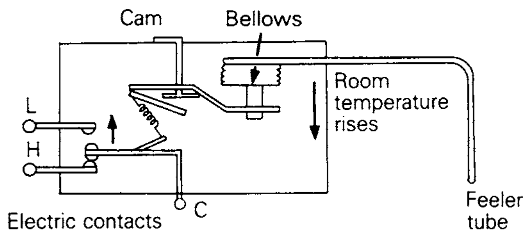
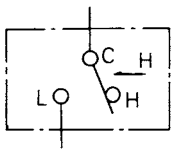
Table 5-3

			1-4	2-5	3-6
	When the rotary switch is set to the position for "OFF", all contacts are open, since there are no black dots.		Open	Open	Open
	When the rotary switch is set to the position for "FAN", the contacts 1-4 and 2-5 are closed, since there is black dot between 1 and 4 or 2 and 5.		Closed	Closed	Open
	When the rotary switch is set to the position for "COOL", the contacts 1-4 and 3-6 are closed, since there is a black dot between 1 and 4 or 3 and 6.		Closed	Open	Closed

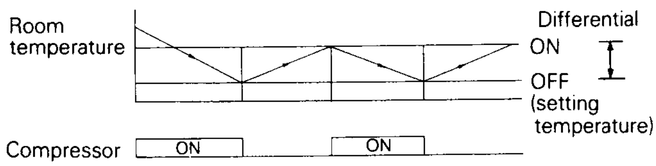
(2) Thermostat

The thermostat senses temperature of suction air and controls operation of the compressor.
Two types of thermostats are available, one is the mechanical thermostat and the other is the electric thermostat.
The comparison between the mechanical thermostat and the electric thermostat is shown in Table 5-4.

Table 5-4 Comparison between the electric and mechanical thermostats

	Electric thermostat	Mechanical thermostat
Temperature sensing	Resistance change of the thermistor	Pressure change in the feeler tube
Circuit operation	By changes of thermistor resistance, the transistor-amplified relay is turned on and off. One or multi-step operation (1, 2, 4 operation)	By changes of feeler tube pressure, the bellows is transformed and the electric contacts open or close. One step operation
Setting	Variable resistor	Spring force
Structure		
	———	
Symbol		

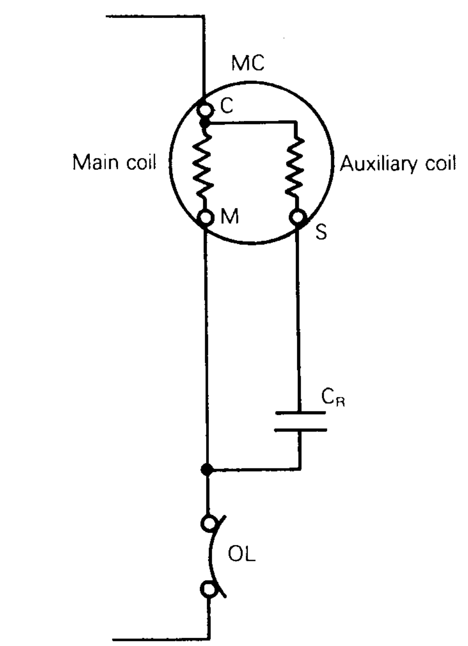
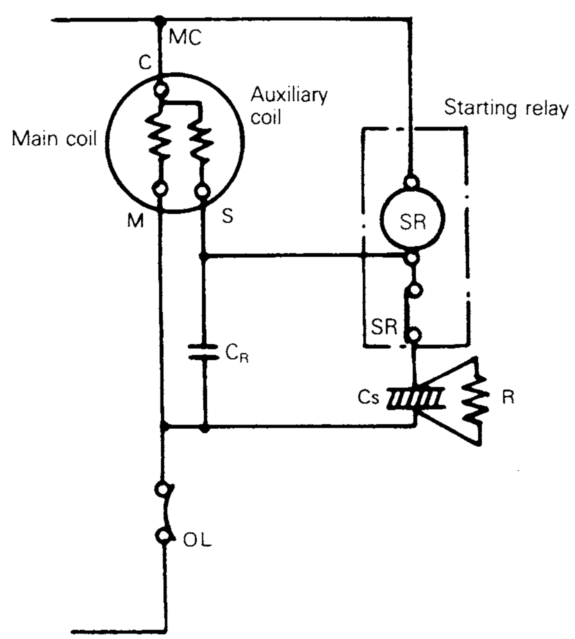
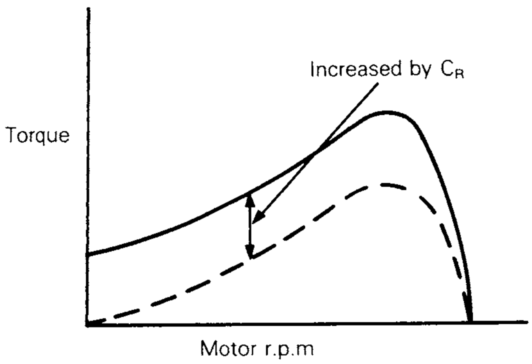
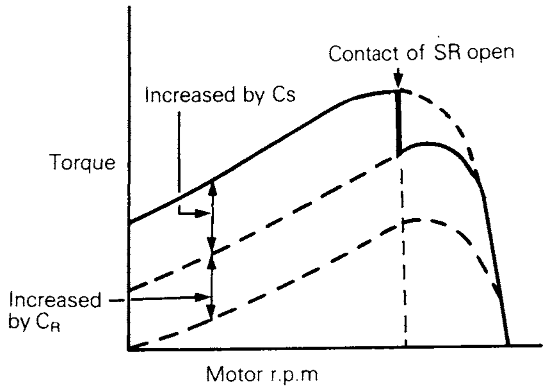
Operation
When room temperature is cooled down to the thermostat setting, the compressor stops. When room temperature rises higher than the temperature which is equal to the thermostat setting plus differential temperature, the compressor starts again. The operation is repeated to maintain room temperature to the thermostat setting.



(3) Starting relay and capacitor

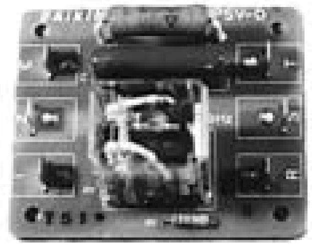
The running capacitor and the starting relay are provided to start the compressor. Two methods are used for starting the compressor having the single-phase induction motor. One is the PSC (permanent split capacitor)method, and the other is the CSR (capacitor-start, capacitor-run) method.

Table 5-5

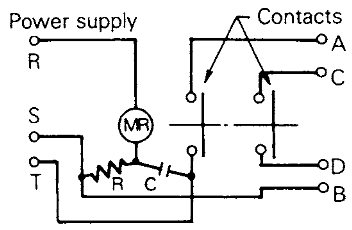
PSC method	CSR method
Used in the units having the capillary tube	Used in the units having the expansion valve
	
 In case of the single-phase induction motor, the starting torque is obtained by the phase difference between the main coil and the auxiliary coil. The capacitor (C_R) generates phase difference.	 The unit having the expansion valve needs higher torque to start the compressor motor. So the starting capacitor (Cs) is added to gain a sufficient torque to start. When the revolving speed increases and the voltage of the auxiliary coil (the voltage of the coil of starting relay) rises to the acting voltage, the contact opens. It operates in the same way as the PSC method.

(4) Reverse phase protector

The revolving direction of the hermetically sealed rotary compressor is fixed. If it is revolved reversely due to some accident, the suction and discharge processes are reversed. Therefore, the compressor inhales the refrigerant from the discharge piping and discharges it to the suction piping. In case of three-phase motors, the direction of revolution will be reversed if the connections of any two of three wires are exchanged.
The reverse phase protector prevents reverse revolution of the compressor.
The operating theory is as shown on the right.
When the wires are connected to the correct phases, MR operates and the contacts are closed. Therefore, the circuit is energized.
When the wires are connected to the incorrect phases, MR does not operate and the contacts are open. Therefore, the circuit is de-energized.



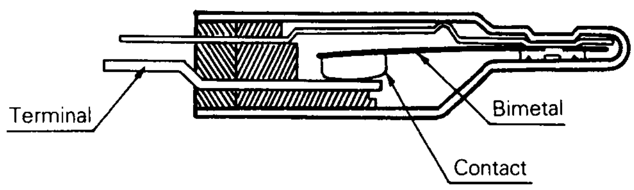
Operation theory

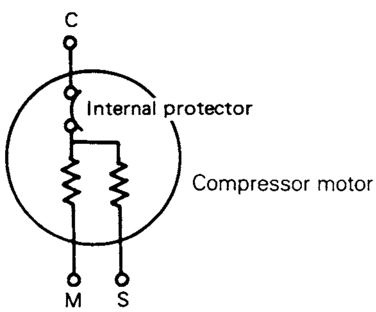


MR: Magnetic relay
R : Resistor
C : Capacitor

(5) Internal protector (IP)

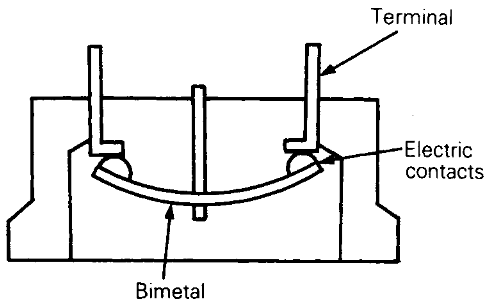
The internal protector is to prevent the compressor motor from burning by detecting motor coil temperature during operation.
The internal protector is installed in a way that it can contact directly with the motor coil inside the compressor.
When motor coil temperature becomes higher than temperature setting, the bimetal is transformed, the electric contacts are open and the compressor stops.





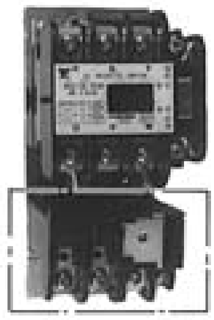
(6) Compressor thermal protector (CTP)

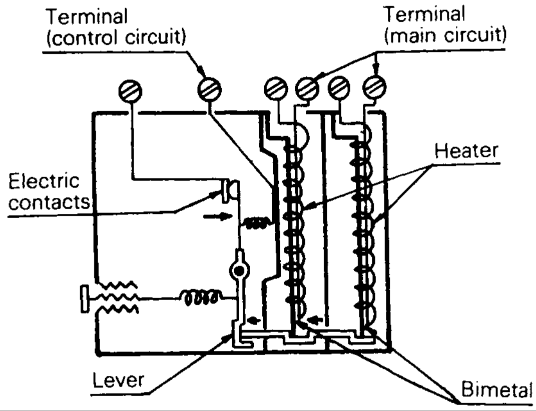
The compressor thermal protector is to prevent the compressor motor from burning by detecting compressor head temperature during operation.
The compressor thermal protector is a bimetal switch which is attached onto the compressor head.
When the motor coil temperature becomes higher, the temperature of the compressor head becomes higher than the temperature setting, the bimetal is transformed, the electric contacts are opened and the compressor stops.



(7) Over-current relay (OC)

The over-current relay is provided to prevent the fan motor and the compressor motor from being locked at the starting or from burning during operation.
The over-current relay is installed in the electric kit box.
When the motor current becomes higher than current setting, the bimetal is heated by over-current and is transformed, so the electric contacts open and the motor stops.
The over-current relay will be reset within a few minutes after having functioned and operation restarts. This cycle is repeated. So operation must be restarted only after the cause is found and repaired. Because the OC setting is determined individually for each unit after tests, the setting must not be changed absolutely if it is replaced. When this is actually activated, the re-heater is heated by over-current, and this heat causes the bimetal to move and the circuit to open.



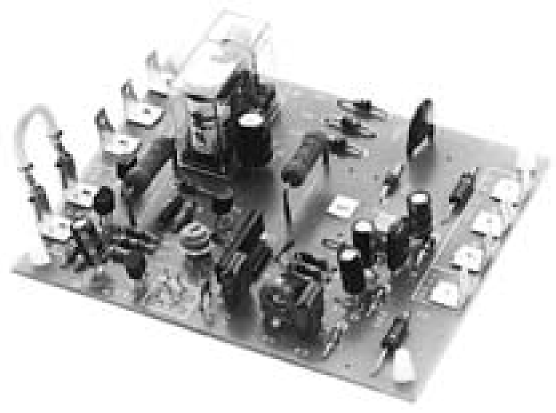


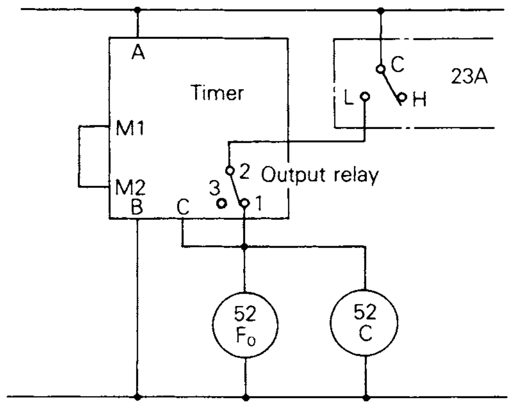
(8) Freeze-up protection thermostat

If a room air conditioner is operated under low room temperature, the indoor heat exchanger is frosted easily, which may cause not only capacity decline but also water leakage into the room.
The freeze-up protection thermostat prevents such troubles.

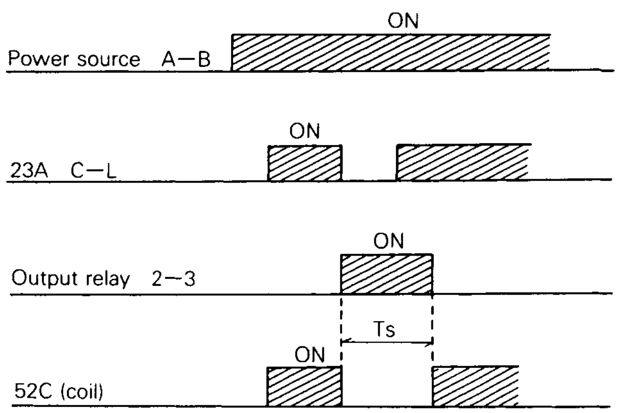
(9) Guard timer

If an air conditioner is turned OFF and will be ON very soon, the compressor will not start the motor will become overheated, and the overload relay may function, because there is great difference in the high and low pressures immediately after the air conditioner stops, which place too much starting load on the compressor. The air conditioner must remain in the stop condition for a certain time immediately after it is was stopped. Thus, the function of this timer is to prevent the compressor from operating for a certain time after stopping the air conditioner.
Two types of timers are used, one is mechanical timer and the other is electronic timer. The former is used in room air conditioners and the latter is used in packaged air conditioners.



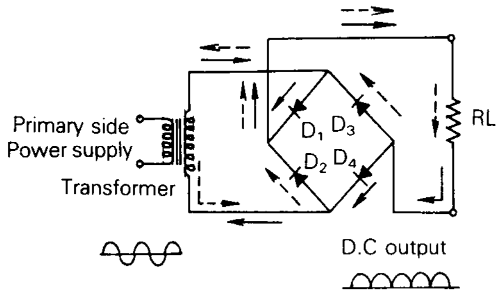


When the contacts C-L are closed, 52C is energized.
The moment when this circuit is de-energized (the contacts C-H are closed), the output relay turns to 3. After a lapse of set time (Ts), it turns back to 1. While 52C is not energized even if the contacts C-L are closed.



(10) Commutator

For certain room air conditioners, direct current is used for exciting the magnetic contactor.
The commutator converts alternating current to direct current by the commutation function of the commutation diodes. The commutation diodes let the current pass in one direction only.
The current flows as shown on the right.

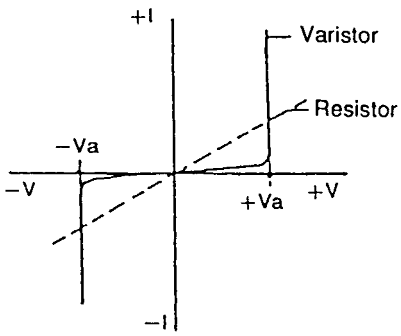


(11) Varistor

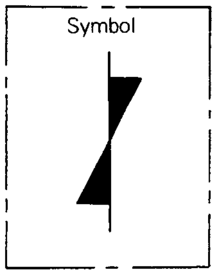
The varistor is one of the safety devices for printed circuit board. When an abnormal high voltage is applied to the unit, this device is burnt out. It is installed on the printed circuit board.

Characteristic of Varistor

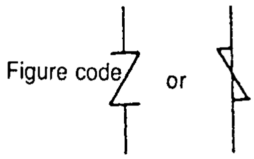
When an abnormally high voltage (AC200V is applied to AC100V circuit, or lightning serge) is applied to an printed circuit board (electronic circuit), the varistor absorbs the abnormal voltage (serge voltage) and is broken (short-circuit) to protect the printed circuit board.



(Characteristics of varistor)



Varistor



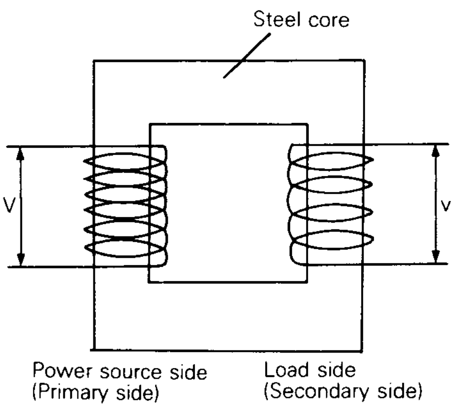

(Appearance)

(12) Transformer

The transformer turns power source voltage to suitable voltage for the control circuit.
This process is as stated below.
The ratio of the secondary voltage to the primary voltage is equal to the ratio of numbers of the secondary turns to numbers of the primary turns.

$$\frac{v}{V} = \frac{n}{N}$$

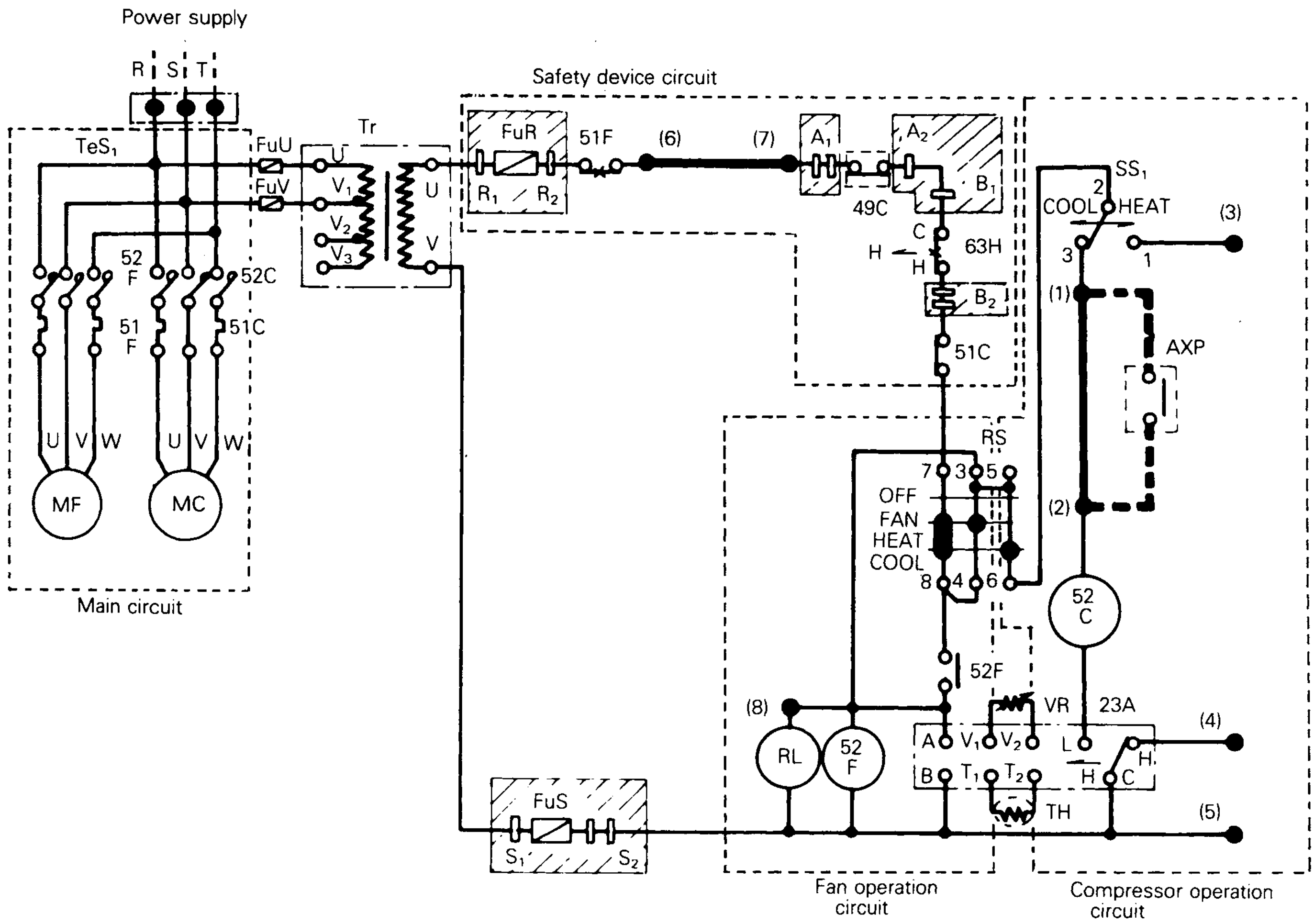
v: Secondary voltage
V: Primary voltage
n: Numbers of secondary turns
N: Numbers of primary turns



5.3 Typical wiring diagrams

A complete wiring diagram for a modern water cooled packaged air conditioner is shown in Fig.5-7.

Fig.5-7



To the beginner, this may be a rather complicated diagram. However, such complicated circuit may be fairly easily broken down into several circuits which vary with the functions as shown below.

1. Main circuit
2. Fan operation circuit
3. Compressor operation circuit
   (The compressor operation circuit includes the interlock circuit.)
4. Safety device circuit

5.3.1 Main circuit

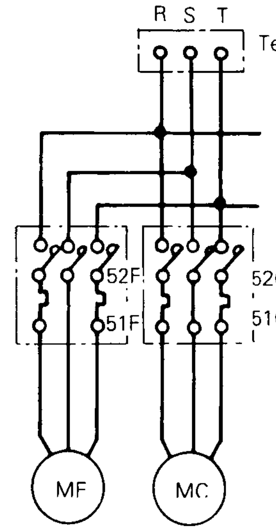
52F Magnetic contactor (For fan motor)
When the coil for this magnetic contactor ((52F) of the fan operation circuit)is energized, the contacts close and the fan motor (MF) is energized.

52C Magnetic contactor (For compressor motor)
This works in the same way as the magnetic contactor for the fan motor.

51F Over-current relay (For fan motor)
If the motor current becomes higher than the current setting, the **b**-contact (51F of the safety device circuit) opens and the motor stops.

51C Over-current relay (For compressor motor)
This works in the same way as the over-current relay for the fan motor.

Fig.5-8 Main circuit



5.3.2 Fan operation circuit

RS Rotary switch
By setting the rotary switch to FAN, the circuit is closed as shown below.

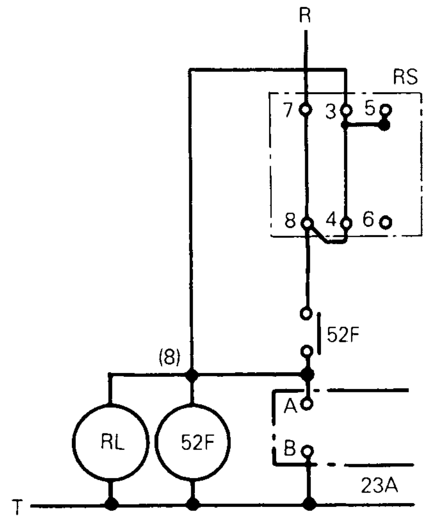
R 7 8 4 3 (8) < A B / (52F) T / (RL)

(52F) Magnetic coil for fan motor
When (52F) is energized, **a**-contact of 52F closes and a current flows as shown below.

R 7 8 52F (8) < A B / (52F) T / (RL)

23A Thermostat
When the voltage is charged between A and B, the temperature controller senses temperature of suction air and operates the contacts of the compressor operating circuit. (Refer to the compressor operation circuit and 5.3.3)

Fig.5-9 Fan operation circuit



5.3.3 Compressor operation circuit

RS Rotary switch
By setting the rotary switch to COOL, the circuit is closed as shown below, if the C-L of 23A and the AXP are closed,

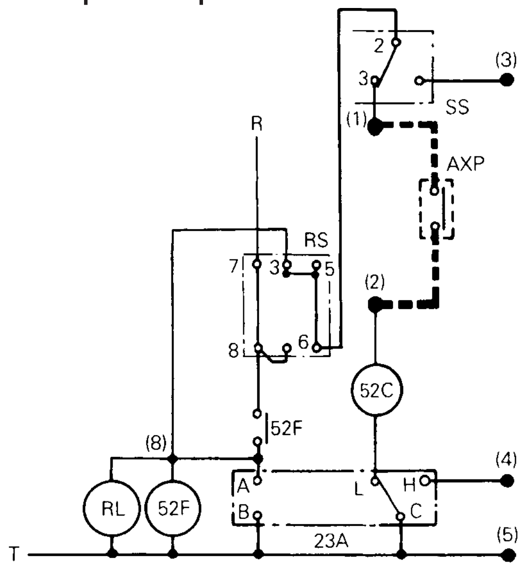
R 7 8 52F (8) < A B / (52F) T / (RL) / 3 5 6 2 3 (1) AXP (2) (52C) L C T

AXP Thermostat
Refer to 5.3.5, Interlock circuit

(52C) Magnetic coil for compressor motor
If (52C) is energized, the contact of 52C of the main circuit closes and the compressor (MC) starts.

23A
if room temperature is higher than temperature setting of the thermostat, the contact turns to L. If the room temperature is lower than it, the contact turns to H.

Fig.5-10 Compressor operation circuit



5.3.4 Safety device circuit

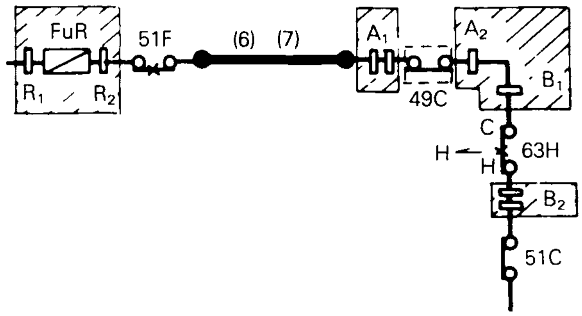
If the safety devices work, all the functions and operation stop.

49C Compressor thermal protector
When motor coil temperature becomes higher than temperature setting, the electric contact opens and the circuit is opened.

63H High pressure switch
If discharge pressure becomes higher than pressure setting, the electric contact opens and the circuit is opened.
Once it has functioned, press the reset button to start the unit again. (If it is manual-reset type.)

51C, 51F Over-current relays
Refer to 5.3.1. Main circuit.

Fig.5-11 Safety device circuit

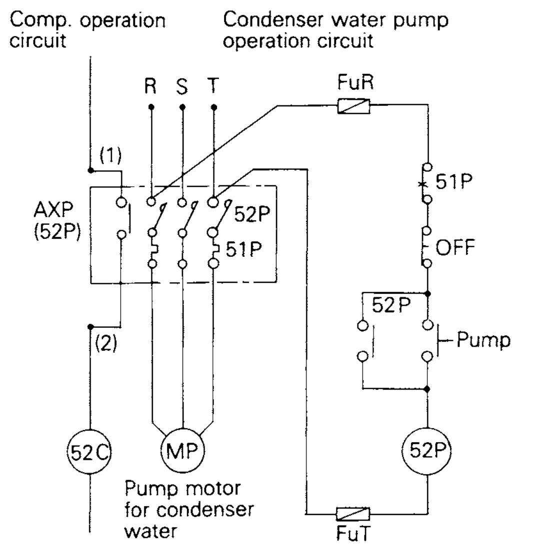


5.3.5 Interlock circuit

AXP(52P)
In case of the water cooled air conditioners, the magnetic contactor for the pump motor for condenser water is used as interlock contact. Coil (52C) is never energized before energizing coil. (52P)
It prevents the compressor from operating without operation of the condenser water pump.

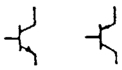
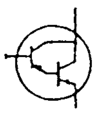
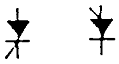
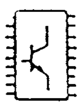
Warnings:
Be sure to provide the interlock contacts in the compressor operation circuit.
Never short-circuit between the terminals (1) and (2).
(Be sure to remove the jumper wire between (1) and (2), before providing field wiring.)

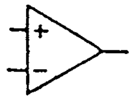
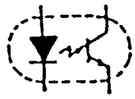
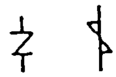
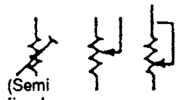
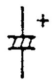
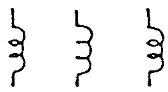
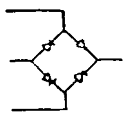
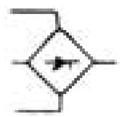
Fig.5-12 Interlock circuit



5.4 Electronic wiring

5.4.1 Main parts and circuit symbol

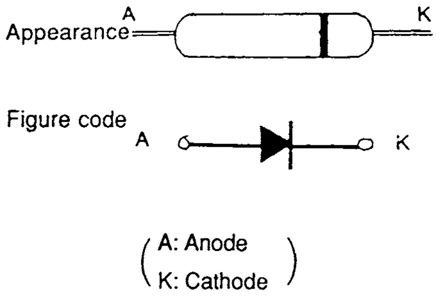
Name	Symbol	Remarks
Diode		 Codes can be put in a circle as shown above. Diode, etc. can be expressed as 
Constant-voltage diode (Zener diode)		
Luminous diode		
Photo diode		
Transistor	 (NPN) (PNP)	
Photo transistor	 (P channel)	
Field effect transistor (FET)	 (N channel) (P channel)	
Darlington transistor		
Thyristor	 (P gate) (n gate)	
Transistor array		
Triac		

Name	Symbol	Remarks
Ope.amp		
Photo coupler		 is accepted.
Varistor	 or	
Thermistor		
Fixed resistor (carbon coating type, metallic firm coating, solid type)		
Variable resistor (carbon coating, metallic coating, wound type)	 (Semi fixed type) (3P) (2P)	
Fixed capacitor (film, ceramic, Mica)		
Electrolytic capacitor (aluminum, tantalum)		
Coil	 or (with steel core)	
Transformer		 is accepted.
Rectifier (bridge connection type)		

(1) Diode

A diode is made by combining P and N type semiconductors, and utilized for rectification, switching and in constant-voltage devices.

Diode



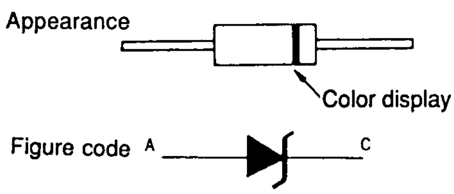
a) Rectifying diode

—▶|— is used as the code for rectifying diode.
The arrow mark (→) shows the flow direction of current.
The rectifying diode is used as the base for generating DC current from AC current.
This diode is utilized to convert the power sources of household electric appliances (single phase 100V) to DC current, and incorporated also into printed circuit boards (electronic circuit) to flow current in one direction.

b) Constant-voltage diode (Zener diode, ZD)

When reverse voltage applied to a diode is gradually increased, electric current flow starts suddenly when the voltage exceeds a certain level.
Due to this characteristics, the constant-voltage diodes are used in constant-voltage circuits in Sky-Air systems and room air conditioners in order to supply constant voltage to the electronic circuits (IC, microcomputer).

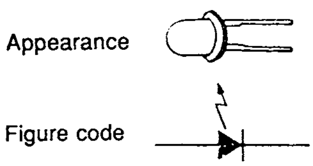
Constant-voltage diode (zener diode)



c) Light-emitting diode (LED)

The light-emitting diode is the semiconducting element which converts electric signals to optical signals, and used in indicator lamps to indicate operation and error.

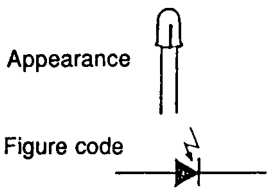
Light-emitting diode (LED)



d) Photo diode (SPD: Silicon Photo Diode)

This is an element to convert optical signals to electric signals, and used by applying voltage in reverse direction.
(A substantial changes in reverse current occurs according to the light amount as shown in the figure on the right.)
The advantages of photo diode is the quick response, which is much quicker than that of Cds.

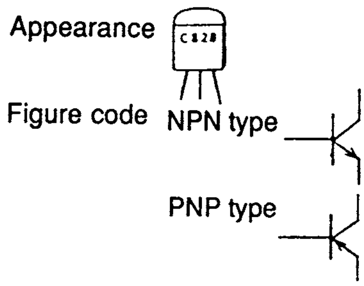
Photo diode



(2) Transistor

A combination of P and N type semiconductors are called transistor. There are two types of transistors, PNP and NPN types, according to the combination of semiconductors.
The function of a transistor is roughly classified into two groups, which are "switching" and "amplification".
In air conditioners, the switching and amplification functions are utilized in control circuits and electronic thermostat, respectively.

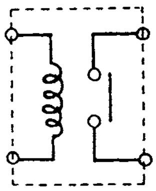
Transistor



The arrow marks indicates the directions of current flowing through the transistor.

(3) Photo coupler

A photo coupler consists of a light emitting diode (LED) and a photo transistor* placed in a case. The photo coupler converts electric signal to optical signal with the light emitting diode and then re-converts the optical signal to electric signal.
The photo couplers are used mainly for signal communications (protective device signal input, defrost signal input and transmission signal input, etc.) between the different voltages (200V and 120V, etc.)
Photo couplers are electrically insulated for optical signal communications and used for prevention of troubles resulting from noise and interferences of voltage and current.
* Photo transistor: Photo transistor controls the current flowing from the collector to the emitter not by the changes of base current but by the changes of light.



Relay

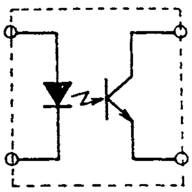


Photo coupler

Photo coupler

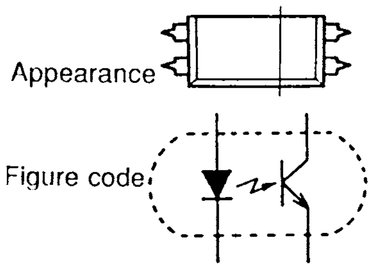
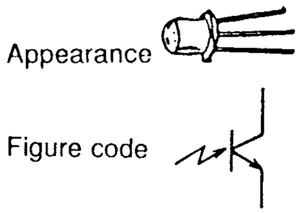


Photo transistor

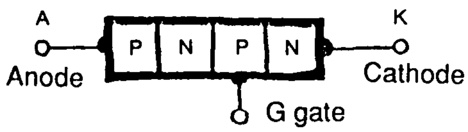


(4) Thyristor [SCR] (SCR : Silicon Controlled Rectifier)

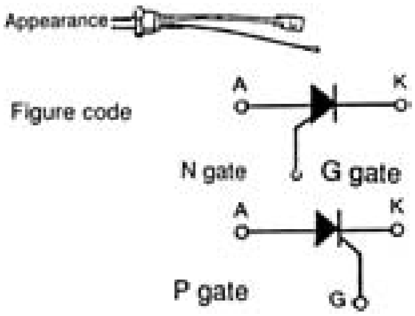
Thyristor is a power control element consisting of P and N type semiconductors connected in 4 layers.
This is used in speed control of DC motor, light control device of electric lamp and non-contact switch utilizing its rectifying and switching functions.
Moreover, the thyristor can turn on and off the extremely high voltage/current of several thousand volts and several thousand ampere with one element which is so small that it is placed on our palm.

Thyristor (SCR: Silicon Controlled Rectifier)

P gate thyristor



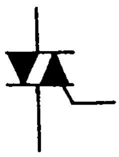
Thyristor



(5) Triac

Triac is a 3-polar dual direction thyristor which can flow electric current in both directions (AC) and functions with both positive and negative gate voltages. The functions are the same as those obtained by combining thyristors in parallel and in reverse direction.

Triac

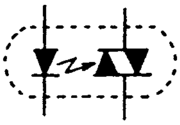
Figure code 

Triac has a 5-layer structure of NPNPN, which is the same as SSS, and is used for AC non-contact switch, electric heater control, light adjusting device, three-phase motor control and temperature control of copy machines (Xerox, PPC). In Daikin products, it is used for phase control of indoor unit fan of room air conditioners and sky air systems.

* Photo triac

Photo triac functions when light is emitted instead of applying gate voltage, and is often used as light receiving element of photo coupler. It is also often incorporated into phase control circuit of fans by combining with light emitting diode (LED).

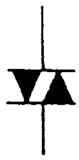
Photo triac

Figure code 

(6) Dyac

Dyac is often used as the trigger element in AC phase control circuit such as muffling access ignition device of water boilers, etc..
Another name of dyac --- Dual direction diode thyristor

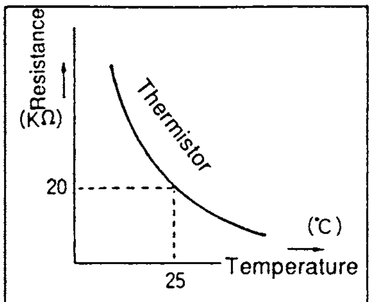
Dyac

Figure code 

(7) Thermistor

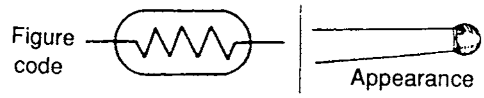
Thermistor has a characteristics that the resistance lowers as the temperature rises, which is opposite to that of normal resistor. (NTC thermistor)
By utilizing this characteristics (resistance change), thermistors are incorporated into the sensors of electronic thermostats in room air conditioners, Sky-Air system and boilers.

Code and characteristics of thermistor



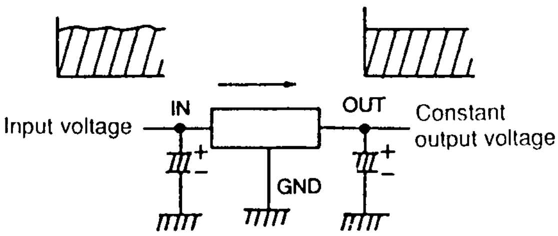
Characteristics of thermistor

Thermistor

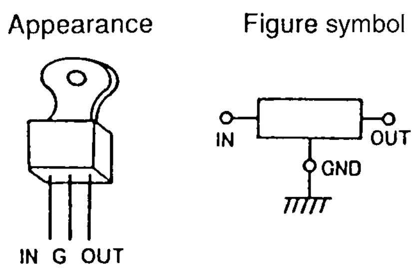


(8) Regulator

Regulator is an IC for power stabilization. The regulator can control the output voltage to a constant level regardless of the input voltage.
The accuracy of regulator is higher than that of zener diode, and can take a heavy power source out.



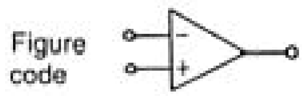
Regulator



(9) Comparator

Comparator compares two input voltages and outputs the result as "H" or "L". The input terminal has positive side and negative side, and if the voltage input to positive side is higher than that input to negative side, the results is output as "H", while "L" is output in the opposite case.
The figure below shows this function using a relay as an example.

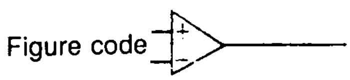
Comparator



(10) Ope. amp

Ope. amp is an integrated circuit called as calculation amplifier. It is used for 1) calculation, 2) Impedance change, 3) measurement control and 4) oscillator, etc. by connecting to an appropriate external circuit.

Ope.amp

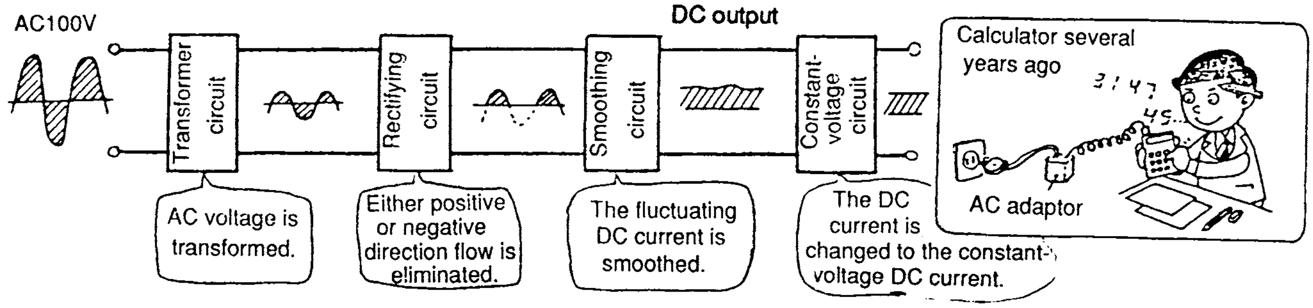


5.4.2 Electronic circuits in air conditioners

(1) Power source circuit

Electronic circuits operates with DC voltages of 5~24V although it differs according to the machines and applications. Since household or commercial use power sources are AC100V or AC200V, it is necessary to convert the power source to low voltage DC current. The procedure to change the AC power source to a low voltage DC power source is as illustrated below:

Fig.5-13



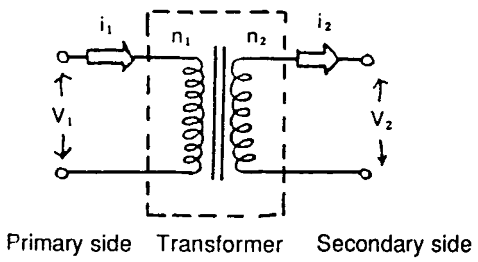
1) Transforming circuit

Normally, voltages are changed to the necessary level with a transformer. When the number of turns, voltage and current are expressed as n_1, n_2, V_1, V_2 and i_1 and i_2, respectively, the equation below is obtained. (See Fig. 5-14)

$$\frac{V_1}{V_2} = \frac{i_2}{i_1} = \frac{n_1}{n_2}$$

$\frac{n_1}{n_2}$ is referred to as turn ratio.

Fig.5-14



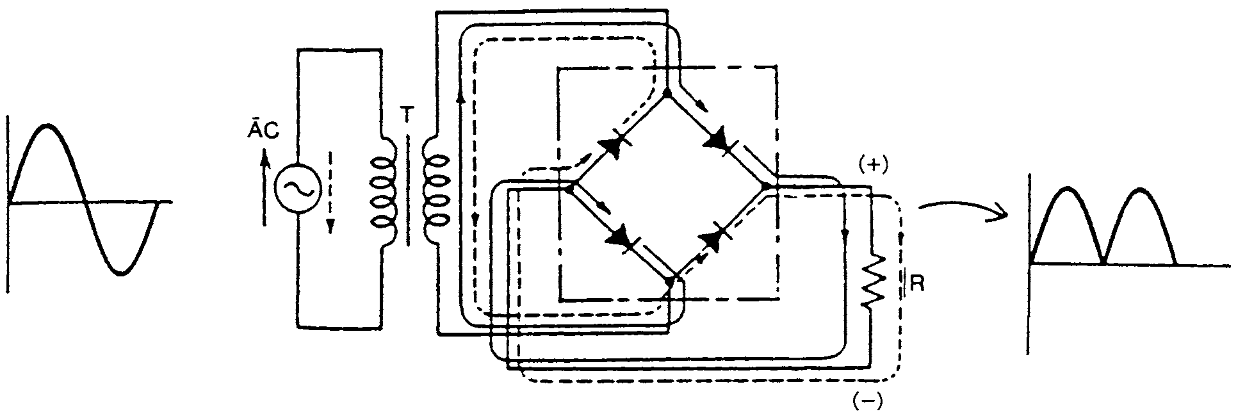
2) Rectifying circuit

Rectifying circuit includes half-wave, all-wave and double-voltage rectifying circuits. The all-wave rectifying circuits with diode bridges are normally used in air conditioners.

Bridge-type all-wave rectifying circuit

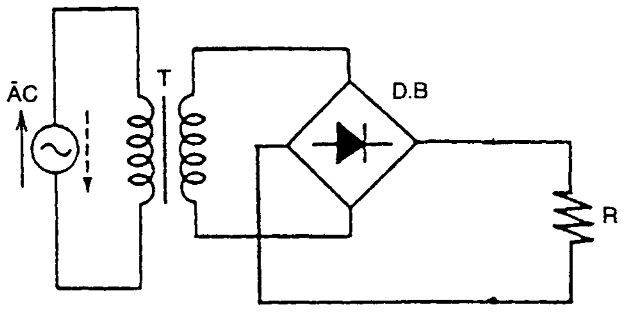
This rectifying circuit is normally used in air conditioners. In addition, diode bridge consisting of 4 diodes is used in actual circuits. (See Fig. 5-15)

Fig.5-15



The diode bridge (D.B) is shown by the code in the Fig.5-16.

Fig.5-16



3) Smoothing circuit

When a capacitor C is connected to a rectifying circuit, the voltage becomes a fairy smooth DC voltage due to the discharge function of the capacitor. The capacitors with this function is called as smoothing capacitors.

Fig.5-17

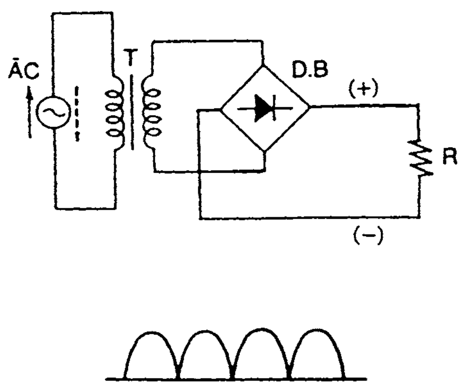
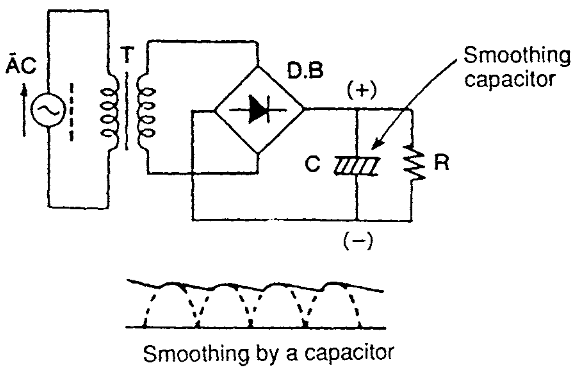


Fig.5-18



4) Constant-voltage circuit

It is necessary for the reference voltage of main circuit in an electronic control circuit to maintain a certain level despite fluctuations in loads.

The elements below are utilized in order to further stabilize the smoothed power source:

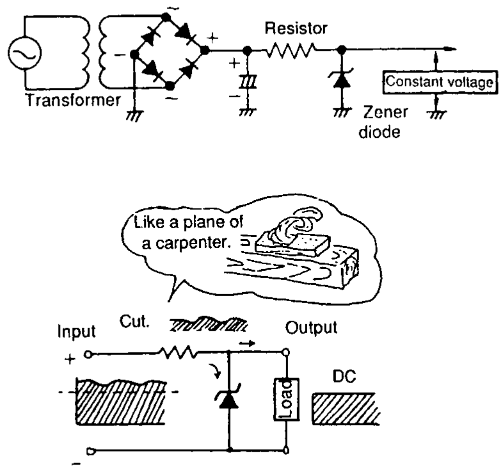
(1) Zener diode (ZD)
(2) 3-terminal regulator

(1) Zener diode (ZD)

Zener diode is used with reverse voltage (zener voltage). When voltage in reverse direction applied to the zener diode is increased, a sudden increase of current occurs at a certain voltage level despite the voltage remains to be constant.

Zener diodes of 3V~40V are available.

Fig.5-19



(2) 3-terminal regulator

Regulator (IC for power source stabilization) is utilized to stabilize the voltage of a circuit whose reference voltage is comparatively high or to take out a large output current.

Fig.5-20

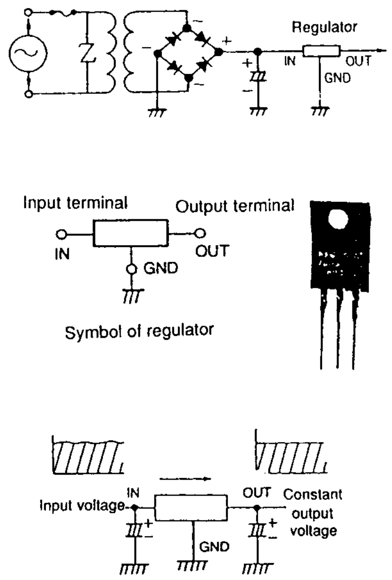
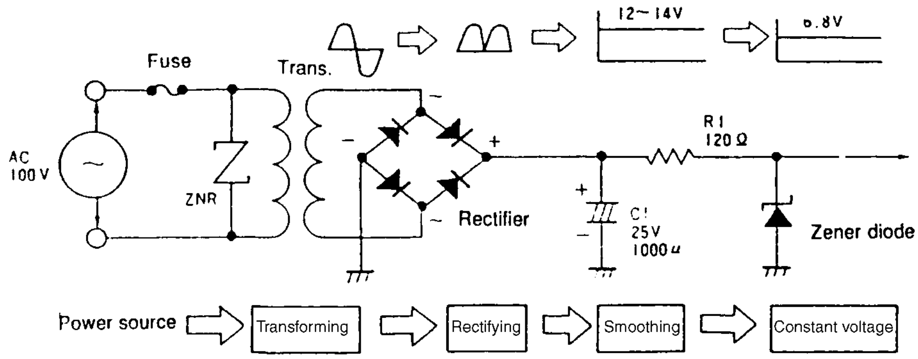


Fig.5-21 Example of integrated circuit



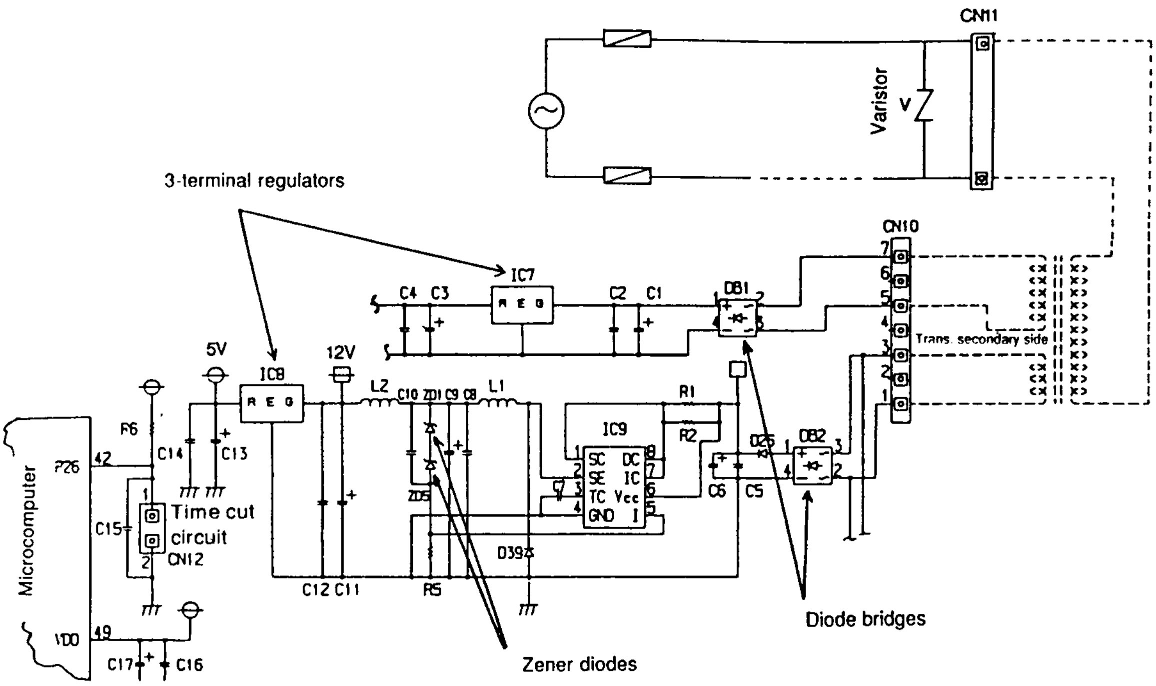
○ Varistor and fuse

Varistor is used to protect electronic circuit against lightning serge or abnormally high voltage (200V in the example above).

When an excessive voltage is applied to power source, the varistor short-circuits and is broken.

At this time, the fuse blows off due to the overcurrent, the electricity route is shut-off, and thus the electronic circuits at the secondary side of the transformer is protected.

Fig.5-22 Example of power source circuit of air conditioner



(2) Room temperature thermostat circuit

- **Example of room temperature input**
  - * The voltage divided by the suction air sensor (Th1) and the resistor (R21) is input to port 57 (AN0) of the microcomputer port (IC1).
  - * When the temperature of the room increases, the resistance of the sensor (Th1) decreases, decreasing the voltage input to the microcomputer port. When the voltage becomes lower than the preset value, a signal to turn the compressor on is output when cooler is in operation.
  - * The voltage V AN0 input to the analogue port (AN0) of the microcomputer is obtained with the equation below.

Fig.5-23

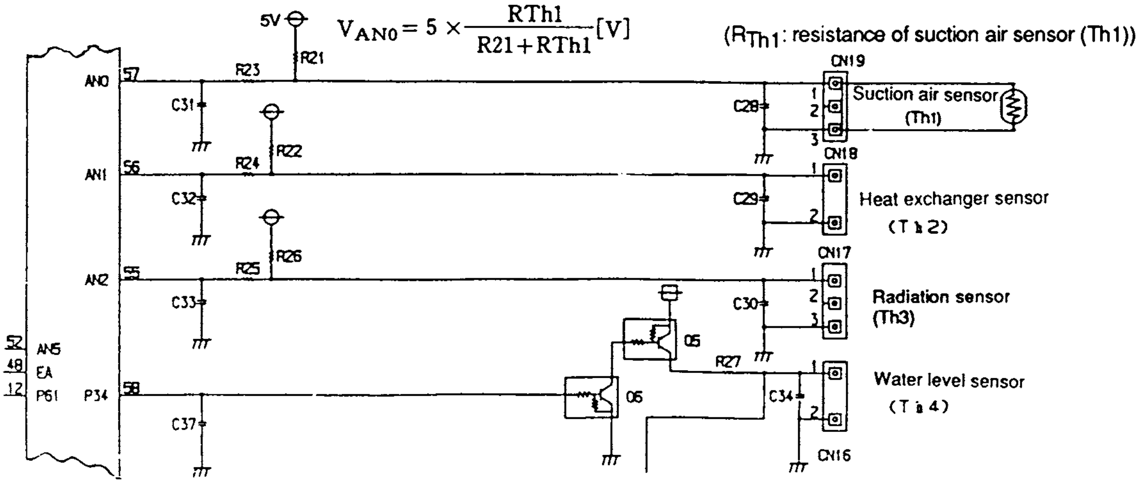
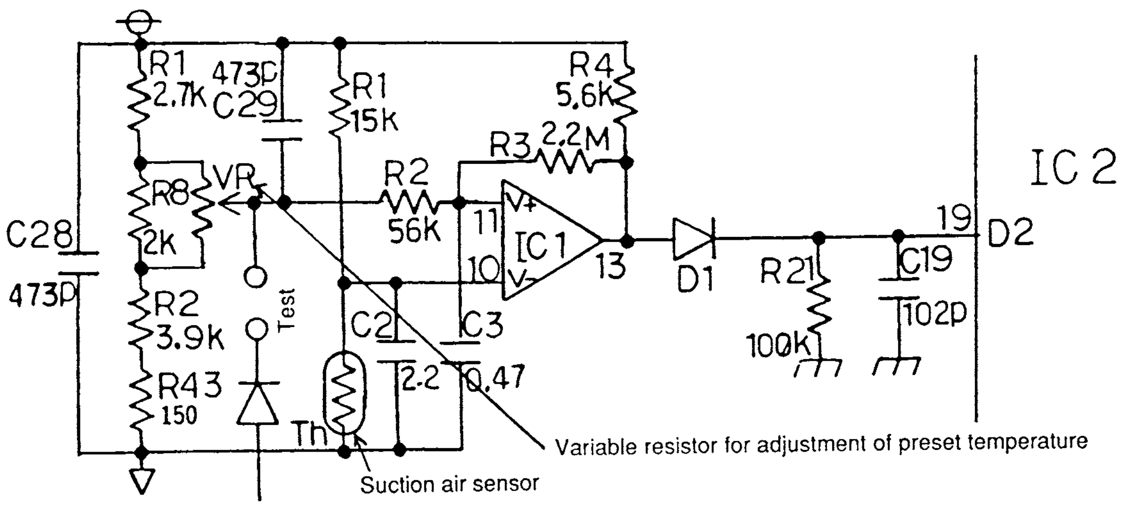


Fig.5-24 Example of inputs of room temperature and preset temperature



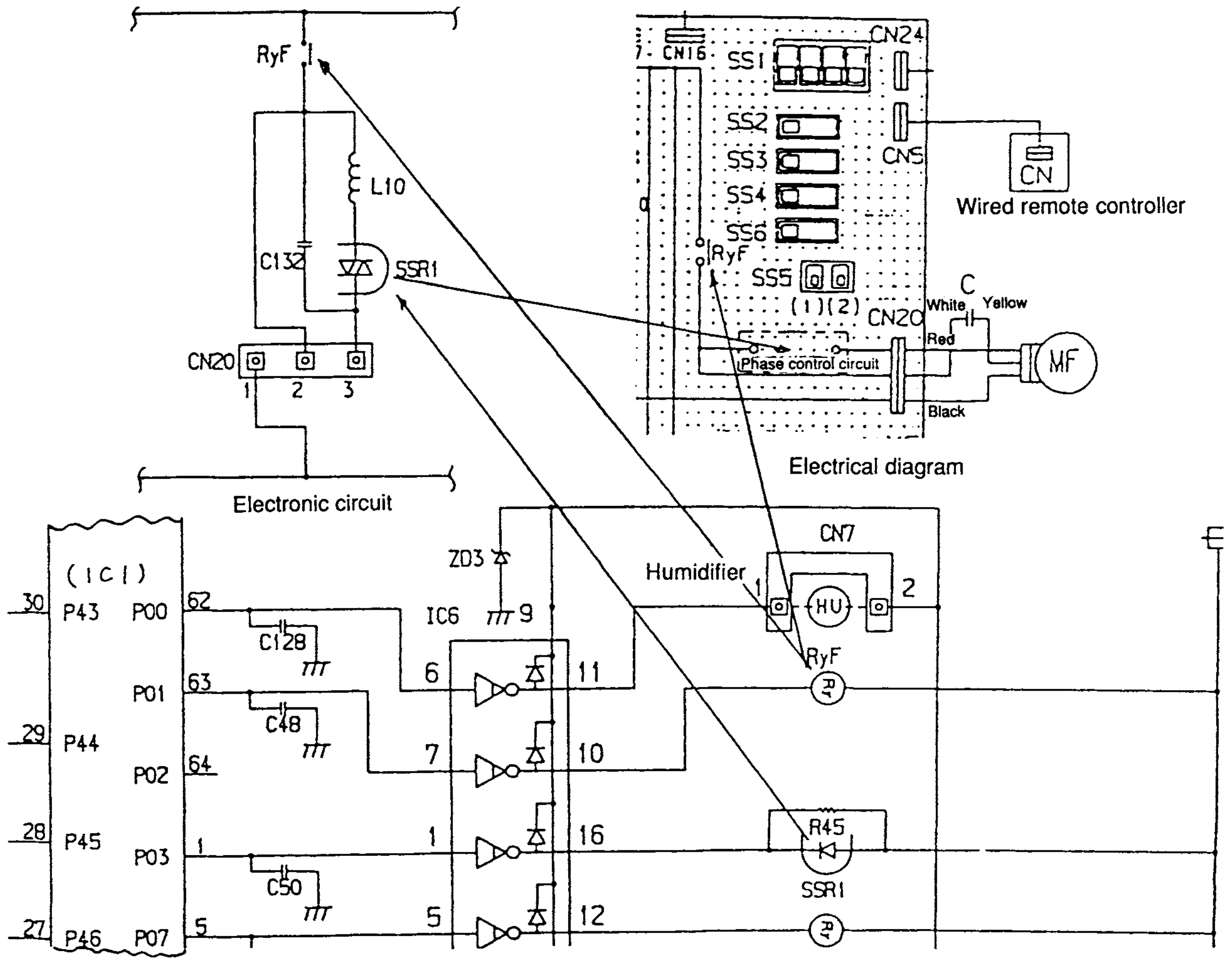
The reference voltage which has already been divided is entered to the positive terminal V^+(pin 11) of the comparator.
The temperature converted to voltage with the thermistor and R1 is entered to V^-(pin 10).
As the temperature increases, the potential at V^-side (pin 10) decreases below the potential at V^+side. Therefore, the comparator outputs "H" signal and this "H" signal is input to microcomputer D2 (pin 19).

On the other hand, when the temperature falls, the potential at V^- side (pin 10) increases above the potential at V^+side. Therefore, the comparator outputs "L" signal and this "L" signal is input to microcomputer D2 (pin 19).

(3) Fan control circuit

When "H" signal is entered to port PO1 (pin 63) of the microcomputer (IC1), port #10 of IC6 outputs "L" signal. The coil of RyF (indoor fan) is excited and contact a closes, thus the indoor fan starts when the photo triac (SSR1) turns on.

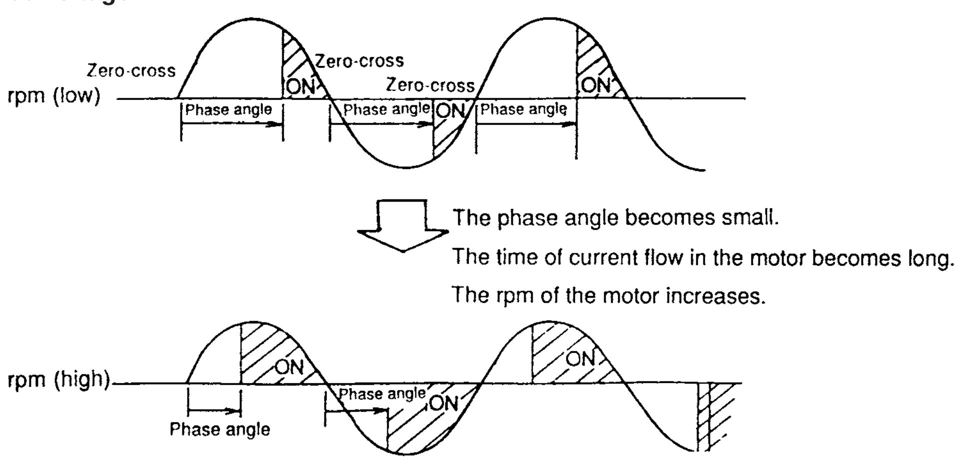
Fig.5-25 Electronic circuit



5.5 Fan motor phase control (constant phase angle control)

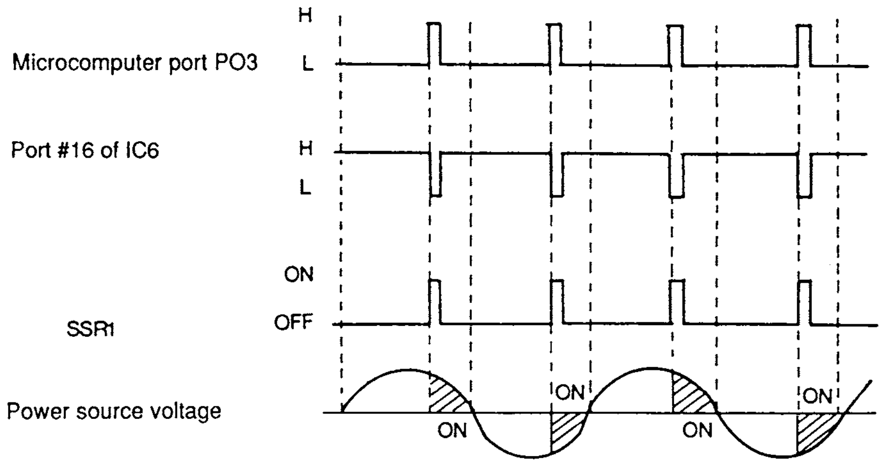
The voltage of fan motor is controlled with the phase angle from the zero-cross of the power source voltage waveform. With this voltage control, he rpm of the fan motor can be changed linearly.

Fig.5-26 Power source voltage



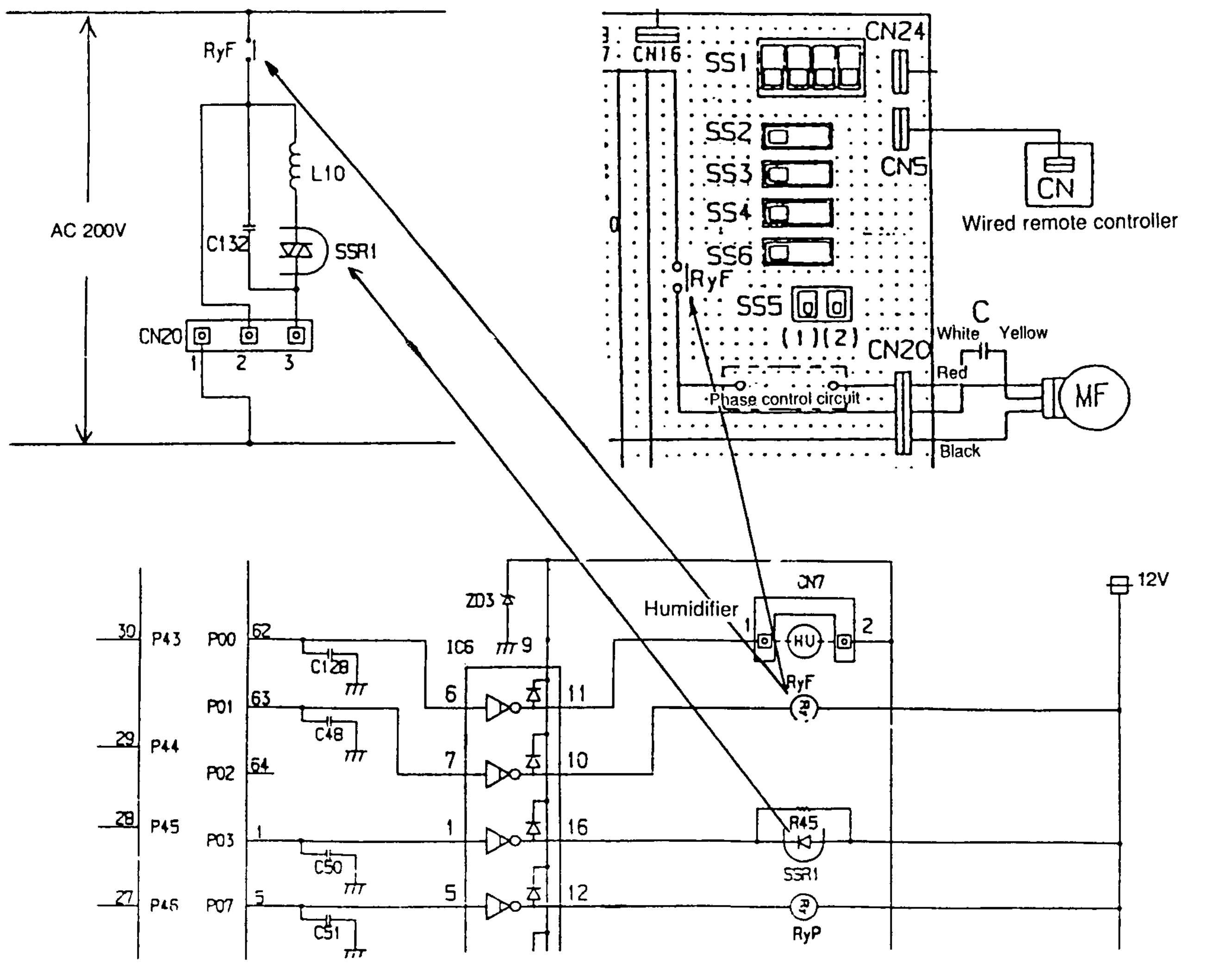
In the figure below, "H" (5V) and "L" (0V) signals are entered alternatively to port PO3(1) of microcomputer (IC1), and also the signals below are entered to port #16 of IC6. The photo triac (SSR1) is turned on and off with these signals and regulates the fan speed with the all-wave phase control.

Fig.5-27



When the fan speed is set to a higher level via the remote controller, "H" signal is output from P03 of the microcomputer more frequently (the phase angle becomes small.), increasing the time length when the power source voltage is turned on. Thus the speed of the fan increases.

Fig.5-28



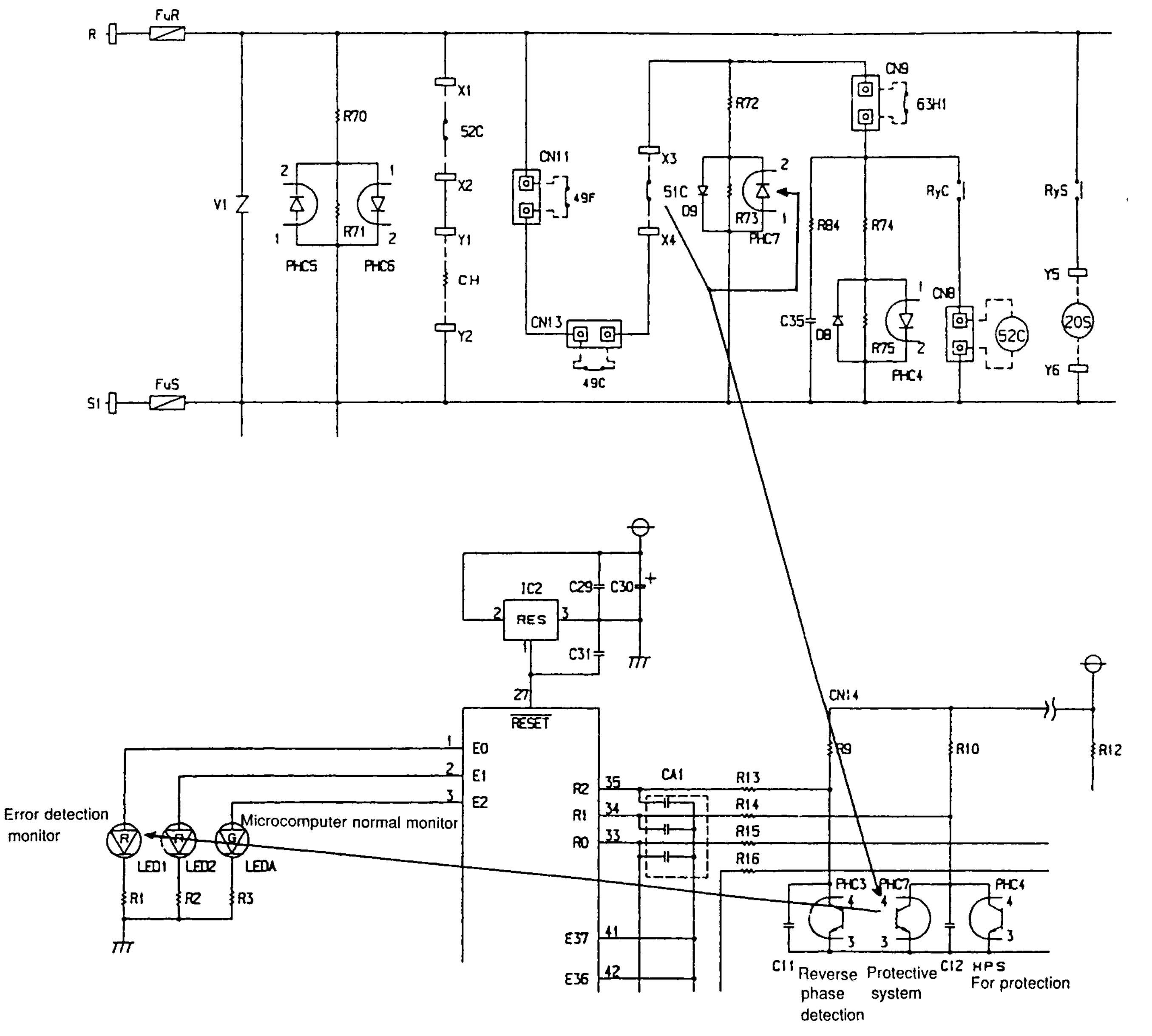
(4) Error detection monitor display circuit

In this section, the process from when the protective system is activated to when the error detection monitor lights is explained.

For example, when 51C (compressor overcurrent relay) is activated, PHC7 (photo coupler) cannot function because voltage is not applied. Therefore, H (5V) is applied to terminal R1 (pin34) of the microcomputer.

When H (5V) is applied to microcomputer terminal R1, terminal E0 (pin 1) detects the H (5V) and LED1 (error detection monitor) lights up, indicating that the protective system is activated.

Fig.5-29

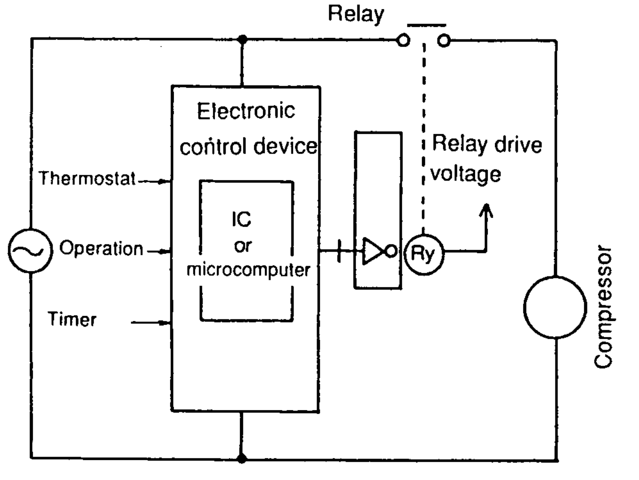


(5) Compressor drive circuit

- Relay drive circuit

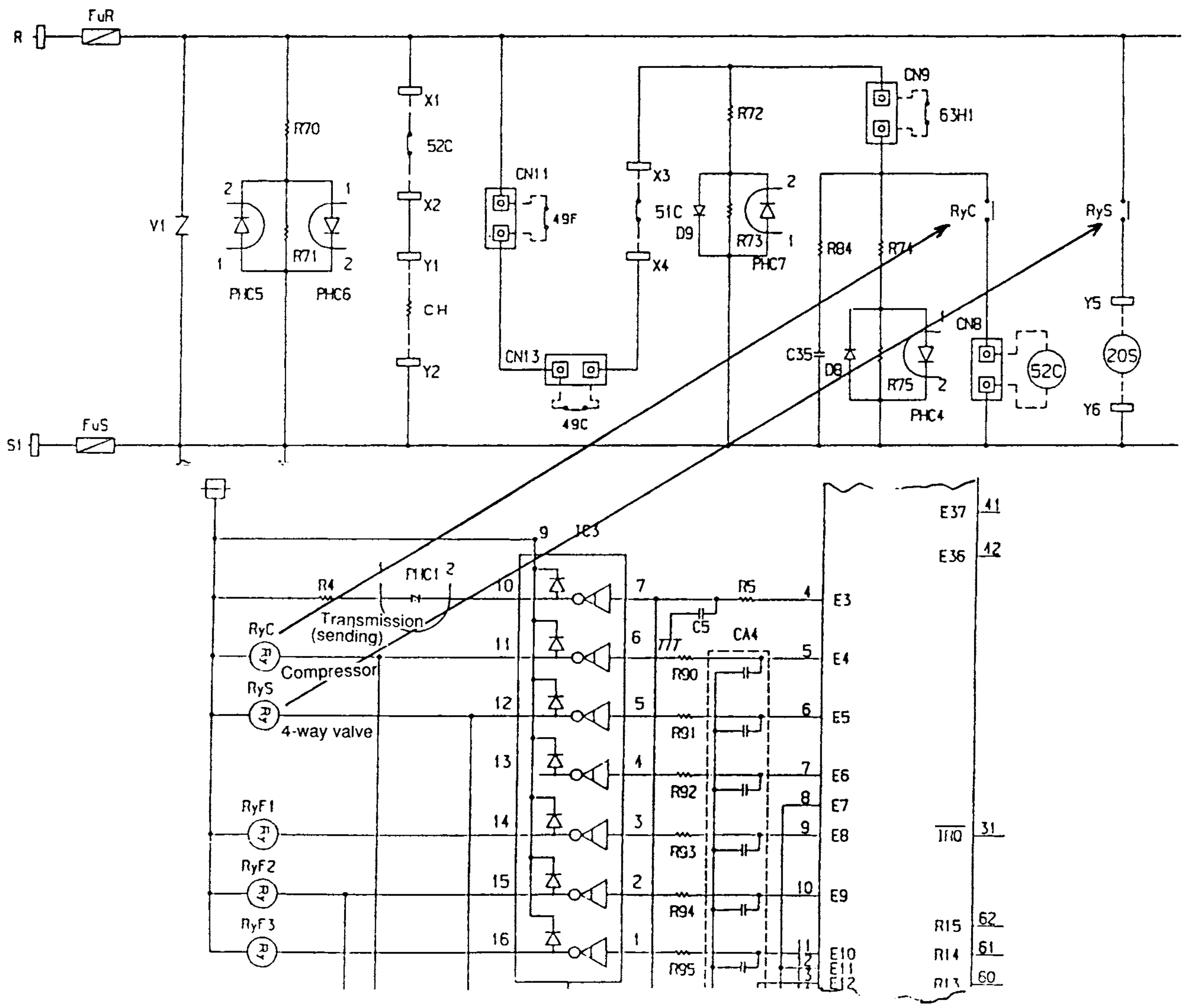
Although the relay is driven by the signal output by the microcomputer, the current output by the microcomputer is insufficient. Therefor, the current is amplified with a transistor or a driver (NOT IC) before it flows to the relay coil. In the figure below, the relay turns on when the output port of the microcomputer is H (50).

Fig.5-30



Relay drive circuit

Fig.5-31 Compressor drive circuit of Sky-Air System outdoor unit



(6) Microcomputer control of air conditioner

The circuits shown in Fig.5-32 and Fig.5-33 are the simple examples of microcomputer control circuits. The microcomputer determines the content to control based on the control signal sent from the remote controller and the data entered from the temperature sensor, and then outputs signals to the relay. Thus the microcomputer controls the indoor fan, compressor and solenoid valve coil, etc. In addition, the microcomputer sends signals to LEDs (light emitting diode) in order to display the operational conditions.

Fig.5-32 Example of microcomputer control (Sky-Air System)

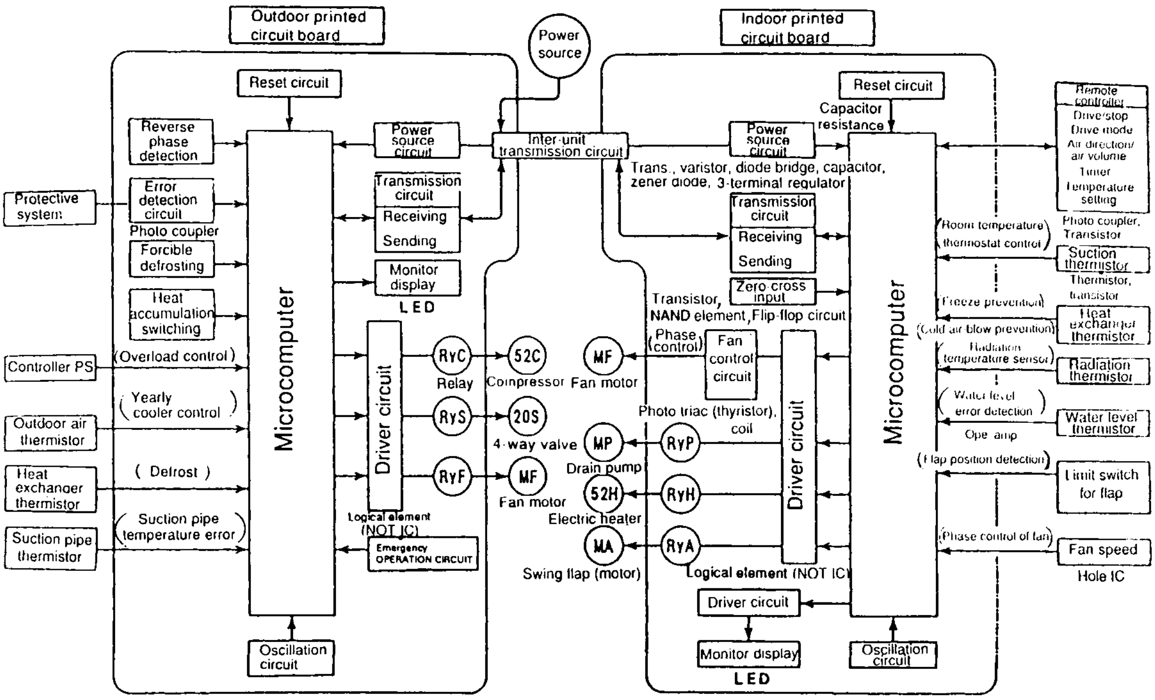
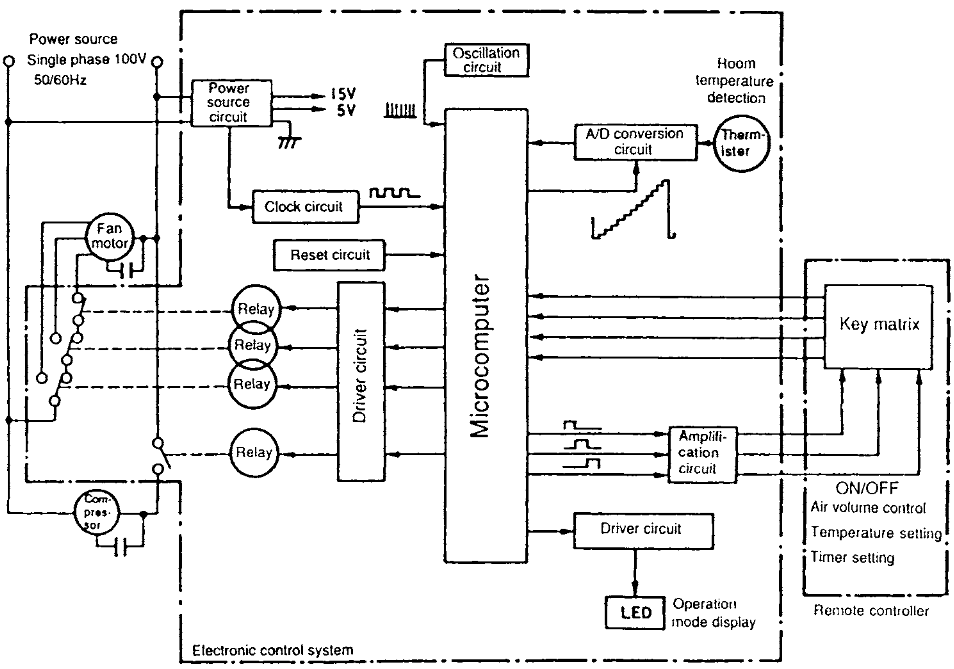


Fig.5-33 Example of microcomputer control (room air conditioner)



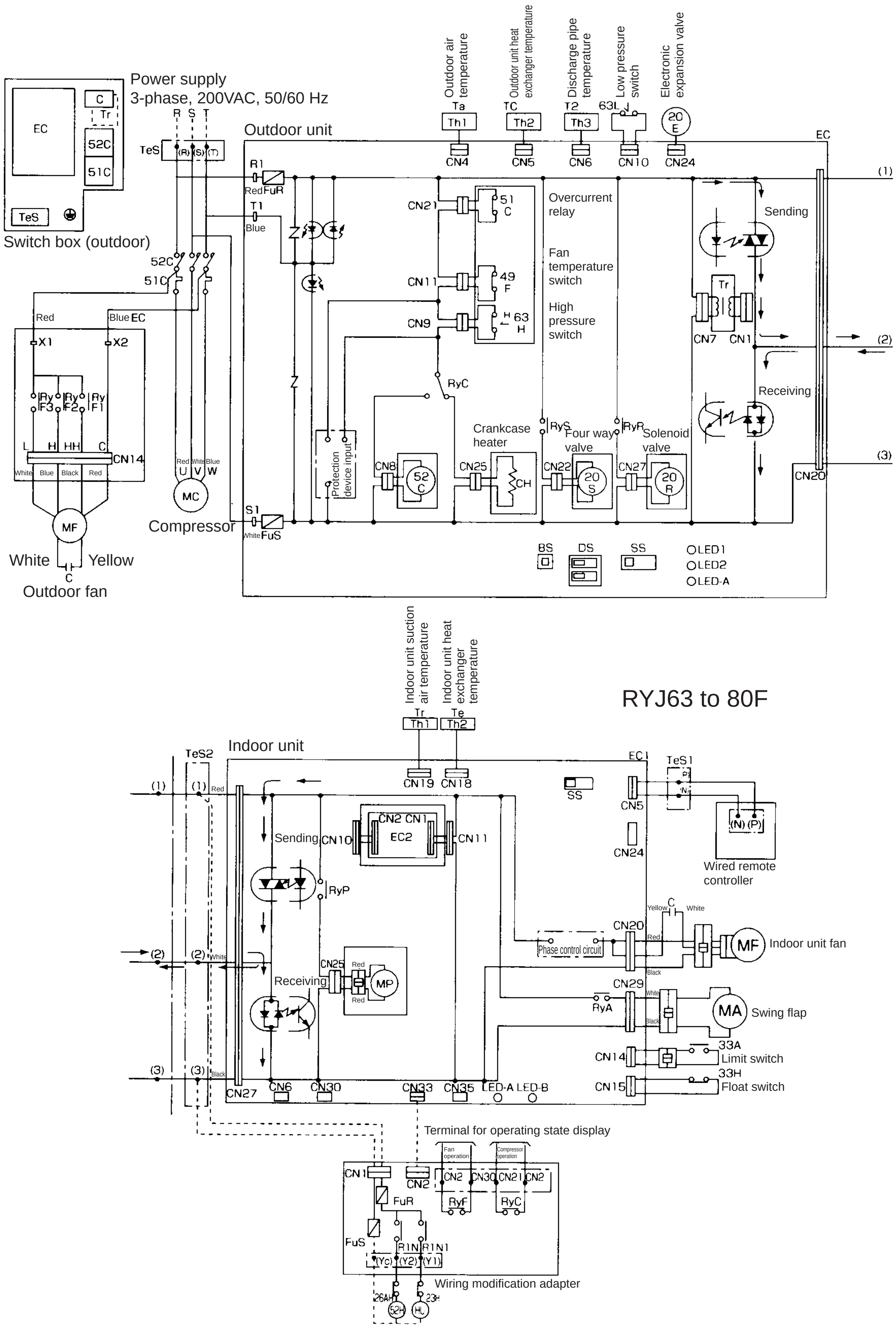
5.6 Electrical Wiring Diagram with frequent use of electronic control

In the previous sections, you have learned the outline of the types and functions of electronic parts.

This section describes the wiring diagram and the configuration of the functions on the latest air conditioners that make wide use of the electronic parts.

5.6.1 Electrical wiring diagram of SkyAir

Fig.5-34

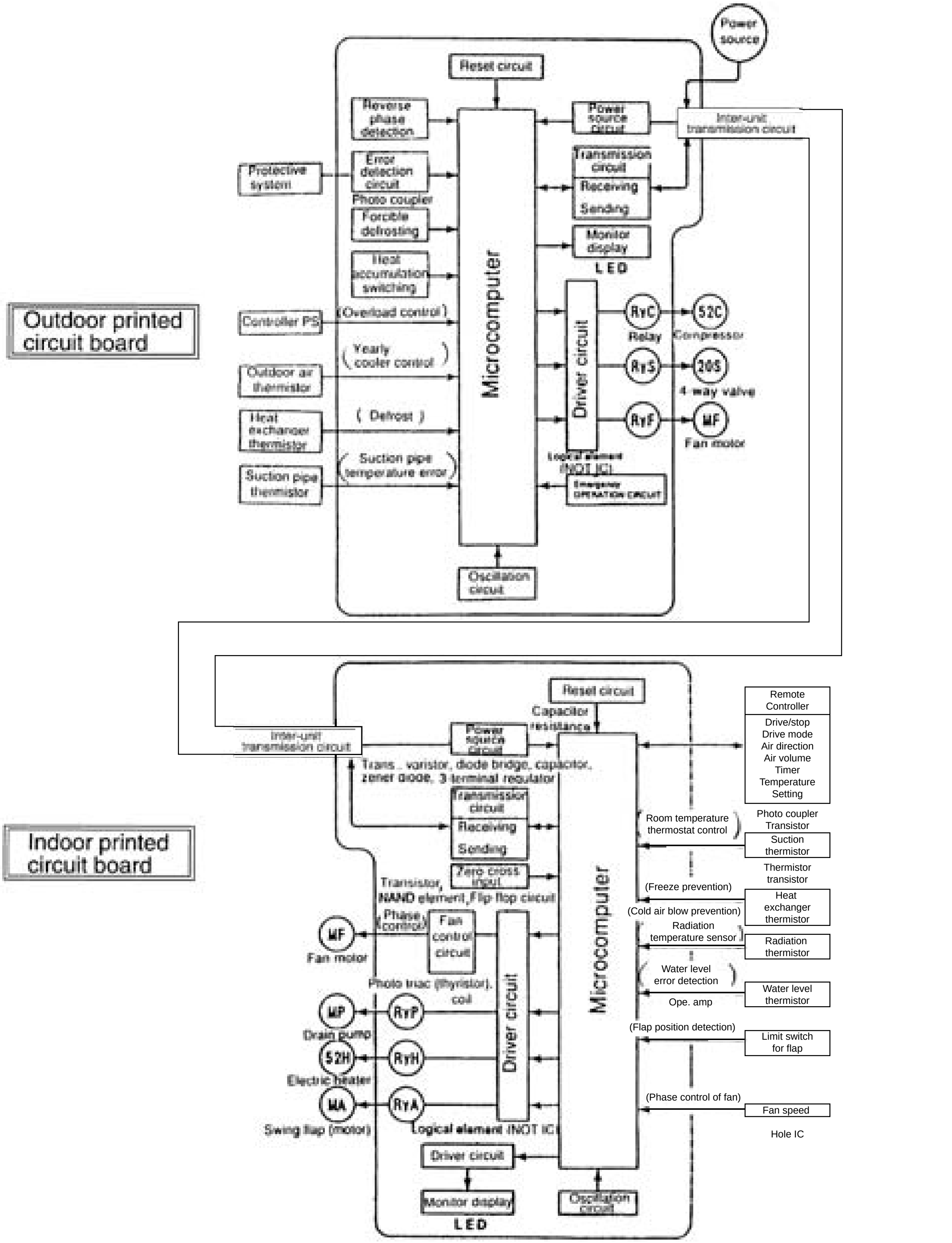


5.6.2 Example of Microcomputer control (SkyAir)

The functions of advanced air conditioners are programmed centering on the microcomputer, which can be called its very brain. Listing the major components, the functions required, and the control circuit makes it possible to draw the following figure.

Since room air conditioners have large variations by each model, we take SkyAir Type, which has comparably integrated functions, as the reference.

Fig.5-35 Example of microcomputer control (Sky-Air System)

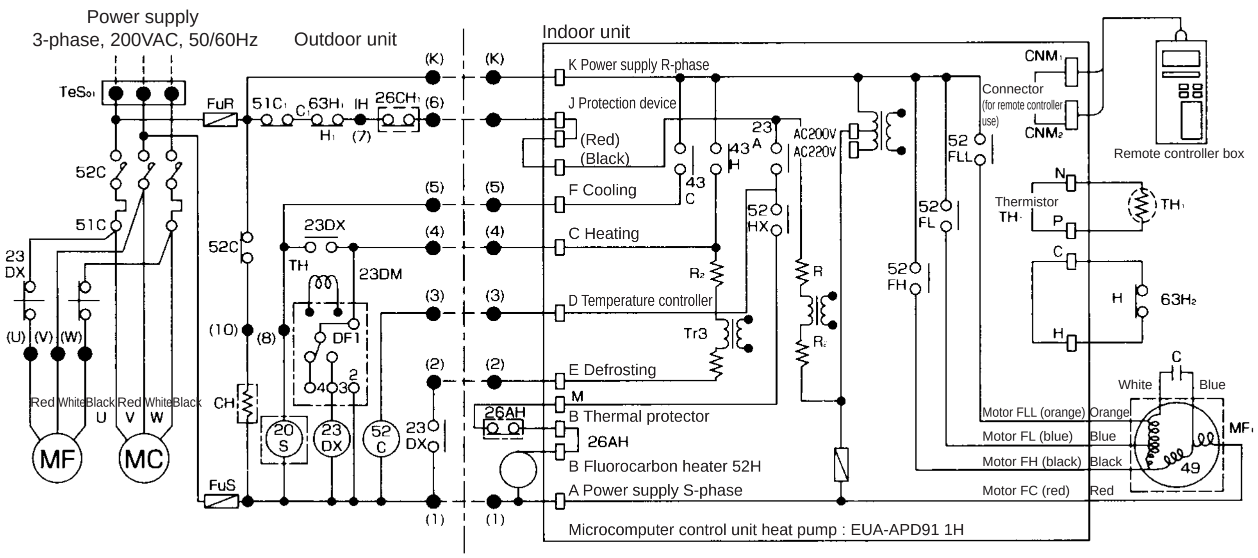


5.6.3 Multistage transmission between indoor and outdoor units

1. Conventional system

Data (control signal), which was transmitted from indoor unit to outdoor unit or vice versa, was transmitted in parallel through the connection cable (signal cable).
In other words, the conventional system transmits single data (control signal) through a single cable, and outputs in what status the data is at all times.
On this system, if the amount of data (control signal) increases, the number of the connection cables logically increases. The increased number of the connection cables results in more difficult installation work, higher costs, or increased errors.

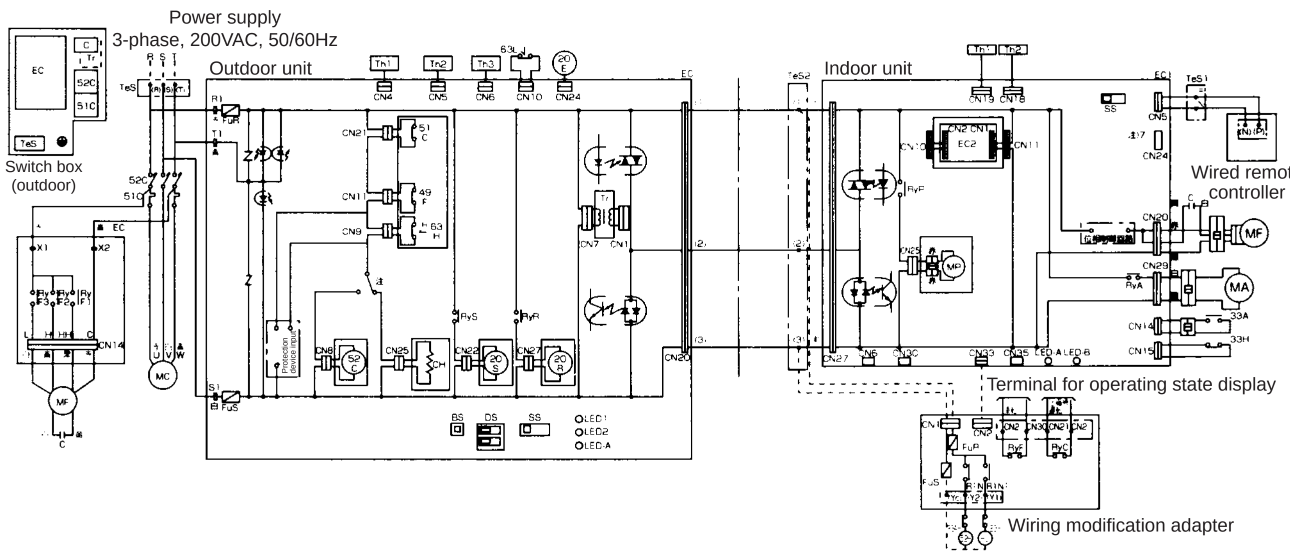
Fig.5-36



2. Multiplex transmission system (Transmission in series ···serial transmission)

The Multiplex Transmission is a system transmitting a number of data (control signals) through putting it in a pair of connection cables (signal cables), which can be considered the same as the telephone we use in a daily life. The telephone enables the transmission or hearing of a variety of data through putting it into words.
The multiplex transmission system on air conditioners transmits digital signals instead of words (analog sound signals). In other words, it sends the signals in series, thus being called "Serial Transmission".
There are two methods available to send the signals. The signals are sent through AM modulation (that is used for VRV, etc.) or through synchronization with power supply frequency. The SkyAir system and room air conditioners use the latter method to send the control signals.

Fig.5-37

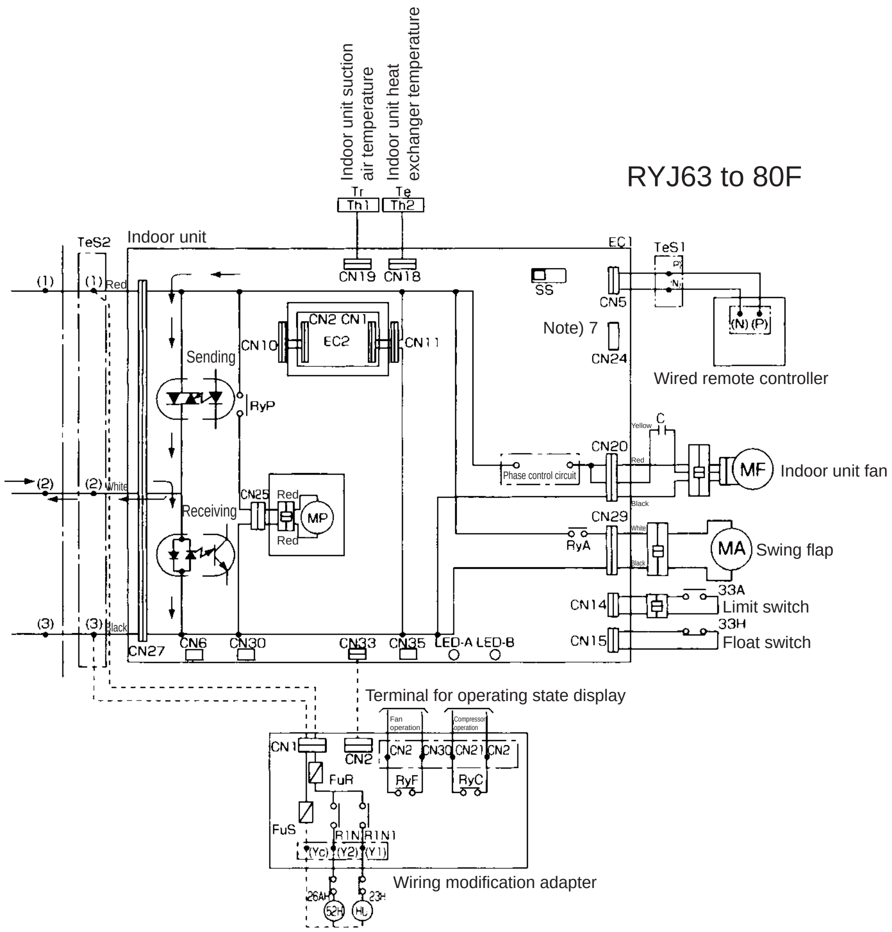


● Transmission circuit - Photo coupler
(Photo transistor, LED) •••Refer to information at Page 122~123.

5.6.4 Control and Function of Indoor Unit

This and the following sections highlight the control and functions of indoor unit and outdoor unit respectively. Since the technology of air conditioners is making steady progress, latest units have difference in detailed points from the description hereunder. The objective of this study is to acquire ability for seeing which part on the PC board controls a given function.

Fig.5-38



- **Thermostat control**
  Thermostat ON-OFF control is performed through the indoor unit suction air temperature or remote controller thermostat temperature. The compressor turns into the standby mode for 3 minutes for machine protection after the thermostat turns OFF, while the drain pump performs residual operation for 5 minutes for the residual drain treatment.
  The thermostat, however, does not turn OFF for 2 minutes and 30 seconds in the initial running.
  (Compressor ON protection control)

- **Microcomputer dry**
  The suction air temperature at the time of starting operation determines the points of turning the thermostat ON or OFF. No setting temperatures and airflow rate are displayed on the remote controller.

- **Blasting operation (indoor unit fan control)**
  Remote controller setting enables the control of airflow rate. LL operation is performed while the compressor stop running in heating mode.
  Furthermore, the fan motor on FHYCJ, FAYJ, and FHYL performs the phase control.

- **Drain pump control**
  In cooling operation, the drain pump runs in synchronization with the compressor, thus discharging drain water accumulated in the drain pan. (Refer to information in **Thermostat control** above. Furthermore, in heating operation, on units with a humidifier equipped, setting to "With drain pump humidifier interlock equipped" through the remote controller local setting runs the drain pump by interlocking it with the humidifier.

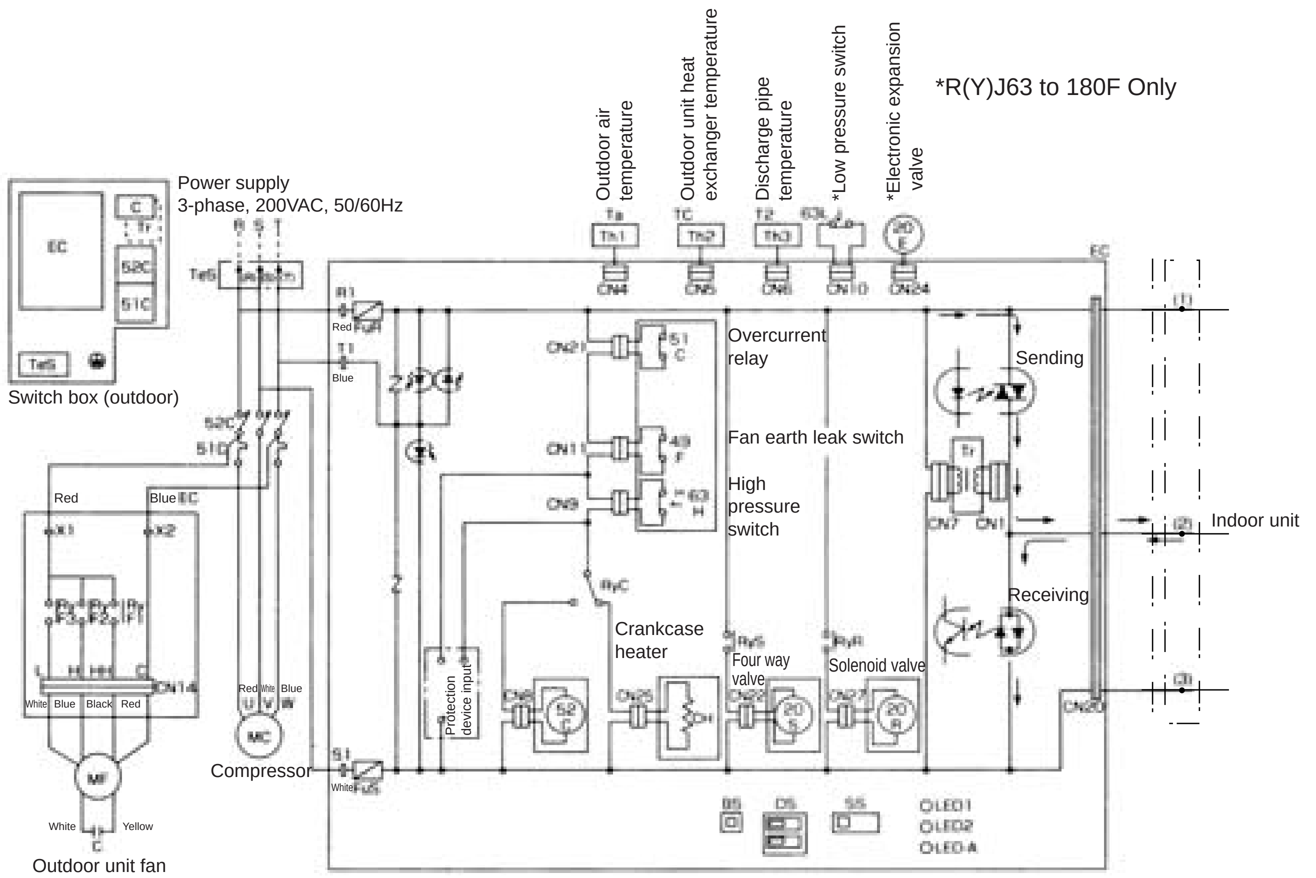
- **Freeze-up protecting function (in cooling operation)**
  While in wet operation and others, this function is used to prevent the frosting and freezing-up of indoor unit heat exchanger,
  If the system judges that the indoor unit heat exchange temperature has fallen to freeze up the indoor unit heat exchanger, the system will stop the compressor and turn into the state of thermostat OFF. It will be reset only after 10 minutes elapses with the indoor heat exchange temperature of 7˚C or more.

- **Heating overload control (in heating operation)**
  In order to prevent the abnormal high-pressure increase in heating operation, this control is used to decelerate the outdoor unit fan as the indoor unit heat exchange temperature (condensation temperature) rises.

- **Cool air prevention function (in heating operation)**
  When the unit starts the heating operation, in order to prevent the draft, the indoor unit fan performs LL operation and the flap keeps horizontal air-blow after the compressor turns ON until the indoor unit heat exchange temperature reaches a temperature of 34˚C or more, or 1 minute elapses. (No displays are available.)

5.6.5 Control and function of outdoor unit

Fig.5-39



- **Compressor ON/OFF control**
  This control is used to turn the compressor ON or OFF according to the thermostat command from the indoor unit. Even with thermostat turned ON, the compressor stops running if any command such as freeze-up protection or high-pressure protection is sent.

- **Four way valve control**
  The changeover (energizing/de-energizing) of this four way valve enables the switching to cooling or heating mode. Four way valves on Model D or later in the case of the SkyAir system are energized while in heating mode. Furthermore, the switching is enabled only while the unit is running.

  Four way valve ON: In heating operation except for while in defrosting operation
  Four way valve OFF: In cooling operation, microcomputer dry operation, and defrosting operation

ONE POINT
Four way valves on model C or older are energized in cooling operation (energized in cooling operation on all RA models).

- **Defrosting**
  Defrosting startup control is called "intelligent system", which will start the control if the conditions such as compressor operating cumulative time, heating integral capacity, relation between outdoor air temperature and outdoor heat exchange temperature, and relation between overloading state and outdoor fan OFF are satisfied.
  The defrosting will end if the conditions such as outdoor heat exchange temperature, elapsed time after the startup of defrosting, and discharge pipe temperature are satisfied.

- **Outdoor fan control**
  The following controls are performed for the outdoor air temperature and the indoor unit suction air temperature, and furthermore, with combined use of the indoor unit heat exchange temperature while in high-pressure control (heating operation).
  - Outdoor unit fan startup control
  - Defrosting prevention control
  - Yearly cooling control
  - Overload control

- **Electronic expansion valve control**
  (1) Electronic expansion valve initializing
  When approximately 40 seconds elapses after the power supply is turned on, in order to fully close the electronic expansion valve, throttle the valve by 520 pulses.
  (Fully closed: 0 pulse Fully open: 480 pulses)

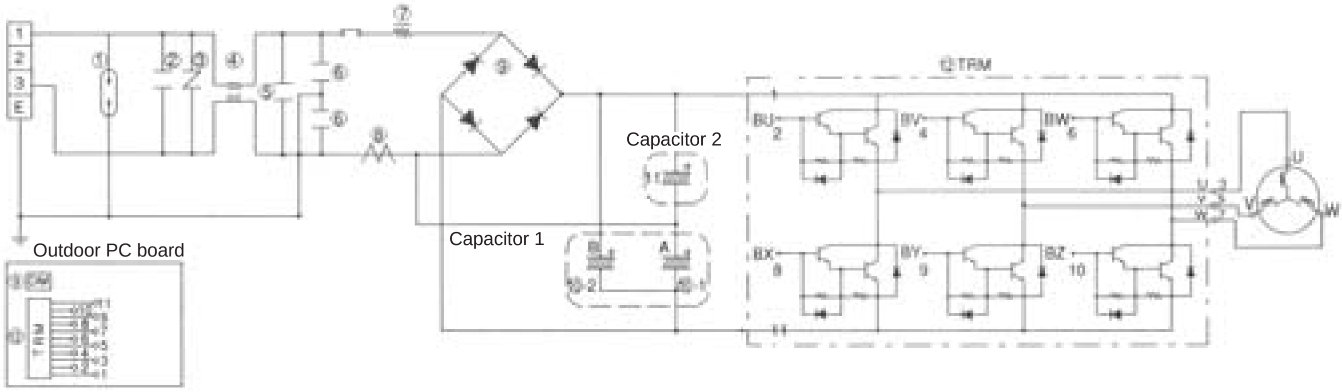
  (2) Discharge pipe temperature control
  According to the indoor unit heat exchange temperature, outdoor heat exchange temperature, and outdoor air temperature, an optimum discharge pipe temperature in the present operating state is calculated, thus controlling the electronic expansion valve so that the discharge pipe temperature comes closer to the optimum one. (Once in 20 seconds)

- **Discharge pipe temperature protection control**
  1. Abnormally high discharge pipe temperature
     This control is used to prevent the burnout of compressor due to the rise of discharge pipe temperature.
     If discharge pipe high temperature thermostat OFF (consecutive 100 seconds at a temperature of 123.5˚C or more, or consecutive 20 seconds at a temperature of 140˚C or more) occurs 6 consecutive times, the compressor stops due to the abnormality. (Malfunction Code: F3)
  2. Wet operation protection
     While in wet operation, this control is used to prevent burnout due to diluted oil in the compressor or damage due to liquid compression.

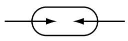
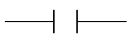
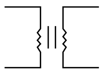
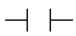
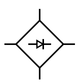
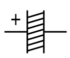
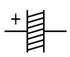
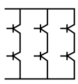
5.7 Inverter Circuit and Control

5.7.1 Configuration of inverter circuit (RAZ226X)

Fig.5-40



5.7.2 Components used for inverter circuit and functions

No.	Symbol	Part Name	Function
(1)		Arrestor	Used to absorb surge voltage (e.g. lightning) of 3600V or more.
(2), (5)		Capacitor (X capacitor: To be extended to power supply.)	Used to absorb noise.
(3)		Varistor	Used to absorb surge voltage (e.g. lightning) of 430V or more.
(4)		Common mode choke coil	Used to absorb noise in common mode (same phase).
(6)		Capacitor (Y capacitor: To be grounded.)	Used to absorb noise.
(7)		Reactor	Used to upgrade input power factor. The reactor is inserted between the power supply and the capacitor and compensates the lead phase caused by capacitor with the coil (reactor) that is a part in lag phase.
(8)		CT (current transformer)	Used to convert the input current into the direct current signal of constant voltage. Applied to detect the input current. Rectification.
(9)		Diode bridge	Used for rectification to convert the AC voltage to the DC voltage (limiting to pulsation flow).
(10)-1(A) (11)		Electrolyte capacitor	Used per a pair of two capacitors to generate the DC voltage of 282V from the AC voltage of 100-V double-voltage rectifying capacitor.
(10)-2(B)		Electrolyte capacitor	This is a smooth capacitor, which is used to turn the DC voltage of pulsation flow rectified through the diode bridge into the smooth DC voltage.
(12)		TRM Power transistor module	Used to convert the DC voltage into the AC voltage of the frequency demanded according to the command of the microcomputer, thus feeding it to the compressor.

5.7.3 Inverter control

The inverter means "DC-AC conversion device". When the inverter is used on air conditioners, it is referred to as a frequency conversion system, which can generate AC current having arbitrary frequency and voltage from the AC power supply for commercial use, including the converter's "AC-DC conversion device" function. This inverter enables free changes of the compressor motor speed.

Operating principle of inverter

(1) 100-VAC power is converted into 280-VDC power through the power supply unit (rectifying circuit). (Double-voltage rectifying circuit made in combination with capacitor and diode)

(2) As shown in the inverter circuit on the right, the microcomputer outputs the ON/OFF signal (i.e., PWM waveform : Pulse Width Modulation) of inverter switch (power transistor) according to the operating sequence (1) through (6).
When the operations (1) through (6) are switched 90 times per second (90Hz), the motor speed is 90 rotations per second, that is, 5400 rpm (in the case of the number of poles of motor is 2).
Furthermore, the switch waveform per rotation is pulse voltage (PWM waveform) finely divided.
Thus, the following section describes the outline configuration of the inverter.

Fig.5-41

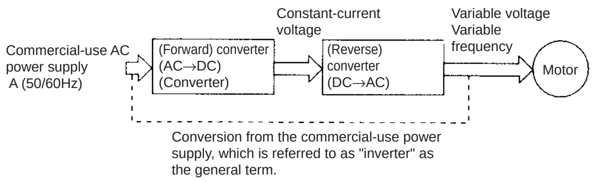


Fig.5-42

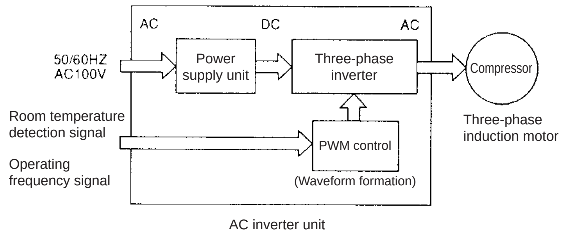


Fig.5-43

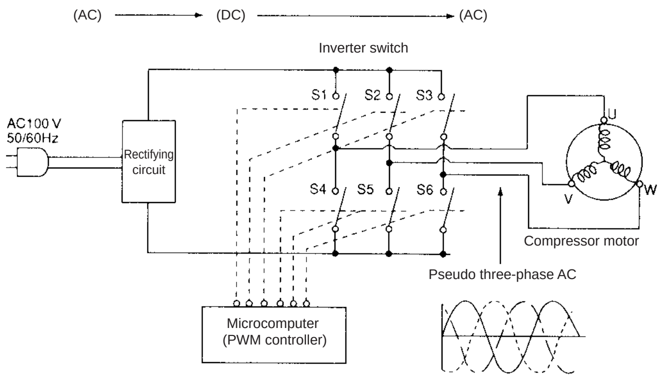
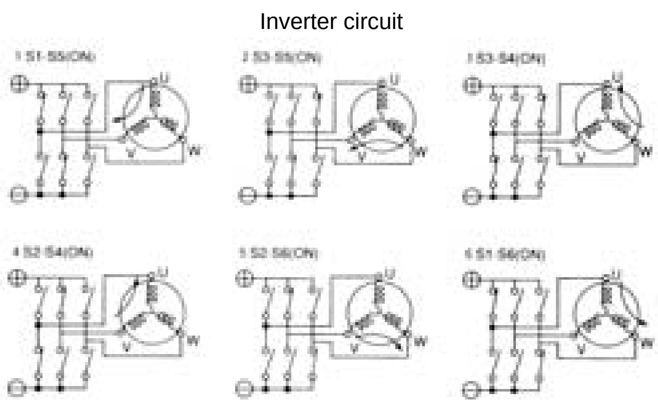
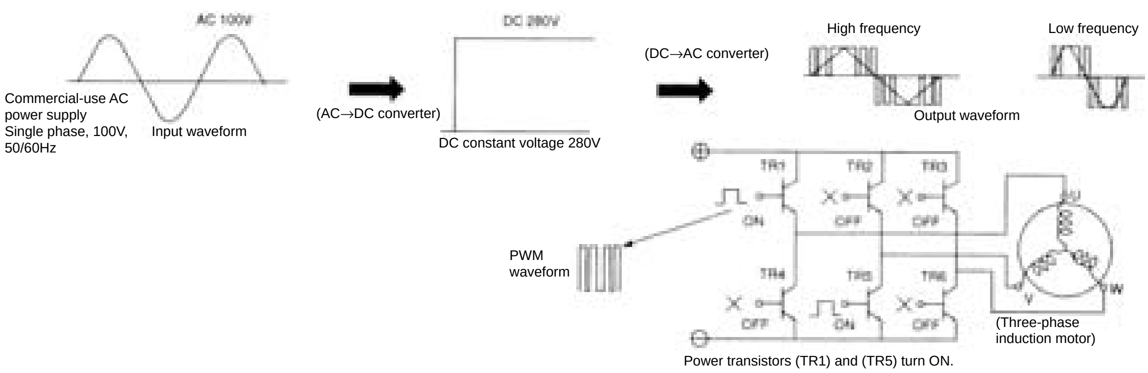


Fig.5-44



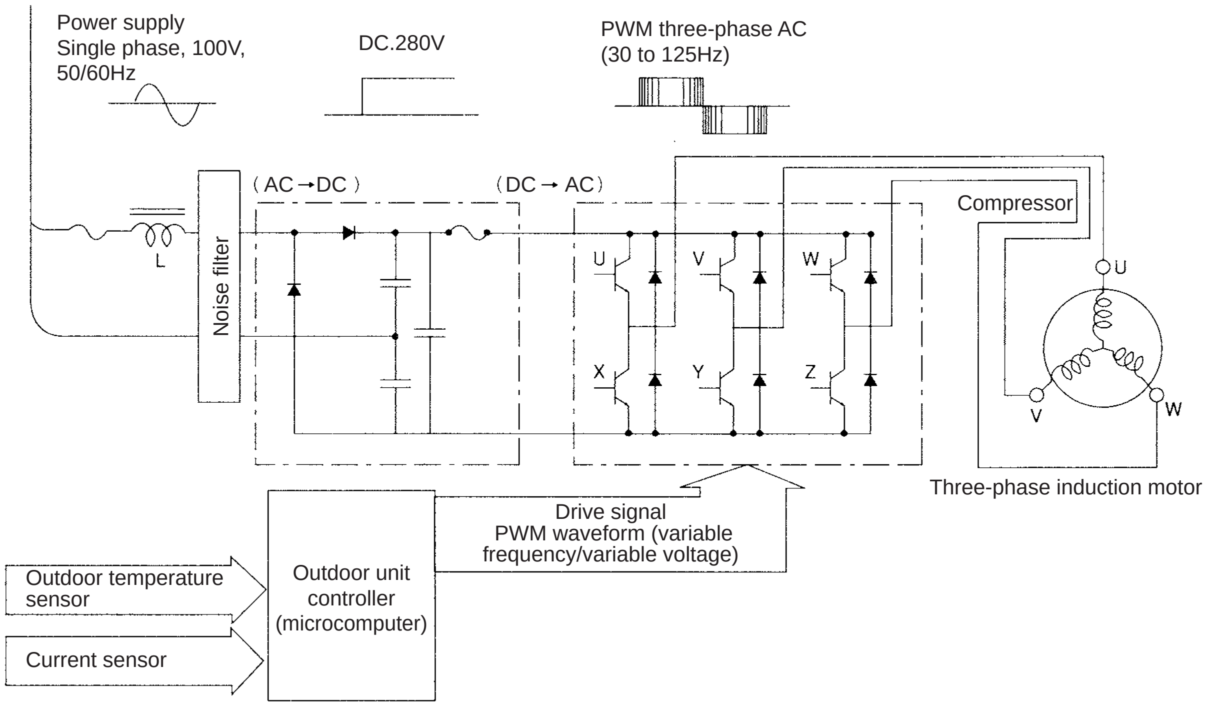
Operating sequence of inverter switch

Fig.5-45



5.7.4 Configuration of inverter

Fig.5-46



5.7.5 Features of inverter air conditioners

The stepless variable control of compressor rotation speed enables the capacity control of air conditioners in accordance with the load applied.

As a result, the following features are achieved.

(1) The operating efficiency is upgraded, thus saving the power consumption.

(2) The startup loss due to the compressor ON/OFF is reduced. (The number of compressor ON/OFF frequencies is minimized.)

(3) The fluctuation in the room temperature is minimized, thus achieving higher degree of comfort.

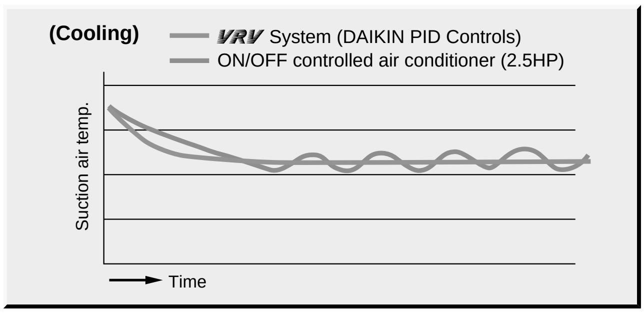
(4) The startup current consumption is reduced. (Units can start at a low frequency and a low voltage.)

(5) Low-temperature characteristics in heating operation are improved.

(6) Defrosting speed is improved, and the defrosting capacity in positive cycle is upgraded.

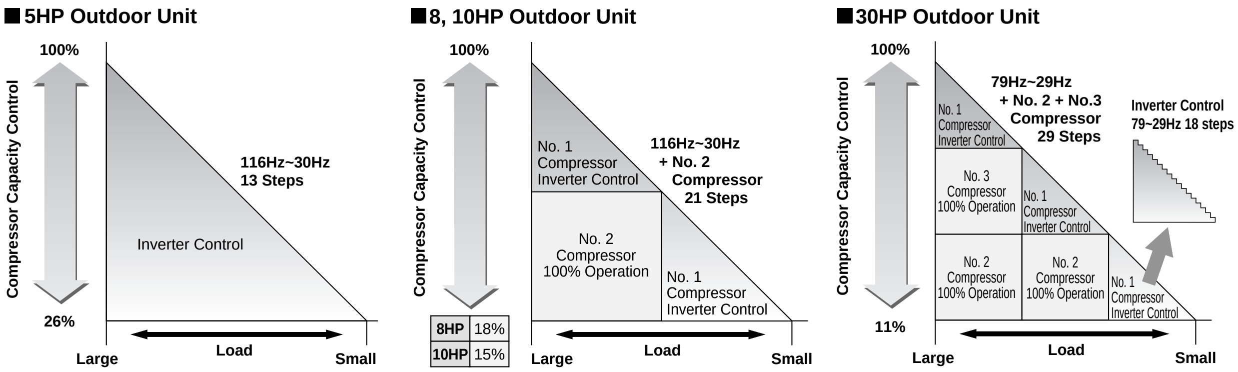
5.7.6 Precise room temperature control

- Electronic expansion valves respond to changes in load in indoor units and continually control the flow rate of refrigerant. In this way, the VRV system maintains a nearly constant room temperature without the typical temperature changes that occur with a conventional ON/OFF control system. The extremely refined PID control maintains the room temperature within ±0.5 ˚C of the set temperature.



5.7.7 Inverter-driven capacity control

Fig.5-47



Chapter 6 Basic works

Chapter 6 Basic works

6.1 Piping

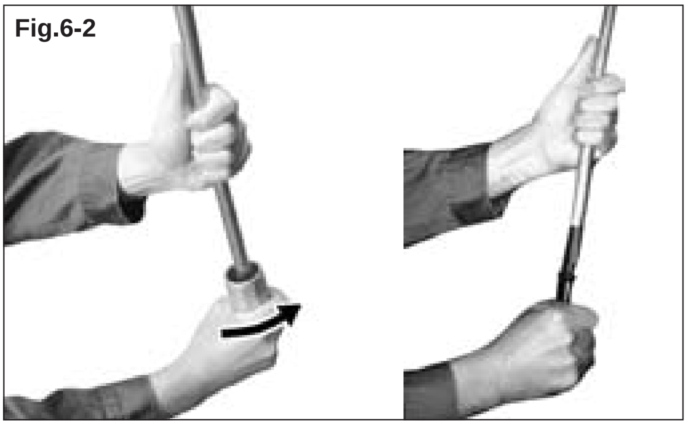
6.1.1 Flaring

(1) Cut copper tube.
- Turn the pipe cutter counterclockwise to cut it off.
- Slowly slide the knob of the pipe cutter.

Fig.6-1

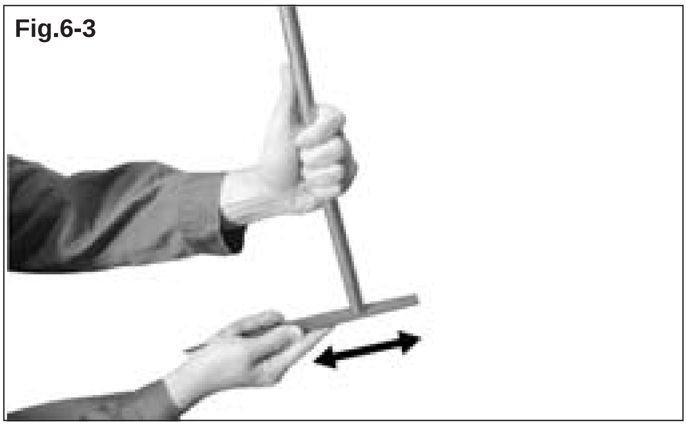
(2) Remove burr from cut face (by a reamer).
- Place the copper tube downwards.
- Do not impair the internal surface of copper tube.

Fig.6-2



(3) Smoothen cut face. (by a file)
- Place the copper tube downwards.

Fig.6-3

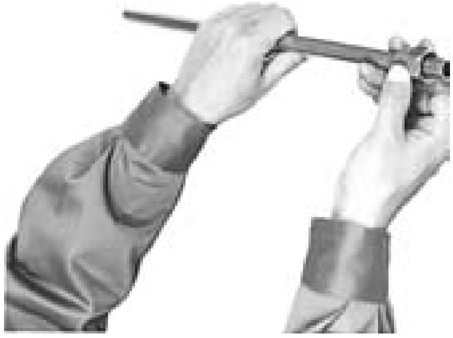


(4) Clean the internal surface of copper tube.
- Completely remove chips from the copper tube.
  (If chips remain in the pipe, the compressor metals may be worn out.)

Fig.6-4

(5) Insert a flare nut onto the pipe.
- Do not forget to insert the flare nut before flaring the pipe end, because a flare nut cannot be inserted onto a pipe after flaring it.

Fig.6-5



(6) Nip the pipe with the flare die.
- Confirm that the internal part of the flare die is cleaned.
- Nip it at the predesigned size.

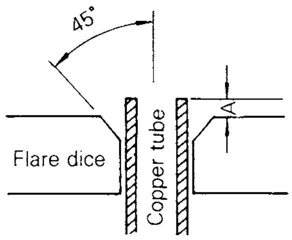
Fig.6-6

Measurement from the die surface to the end of the copper tube.
- If A measurement is small, connecting part of flare is small accordingly, which may cause gas leakage.

Size of copper tube	ϕ 6.4 (1/4”)	ϕ 9.5 (3/8”)	ϕ 12.7 (1/2”)	ϕ 15.9 (5/8”)	ϕ 19.1 (3/4”)
A	0.5mm				1.0mm

Caution: Refer to p.326 and 328 for “A“ measurement of R410A flaring

Fig.6-7



(7) Set the punch body as shown in the photo.
- Set the punch body to the designed position on the flare die.

Fig.6-8

(8) Flaring

- Tighten the handle of the flare die until it turns idle after giving click noise.(in case of RIDGED type)

Fig.6-9

(9) Remove the flare die.

- Turn the handle counterclockwise to its top position.

Fig.6-10

(10) Inspect flaring surface.

- Is flaring part eccentric?
- Is flaring part cracked?
- Is there any scar on flaring part?
- Is there any burr left on flaring part?

Fig.6-11

Measurement of flaring part when finished (JISB8607-1975)

(Unit: mm)

Nominal dia	Pipe external diameter (D)	A
1/4"	6.35	8.3~8.7
3/8"	9.52	12.0~12.4
1/2"	12.7	15.4~15.8
5/8"	15.88	18.6~19
3/4"	19.05	22.9~23.3

Caution: Refer to p.326 and 328 for "A" measurement of R410A flaring

Fig.6-12

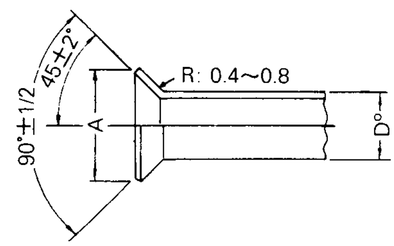
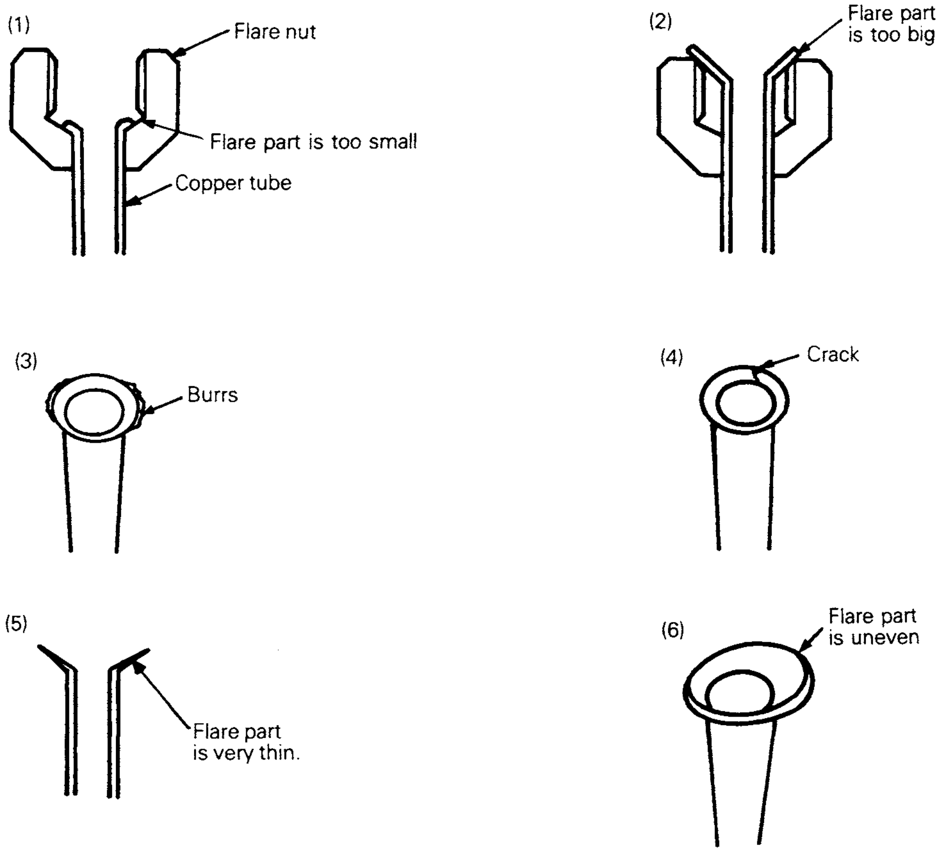


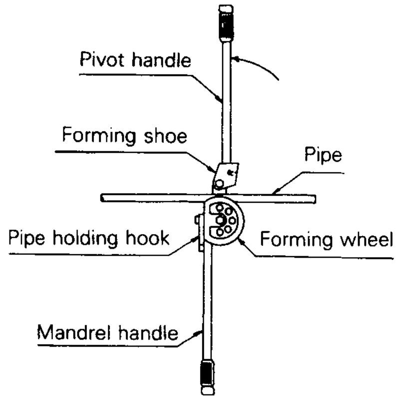
Fig.6-13 Examples of bad flaring



6.1.2 Bending

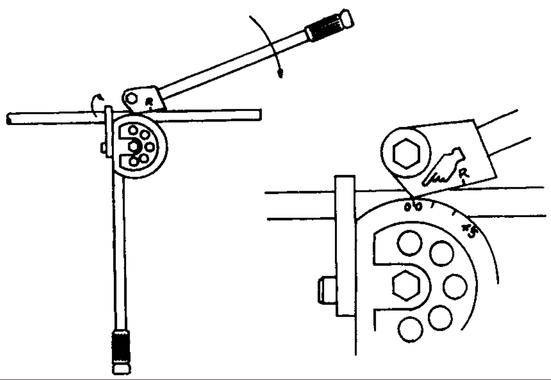
(1) To insert a pipe into the bender, place the handles by 180˚, and raise the pipe holding hook out of place.
Place a pipe in the forming wheel groove.

Fig.6-14



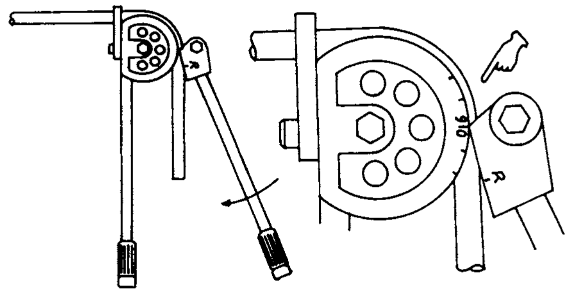
(2) Place the pipe holding hook over a pipe and bring the handle to approximate right angle position,
engaging the forming shoe over tubing. Note that zero mark on the forming wheel is even with the front edge of the handle forming shoe.

Fig.6-15



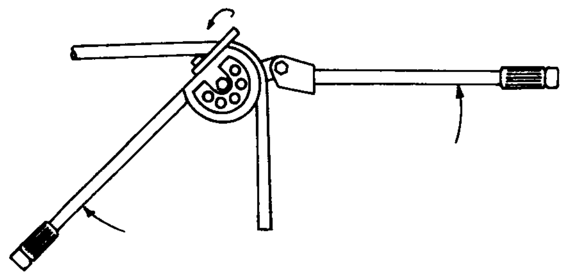
(3) Proceed to bend a pipe by desired angle as indicated by calibrations on the forming wheel. Bend it by up to 180˚ with a single, smooth, and continuous motion.

Fig.6-16 In case of 90˚ bending



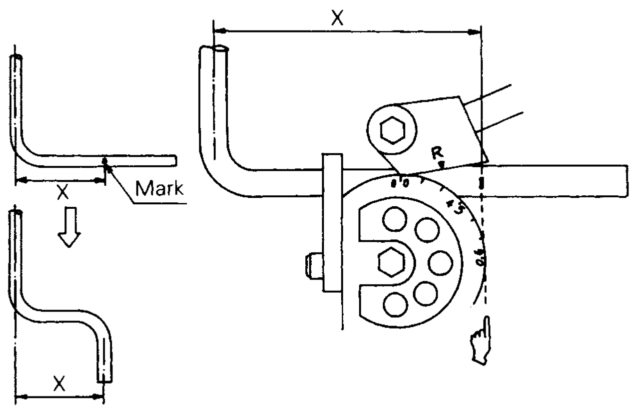
(4) To remove a pipe, pivot handle to right angle with a pipe, disengaging the forming shoe. Release the pipe holding hook and remove a pipe.
Note:
Apply oil occasionally to the handle pins and handle forming shoe for easier bending. The forming wheel groove should be kept dry and clean to prevent a pipe from slipping while bending. For pipes to be bent hardly, hold the mandrel handle in a vise. Lock the vise jaws as near as possible to the forming wheel as practical to bend a pipe.

Fig.6-17



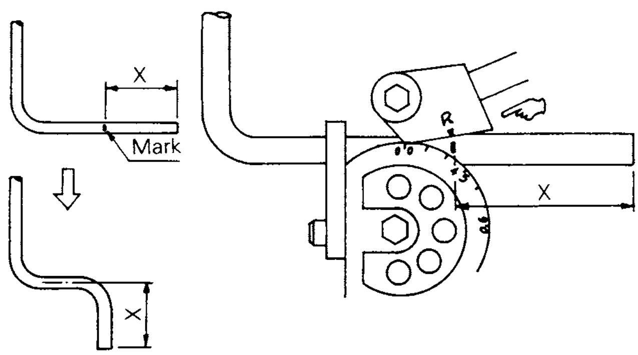
Guide for marking dimensional bends.
Place a pipe in the bender as shown on the right.
Align "X" dimension mark with edge of the forming wheel.

Fig.6-18



Place a pipe in the bender as shown on the right.
Align "X" dimension mark with "R" mark on the handle shoe.

Fig.6-19



6.1.3 Brazing

(1) Hard brazing

Hard brazing means brazing with soldering materials, fusing point of which is over 450˚C.

Consequently hard brazing work is not so easy as that of soft brazing. However, hard brazing excels in strength and thermal resistance. Certain Solders stand against applications up to 800˚C. In addition, solders which excell in acid proof are available. Solders which are commonly used are silver, brass, aluminium, libethenite or thermal resistance alloy solder.

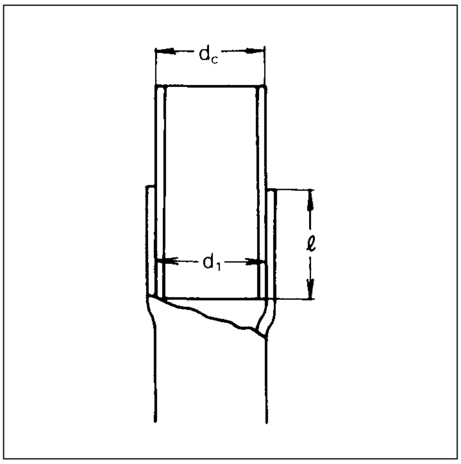
Silver solder is an alloy of mainly silver, copper and zinc and its color is yellow. This fuses at comparatively low temperature approximately from 600˚C to 800˚C and its fluidity is excellent. Brass solder is an alloy of mainly copper and zinc, but sometimes nickel, tin and stibium are added. This solder is good in color and excellent in acid proof. Normally brazing with these solders is called by the name of solder used instead of hard brazing.

(2) Kind of brazing rod

Material	Braze rod		Flux	Fusing temp ˚C	Shearing force kg/mm^2
	Trade name	Spec. JIS Z3264			
Copper-copper	Copsil-2 (NEIS Co.)	BCup-6	—	735~815	Approx 25
Copper-steel Copper-cast iron	Brass-64 (NEIS Co.)	BCuZn-1	F64	905~955	Approx 30
Copper-brass Copper-steel Copper-cast iron	Sil 107 (NEIS Co.)	BAg-2	F107	700~845	Approx 20

(3) Inserting measures of pipes and specifications of burner

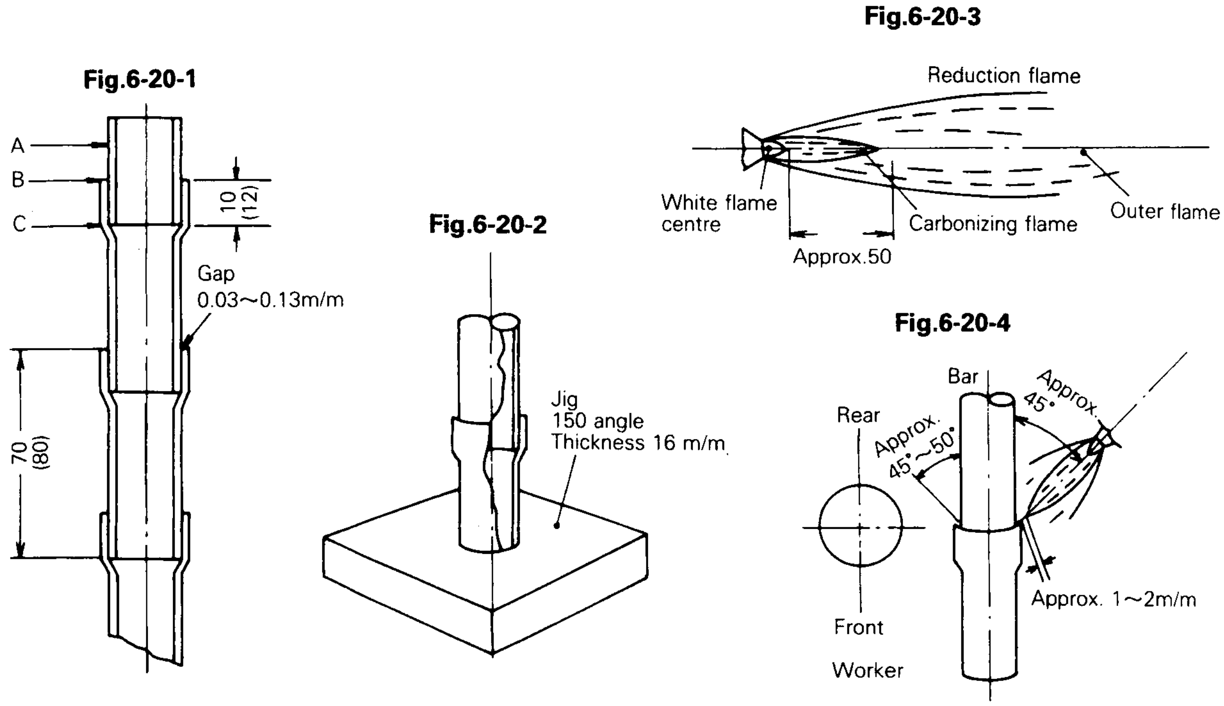
Pipe dia. (ϕ)	d_C	d_1	ℓ (Cu vs. Cu)	ℓ (Al vs. Al)	Burner (Cu vs. Cu)	Burner (Al vs. Al)
6.4	6.350	$6.45^{+0.1}_{0}$	7	6	# 50	#140~#200
7.9	7.938	$8.05^{+0.1}_{0}$	7		≀	
9.5	9.525	$9.65^{+0.1}_{0}$	7	7	#250	#200~#225
12.7	12.700	$12.85^{+0.15}_{0}$	9	8		#225~#250
15.9	15.875	$16.05^{+0.15}_{0}$	10.5	10		#225~#300
19.1	19.050	$19.20^{+0.15}_{0}$	10.5		#250	
22.2	22.225	$22.40^{+0.15}_{0}$	11	11	≀	#250~#450
25.4	25.400	$25.60^{+0.2}_{0}$	12	13.5	#500	#400~#500
31.8	31.750	$31.95^{+0.2}_{0}$	13			
38.1	38.100	$38.30^{+0.2}_{0}$	14			



(4) Detailed examples of brazing work

Fig.6-20

a. Downward brazing for copper pipe 5/8” 15.9mm (1’25.4mm)
Parenthesized figure is for 1” pipe.



Work step	Work order	Auxiliary and other materials		Jigs, tools and devices	Work conditions	Points and reasons
		Name	Spec.			
1	Cleaning the mother material and inspecting brazing parts.		CuT 5/8” (1”)		( )is for 1” pipe	1. Remove oil, rust and other impurities from the brazing part. 2. No burr or deformation is found at the brazing part.
2	Adjusting flame length		-do-		Downward brazing	1. Length of carbonizing flame should be approx. 50mm with reduction flame.
3	Preheating		-do-	Burner #200 (250)	-do-	1. Evenly heat pipe periphery, but do not heat the part marked with B in Fig. 6-20-1 as much as possible, but heat the places marked with A and C in that order. 2. Direct flame to the center of a mother metal.
4	Brazing	B Cup 1.6mm (2.4mm)	-do-	-do-	-do-	1. Hold a soldering material just like one holds a pencil and press it to joint part. Holding angle is 45~50˚. 2. Start fusing a material, considering timing of preheating. See Fig 6-20-4. 3. Make fusing flow like a liquid as quick as possible. 4. Interval between the tip of carbonizing flame and a mother metal should be approx. 1~2mm.
5	Confirming brazed parts					1. Soldering material is fused evenly at the brazed part. 2. No pin hole and drop is found in the braze part.

Fig.6-21

b. Upward brazing for copper pipe 5/8" 15.9mm (1"25.4mm)
Parenthesized figure is for 1" pipe.

Fig.6-21-1

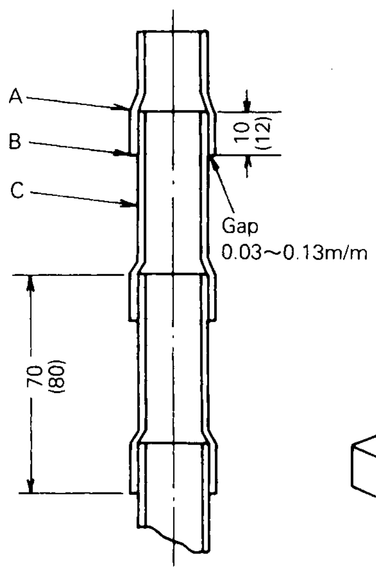


Fig.6-21-2

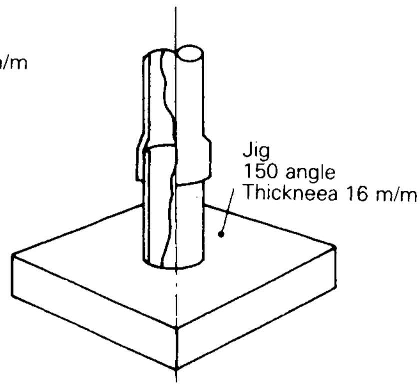


Fig.6-21-3

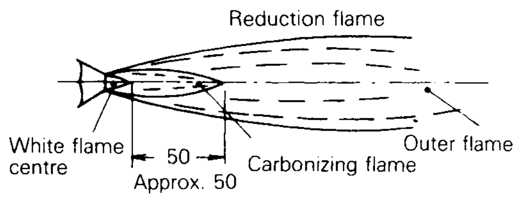
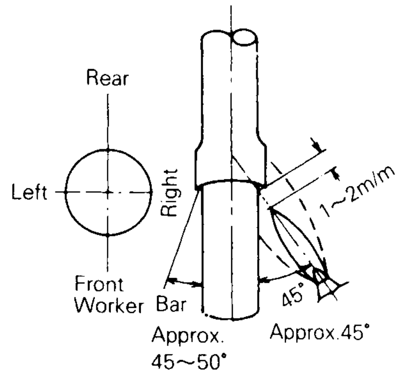
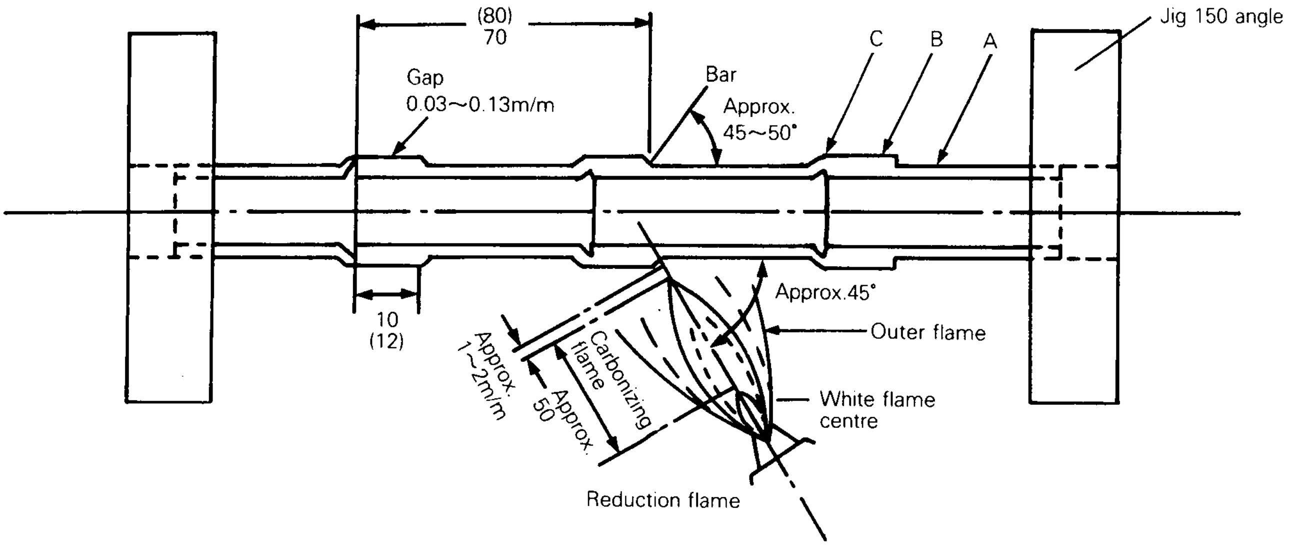


Fig.6-21-4



Work step	Work order	Auxiliary and other materials		Jigs, tools and devices	Work conditions	Points and reasons
		Name	Spec.			
1	Cleaning the mother material and inspecting brazing parts.		CuT 5/8" (1")		( )is for 1" pipe	1. Remove oil, rust and other impurities from the brazing part. 2. No burr or deformation is found at the brazing part.
2	Adjusting flame		-do-		Upward brazing	1. Length of carbonizing flame should be approx. 50mm with reduction flame.
3	Preheating		-do-	Burner #200 (250)		1. Evenly heat pipe periphery, but do not heat the part marked with B in Fig 6-21-1 as much as possible but heat the places marked with A and C in that order. 2. Direct flame to the centre of a mother metal.
4	Brazing	B Cup 1.6mm (2.4mm)				1. Hold a soldering material just like one holds a pencil and press it to the joint part. Holding angle is 45~50˚. 2. Fuse soldering material in a small quantity into a gap so as not to drop it down, considering timing of preheating. 3. Do such work stated above quickly. See Fig.6-21-4. 4. Interval between the tip of carbonizing flame and the mother metal should be approx. 1~2mm.
5	Confirming brazed parts					1. Soldering material should be fused evenly at the brazed part. 2. No pin hole and drop is found in the brazed part.

Fig.6-22



Work step	Work order	Auxiliary and other materials		Jigs, tools and devices	Work conditions	Points and reasons
		Name	Spec.			
1	Cleaning the mother material and inspecting brazing parts.		CuT 5/8" (1")		( )is for 1" pipe	1. Remove oil, rust and other impurities from the brazing part. 2. No burr or deformation is found at the brazing part.
2	Adjusting flame		-do-		Horizontal brazing	1. Length of carbonizing flame should be approx. 50mm with reduction flame.
3	Preheating		-do-	Burner #200 (250)	-do-	1. Evenly heat pipe periphery, but do not heat the part marked with B in the above figure as much as possible but heat the lower part of A and C in that order without directing flame as much as possible. 2. Direct flame to the centre of the mother metal.
4	Brazing	B Cup 1.6mm (2.4mm)	-do-	-do-	-do-	1. Hold a soldering material just like one holds a pencil and press it to the joint part lightly. Holding angle is 45~50˚. 2. Fuse soldering material in a small quantity from the lower part of a gap, and make it flow to the upper part by means of capillary action. 3. Heat the upper part a little so that fused material can be moved horizontally. Be careful not to drop it. 4. Interval between the tip of carbonizing flame and the mother metal should be approx. 1~2mm.
5	Confirming brazed parts					1. Soldering material is fused evenly at the brazed part. 2. No pin hole or drop is found in the brazed part.

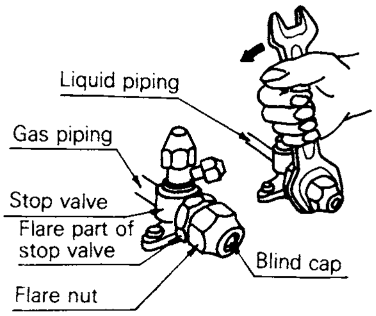
6.1.4 Flare tightening

Flare joints are used in almost all split type air conditioners. Tightening of flare joints is one of the important tasks in the piping work. No matter how accurately the flare nut is machined, if the flare nut is inaccurately tightened, the piping cannot be laid correctly. Since most of troubles with the air conditioners are caused by refrigerant leakage, try to master the work. The following is the standard tightening work of flare nuts.

(1) Remove the attached flare nuts.
In case of the condensing (outdoor) unit

- Remove the flare nuts attached to the shop valves for both liquid and gas piping and the blind caps.

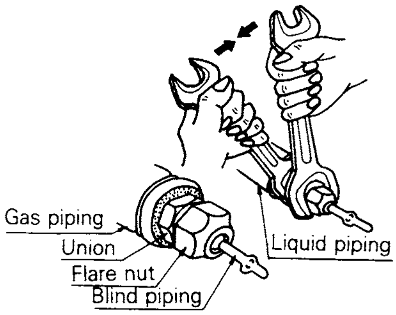
Fig.6-23



In case of the fan coil (indoor) unit

- Remove the flare nuts from the connecting piping of the fan coil (indoor) unit and blind piping.

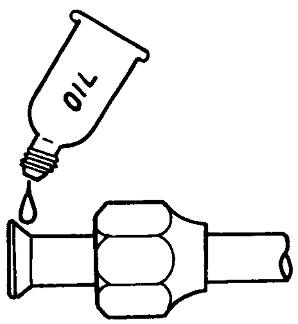
Fig.6-24



※ **Be sure to use two spanners to remove them.**

(2) Apply oil to the flare part.

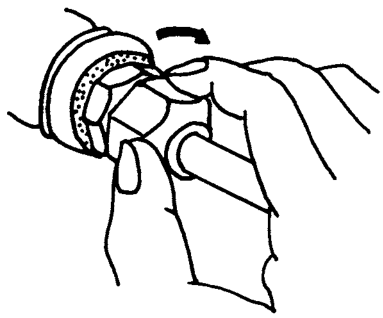
Fig.6-25



Caution: Donot use SUNISO oil on R410A unit flaring
Refer to p.326 for more details.

(3) Align the flare nut with the auxiliary pipe or the stop valve and tighten the flare nuts by 4-5 times with hand. If the flare nuts are tightened up by turning them by two or three times, once again align them and tighten them.

Fig.6-26



(4) Tighten the flare nuts in the liquid and gas piping (for both condensing (outdoor) unit and fan coil (indoor) unit).

- If the air is purged from the piping by use of the gaseous refrigerant in the air conditioner, tighten the flare nuts for the stop valves in the gas piping after purging the air.
- Use two spanners to tighten the flare nuts on the indoor side.

Tightening torque

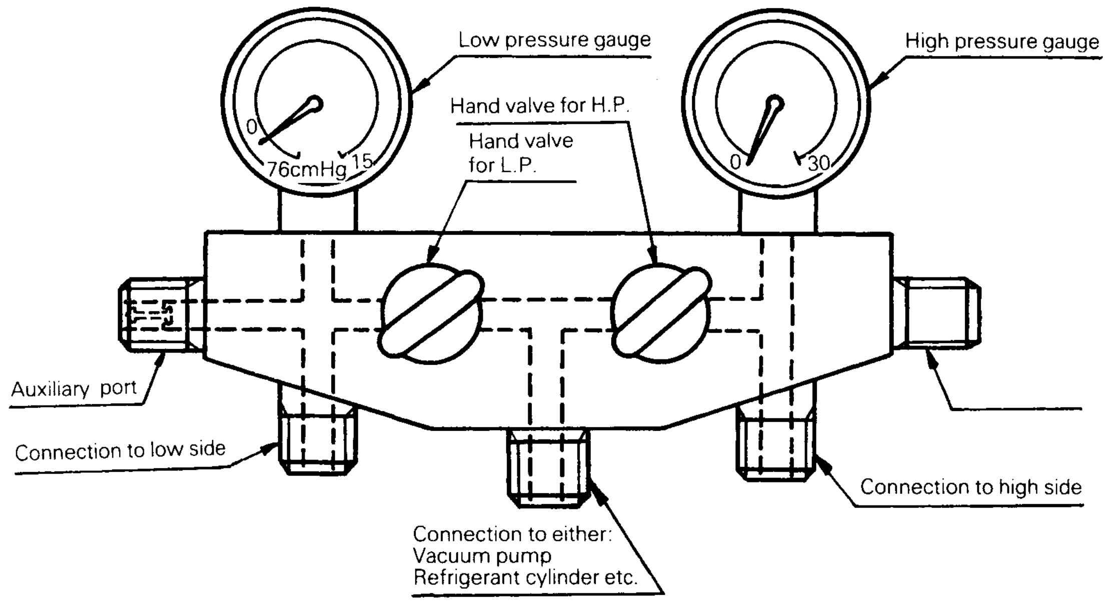
Size of pipe [mm]	Tightening torque [kg-cm]
ϕ 9.5	330~400
ϕ 12.7	500~620
ϕ 15.9	630~770
ϕ 19.1	1000~1200

Caution: Refer to p.326 for tightering torque of R410A unit flaring.

6.2 How to use the gauge manifold

(1) Structure

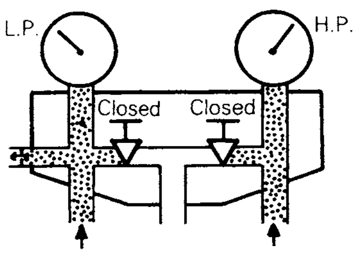
Fig.6-27



(2) Function

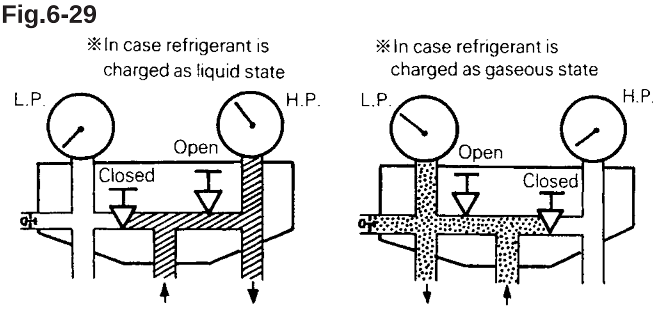
① Pressure measurement

Fig.6-28



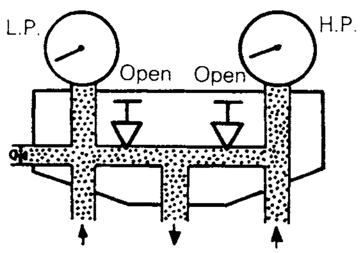
② Charging refrigerant

Fig.6-29



③ Vacuum pumping

Fig.6-30



6.3 Valve operation

It is necessary to know the structure of stop valves before performing the vacuum dry and refrigerant charge. If not, you may make mistakes during the works. The structures and operation methods of representative stop valves will be explained below.

6.3.1 Three-way stop valves

Remove the blind cap and move the valve shaft up or down to open the internal passage between the piping side and the condensing unit side or between the piping side and the service port side.
When the valve shaft is held at the neutral position, the three passages are open in the valve.

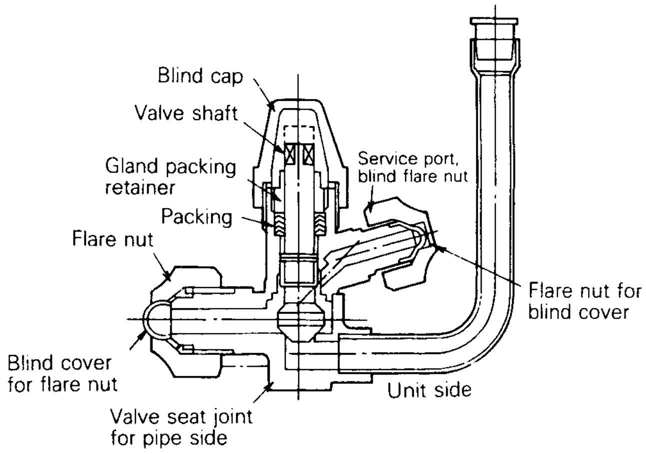


Fig.6-31 Three-way stop valve

(1) The valve shaft is shifted down to the bottom.
① When the valve shaft is shifted down to the bottom, the passage between the piping side and the service port side is open.
② Before operating the valve shaft, loosen the gland packing retainer a little for ease of handling, but do not forget to retighten it after it is shifted.
③ The stop valve is delivered in this state.
④ Keep the valve in this state until the air purge from the piping and the fan coil unit is completed.
⑤ If the valve shaft is operated from this state, the refrigerant is extracted.

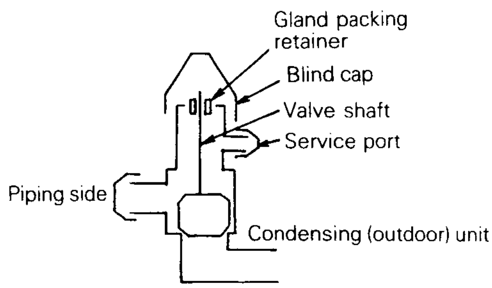


Fig.6-32

(2) The valve shaft is held at the neutral position.
① When the valve shaft is held at the neutral position, the passages are open to three ways, piping side, service port side and outdoor unit side.
② The valve at this state resists the refrigerant flow. In addition, if the service port and the blind cap are insufficiently tightened, the valve may cause refrigerant leakage.
③ Keep the valve in this state when the pressure gauge is installed.

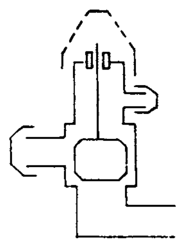


Fig.6-33

(3) The valve shaft is lifted up to the top.
① When the valves shaft is lifted up, the passage between the piping side and the condensing unit side is open.
② The valve shaft must be lifted up during normal operation.
③ After lifting up the valve shaft, firmly tighten the gland packing retainer.
④ Tighten up the blind cap so that air tightness is maintained doubly between the cap and the valve body.

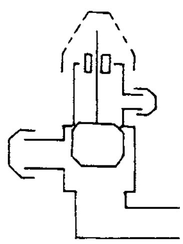


Fig.6-34

6.3.2 Ball valves

When connecting piping to the stop valve, use two wrenches; one on the hexagonal port of the body and the other on the flare nut (Refer to Fig.6-35).

How to open the ball valve:

① Turn the valve stem counterclockwise by 1/4 of a turn.

② Stop turning the stem when the pin is in contact with the stopper, and the valve is open.

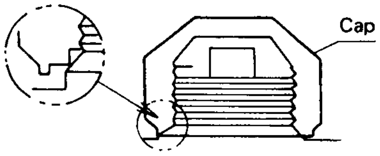
How to close the ball valve:

① Turn the valve stem clockwise by 1/4 of a turn.

② Stop turning the stem when the pin is in contact with the stopper, and the valve is closed.

How to attach the cap:

① The valve is sealed at the part pointed by the arrow mark. So carefully place the cap not to impair it.



② After manipulating the valve, be sure to tighten up the cap accurately.
Liquid side :150~200kg·cm
Gas side :200~250kg·cm

How to connect a charge hose to the service port:
Connect the charge hose with its mouth piece equipped with push bar to the service port.

Fig.6-35

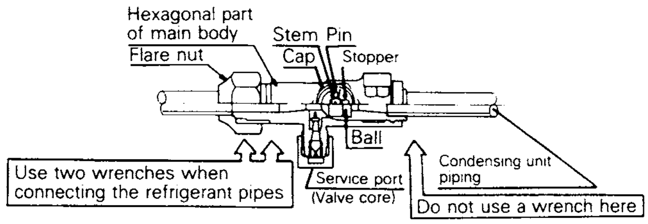
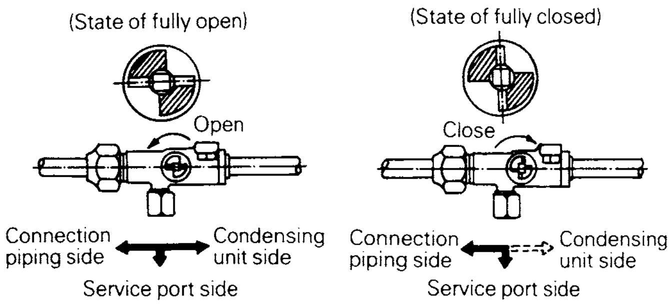


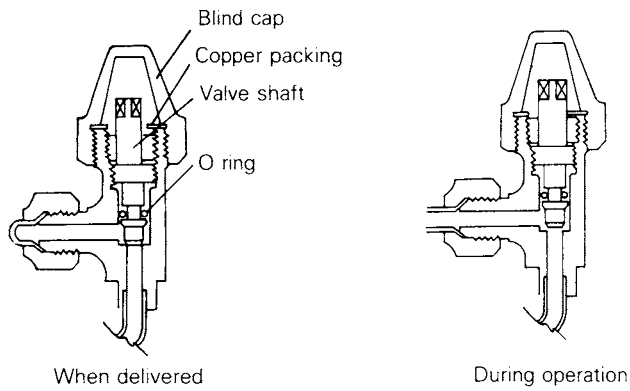
Fig.6-36



6.3.3 Two way stop valves

- If the refrigerant leaks from the valve shaft of the stop valve in the liquid line, repeatedly turn the valve from 90˚ to fully closed until the sealing surface of O ring fits in the valve seat. In addition, check that a copper packing is inserted in the blind cap and then tighten up the blind cap.

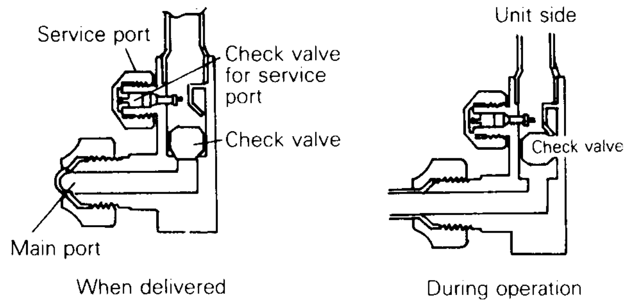
Fig.6-37



6.3.4 Automatic check valves

- Automatic check valve in the gas line
  The service port of the valve is used for measuring low pressure and charging the refrigerant. In this case, the service port should be equipped with a check valve. Connect a charge hose with its mouth piece equipped with push bar to this port. When the blind nut is removed from the main port, a small amount of the gaseous refrigerant may sometimes leak.

Fig.6-38



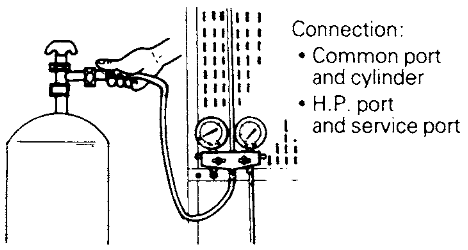
6.4 Leak test

6.4.1 Testing method for air tightness

After piping work, charge nitrogen gas and fluorocarbon refrigerant (R-22) from the service port.

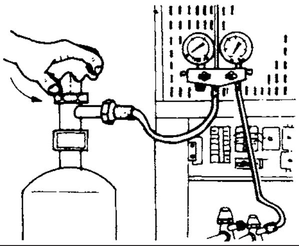
(1) Connect a manifold gauge with the refrigerant cylinder and the service port of the stop valve in the liquid line.

Fig.6-39



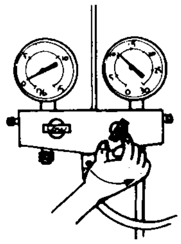
(2) Fully open the stop valve of the refrigerant cylinder.

Fig.6-40



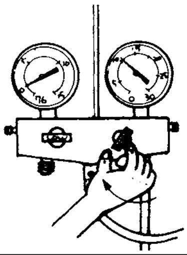
(3) Open the valve of the gauge manifold (high pressure side).

Fig.6-41



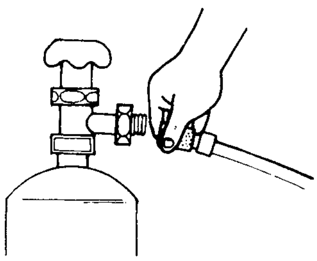
(4) Close the valve after filling the circuit with the refrigerant.

Fig.6-42



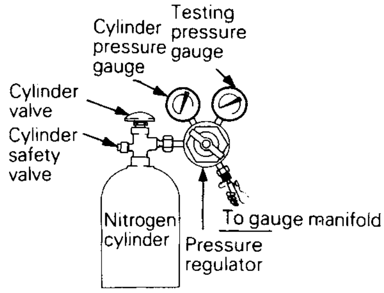
(5) Remove the charge hose from the refrigerant cylinder.

Fig.6-43



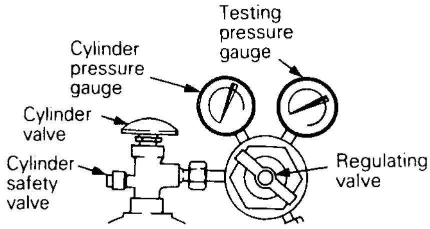
(6) Connect the charge hose to the nitrogen cylinder.

Fig.6-44



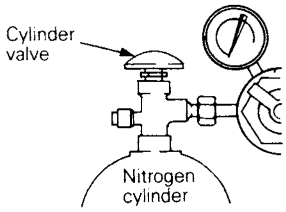
(7) Confirm that the cylinder valve and regulating valves are closed.

Fig.6-45



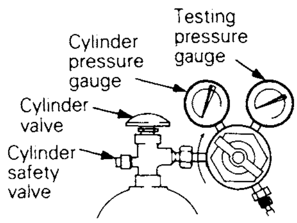
(8) Open the nitrogen cylinder valve and the valve of the gauge manifold.

Fig.6-46



(9) Pressurize the circuit up to 28kgf/cm^2 by turning the regulating valve clockwise little by little (opening).

Fig.6-47



(10) Close the cylinder valve.
(11) Close the valve of the gauge manifold.
(12) Loosen the mouth piece of the charge hose to release pressure in the charge hose.
(13) Close the regulating valve by turning counterclockwise fully.
(14) Remove the charge hose from the gauge manifold.
(15) Check the piping for leakage.
(16) Release pressure in the circuit.

Caution:

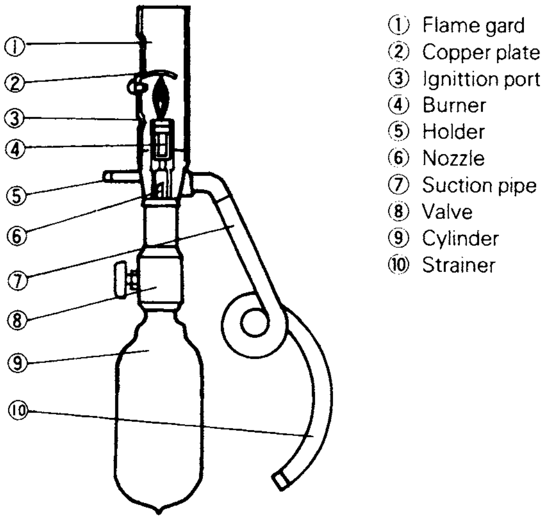
- Never use oxygen or acetylene to raise system pressure when checking for leaks.
- Do not pressurize the circuit higher than 28kgf/cm^2.
- The air tight test explained here cannot sometimes be applied depending on models, so read the installation manual before undergoing the air tight test.

6.4.2 How to use refrigerant leak detectors

The simplest way for detecting refrigerant leak is to use soap-and-water solution, but if after-treatment of soap-and-water solution is improper, rust is collected, which way cause refrigerant leakage. If a minute of the refrigerant leaks, it is very difficult to find leakage through the soap-bubble test. In this regard, it is recommended to use a refrigerant leak detector for accurate detection. Refrigerant leak detectors of good quality are available recently, but the following two detectors are normally used.

(1) McKinley fluorocarbon refrigerant leak detector (LP gas cylinder type)

Fig.6-48



Cautions for operation

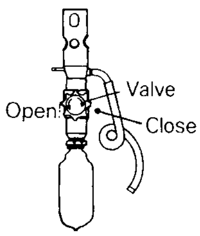
1. Since the liquid LP gas is used, be sure to hold the detector vertically after ignition. (If it is inclined, flame may become intense or the nozzle be clogged.)
2. When the detector is not used, loosen the cylinder (turning it counterclockwise) and store it upright.
3. If the gas leaks from the cylinder, tighen the valve core with the attached tool.

Notes:

1. Clean the strainer at the end of the suction pipe time to time.
2. Wipe off scales on the copper plate.
   When the copper plated is replaced, check if the flame comes out of the center hole of the plate.

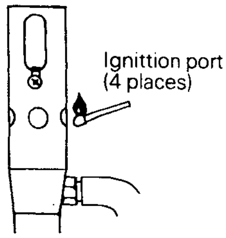
① Open the valve a little.
- If the valve is opened suddenly, large amount gas comes out. So it is difficult to ignite it.

Fig.6-49



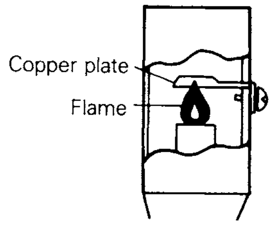
② Ignite the detector quickly with a lighter or match.
- Ignite the LP gas from the ignition port.

Fig.6-50



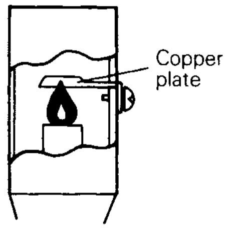
③ Adjust flame length.

Fig.6-51



④ Check flame reaction on the copper plate.
- Since liquid LP gas is used, be sure to hold the detector vertically after ignition.

Fig.6-52



- If leaking amount of refrigerant is small
  ...... Green (low concentration)
- If leaking amount of refrigerant is large
  ...... Bright blue (high concentration)

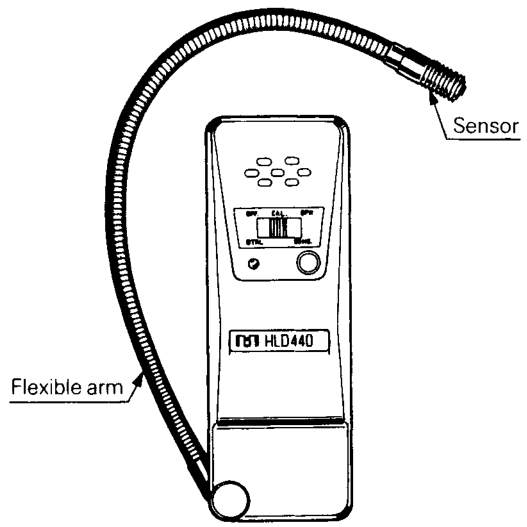
Reaction in flame colors

Leaking amount Approx. g/month	Leaking amount of refrigerant Approx. mm^3/sec.	Color of flame
5~25	0.35~0.85	Slightly green
25~40	0.85~3.2	Light green
40~110	3.2~8.5	Greenish purple
110~160	8.5~12.5	Purplish greenish purple
160~500	12.5~38.5	Deep purplish greenish purple

Caution: HFC (R410A, R407C etc.) refrigerant can not be defected by this detector. Refer to p.326 for details of HFC leak detector.

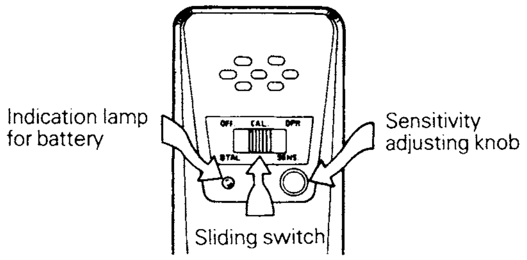
(2) Battery type refrigerant leak detector -HLD440 Yamatake

Fig.6-53



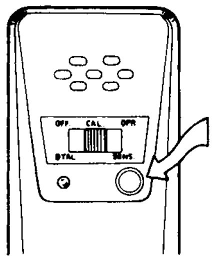
① Shift the sliding switch to CAL.

Fig.6-54



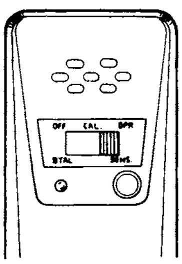
② Turn the sensitivity adjusting knob until pulsatile noise is heard.

Fig.6-55



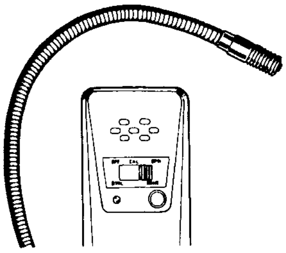
③ Shift the sliding to OPR.
- Although leaking amount of the refrigerant is small, when it enters the sensor tip, pulsatile noise becomes quick, and then siren horn is heard when more refrigerant enters the tip.

Fig.6-56



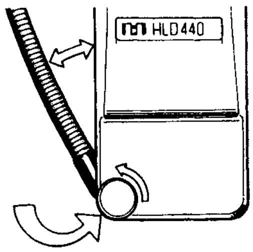
④ Find a leaking point.
- It is ideal to move the sensor at the speed of 2-3cm per second.

Fig.6-57



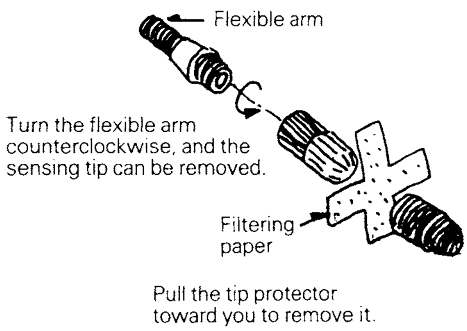
⑤ Loosen the knob at the bottom of this detector, and the flexible tube can be moved by 180˚.
- Turn the knob twice counterclockwise to loosen it and then turn the detecting part.

Fig.6-58



Notes:
1. If the leak test is performed in a windy place, leaking refrigerant is blown off from a leaking point. In this case, block the wind and check it.
2. In order to find a minute amount of refrigerant leak, set the sliding switch to CAL, because pulsatile noise changes greatly in the presence of a minute amount of halogen. (Sensitivity of the detector at CAL is very strong.)
3. If pulsatile noise becomes erratic or continuous siren horn is heard, replace the sensor tip with correct one.
4. When the indication lamp for battery does not light up, replace alkaline dry battery.
5. When the tip is replaced, be sure to turn off the switch. Turn the tip counterclockwise to remove it.

Fig.6-59

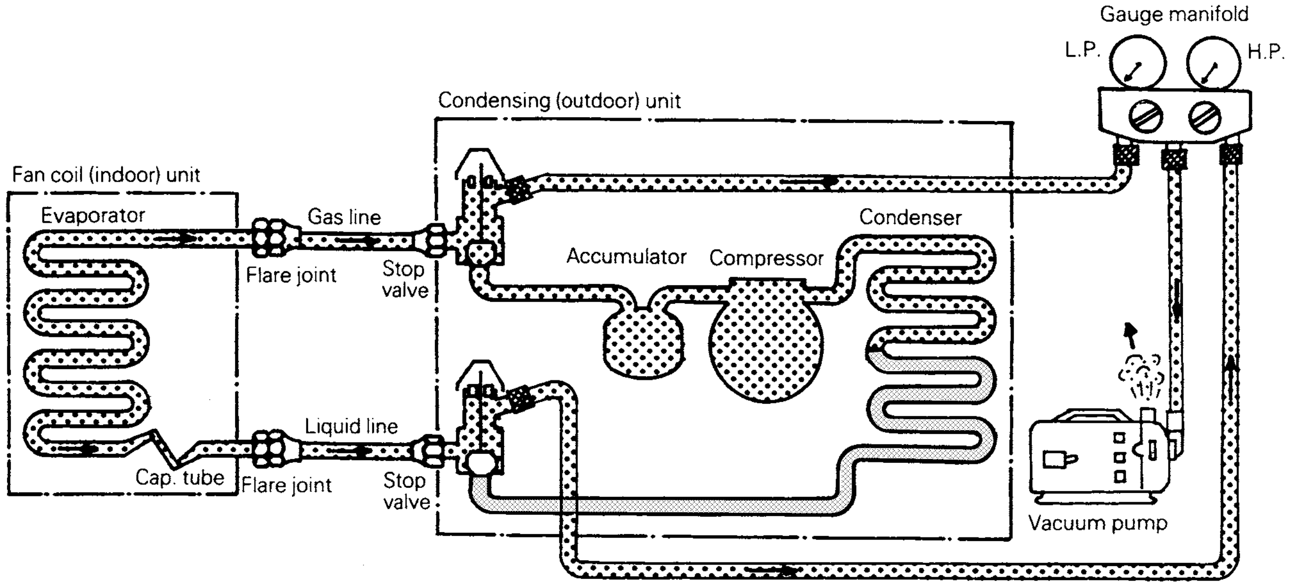


Caution: HFC (R410A, R407C etc.) refrigerant can not be defected by this detector. Refer to p.326 for details of HFC leak detector.

6.5 Evacuation

Method to utilize a vacuum pump

Fig.6-60



Notes:

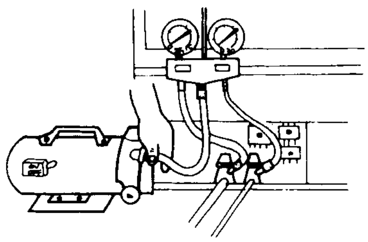
- Perform the air tight test (leak test) before undergoing this work.
- Be sure to check whether residual pressure exists in the piping before undergoing this work. If it exists, release it from the piping .

Work order:

① Remove the blind flare nuts from the service port of the stop valves in the liquid and gas lines.

② Connect the gauge manifold to the vacuum pump and the service ports of the stop valves.

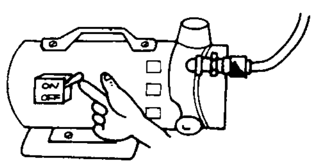
Fig.6-61



③ Open the valves of the gauge manifold.(Hi, Lo)

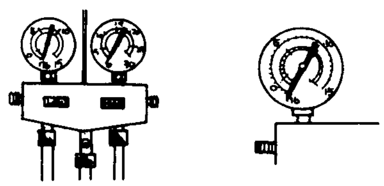
④ Operate the vacuum pump for approx.20 minutes.

Fig.6-62



⑤ Confirm the gauge pressure (760mmHg)

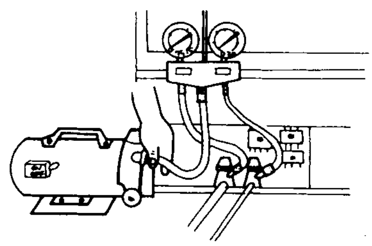
Fig.6-63



⑥ Close the valves of the gauge manifold. (Hi, Lo)

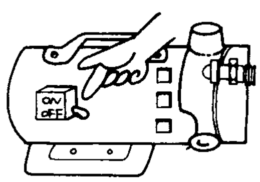
⑦ Loosen the charge hose to balance the pressure of the vacuum pump.

Fig.6-64



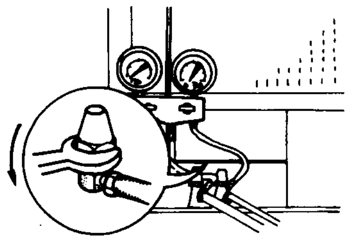
⑧ Stop the vacuum pump.

Fig.6-65



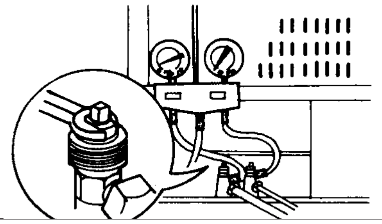
⑨ Remove the blind caps of the stop valves.
Do not lose copper packings.

Fig.6-66



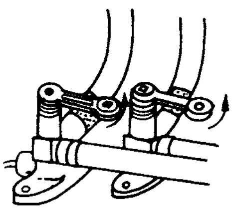
⑩ Loosen the gland packing retainer of the valve by approx. a quarter turn(90˚).

Fig.6-67



⑪ Fully open the valves for both liquid and gas piping.

Fig.6-68



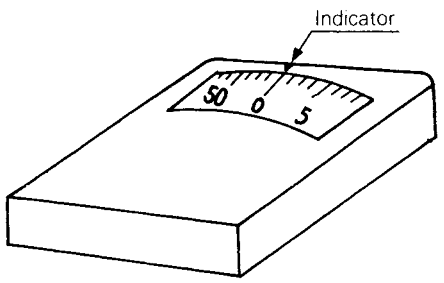
⑫ Tighten the gland packing retainer.
⑬ Tighten up the blind caps of the stop valves.

6.6 Refrigerant charge

6.6.1 Method to utilize a weighing instrument

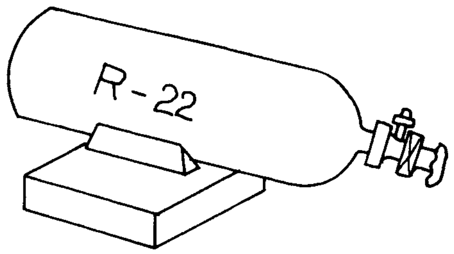
① Check graduation of a weighing instrument.
Be sure to the indicator rests on "0". If not, adjust it to the zero graduation.

Fig.6-69



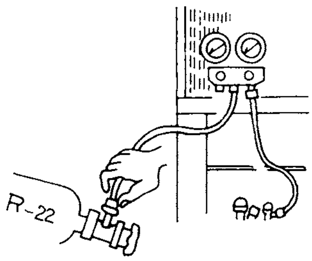
② Weigh the refrigerant cylinder.

Fig.6-70



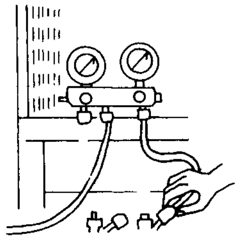
③ Connect the charge hoses to the valve of a refrigerant cylinder and the common port of the gauge manifold, and the service port of the stop valve in the liquid line and the H.P. port of the gauge manifold respectively.

Fig.6-71



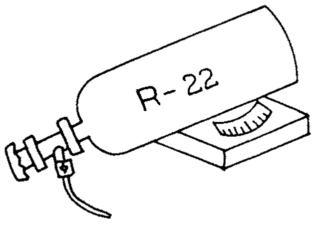
④ Open the valves of the refrigerant cylinder and the high side valve of the gauge manifold.
⑤ Loosen the mouth piece of the charge hose attached to the stop valve a little to purge the air.

Fig.6-72



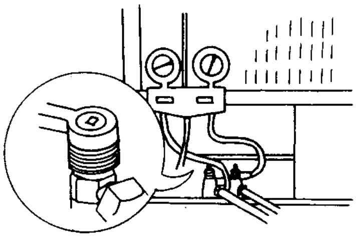
⑥ Retighten the mouth pieces of the charge hoses which were loosened previously.
⑦ Confirm the graduation of the weighing instrument.

Fig.6-73



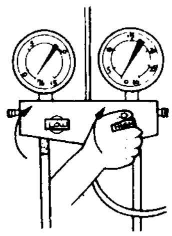
⑧ Remove the blind caps of the stop valve in the liquid line.
⑨ Loosen the gland packing retainer of the stop valve.
⑩ Open the stop valve of the liquid line.

Fig.6-74



⑪ Close the stop valve of the liquid piping after charging the predesigned volume of the refrigerant.
⑫ Tighten the gland packing retainer of the stop valve.
⑬ Close the valves of the refrigerant cylinder and the valve of gauge manifold.

Fig.6-75



⑭ Remove the charge hose.
⑮ Remove the gauge manifold.
⑯ Tighten up the blind caps of the valves.

Caution: HFC refrigerant such as R410A, R407C shall be charged in liquid. Refer to p.344 for more details.

6.6.2 How to use the charging cylinder

① Set the graduation of the charging cylinder.
- Set the graduation of the charging cylinder to the kind of refrigerant.
- Set the graduation of the pressure to the pressure indicated on the pressure gauge of the charging cylinder.

Fig.6-76

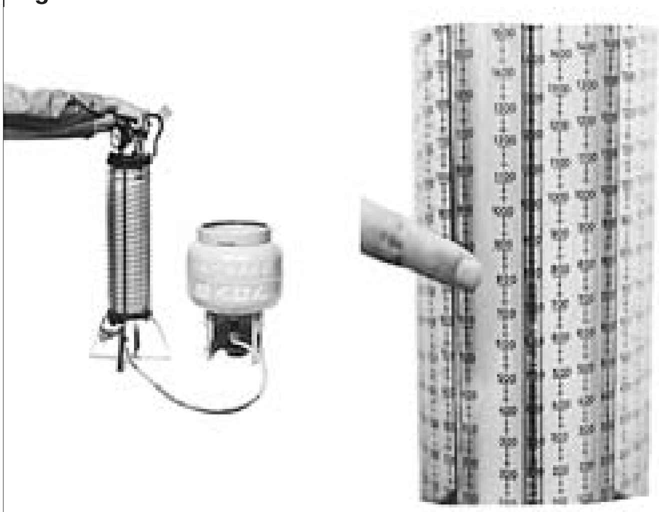
② Connect the refrigerant cylinder to the charging cylinder.
- Attach a mouth piece to the refrigerant cylinder.
- Connect the connecting port at the lower part of the charging cylinder to the refrigerant cylinder.
- Open the valve of the refrigerant cylinder.
- Purge air from the charge hose.

Fig.6-77

Caution: The charging cylinder can not be used for HFC refrigerant such as R410A and R407C. Refer to p.327 for more details.

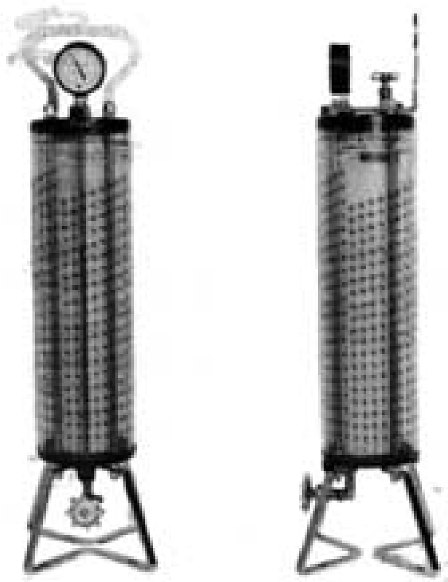
③ Measure the refrigerant volume to be charged in the charging cylinder.
- Open the valve of the charging cylinder, and charge the predesigned volume of refrigerant.
- If the predesigned volume of refrigerant is hardly charged into the charging cylinder, it is advisable to open the upper valve for few seconds, because pressure in the cylinder is lowered.
- Keep the refrigerant in the charging cylinder while evacuating the refrigeration circuit.

Fig.6-78



④ Charge the refrigerant in the system in the same manner as explained in 6.6.1

Fig.6-79

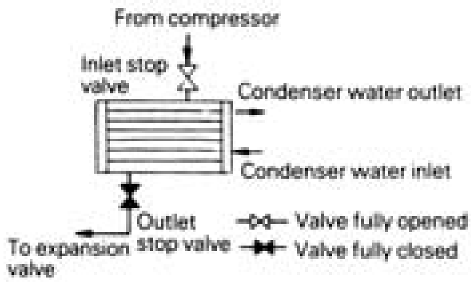
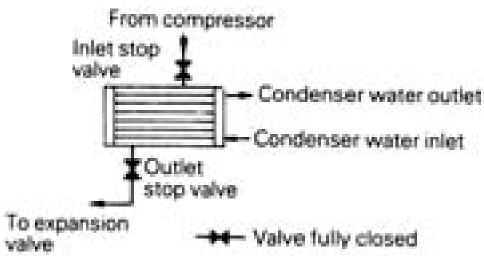


6.7 Pump down

Caution: Do not perform pump-down of the unit at scroll or screw compressor. Refer to the operation or service manual of each product for details.

Method of pump down

Necessary tools and parts for pump down:
Valve key, spanner, angle wrench, screwdriver, alligator clips (short-circuit wires)

Work order	Point	Remarks
1. Do not have the low pressure switch function. (In case low pressure switch is provided)	a. Disconnect the power supply. b. Short-circuit the contact points of the low pressure switch with alligator clips.	See the electric wiring diagram and figure on the cover of pressure switch. 
2. Operate the air conditioner or chiller.	a. Connect power supply again. b. Operate the condenser water (chilled water) pump and tower fan. c. In case the thermostat functions during cooling operation, short-circuit it.	Operate the cooling water and chilled water pumps.
3. Fully close the condenser outlet valve or receiver outlet valve.	a. Remove the caps from the condenser outlet and inlet valves with an angle wrench. b. Slightly loosen the valve gland with a spanner. c. Turn the valve shaft of the condenser outlet valve clockwise with a valve key to close it d. Tighten the outlet valve gland of the condenser.	
4. Collect refrigerant, reading the low pressure gauge.	a. Stop the compressor when reading of low pressure gauge drops to -200~-300mmHg from 0 kgf/cm²G.	Compound gauge 
5. Fully close the condenser inlet valve or receiver inlet valve. 0.2~0.5 	a. Fully close the condenser inlet valve with a valve key as soon as the compressor stops. b. Tighten the inlet valve gland of the condenser. (Do it quickly, otherwise pump down efficiency reduces…reading of low pressure rises.)	
6. Leave it for a while and read rise of low pressure.	a. Confirm that gaseous refrigerant in lubrication oil evaporates and that low pressure gauge reading rises up to 0.05MPa (0.5kgf/cm²G) or more.	Confirm whether refrigerant remains in lubrication oil.
7. In case low pressure gauge reading is over 0.5kgf/cm²G, once again collect refrigerant.	a. Fully open the condenser inlet valve. b. Repeat procedures written in (2),(4),(5)in order. c. Stop compressor and leave it for a while. If low pressure gauge reading does not exceed 0.02~0.05MPa (0.2 ~0.5 kgf/cm²G), finish the pump down.	Confirm that pressure 0.02~0.05MPa (0.2~0.5kgf/cm²G) remains in the refrigerant system. (When the refrigeration system is left evacuated, water and air invade into the system while system is opened.)
8. Treatment after pump down	a. Tighten up the caps with an angle wrench. b. Disconnect power supply from the refrigeration unit. c. Remove the short-circuit wire from the low pressure switch. d. Stop the cooling water and chilled water pumps and tower fan.	It is preferable to open refrigeration system when its temperature becomes equal to ambient temperature. (This is for prevention of dew formation in piping.)
9. 9.Place a caution plate on the refrigeration unit.	Place a caution note written in "Under pump down" on refrigeration unit ostentatiously.	For prevention of trouble.

6.8 How to use the measuring instruments

6.8.1 Megger tester

Reading procedure

(1) Insert the black lead wire into the ground terminal and the red one into the L (line) terminal. Turn them clockwise, and they are fixed.

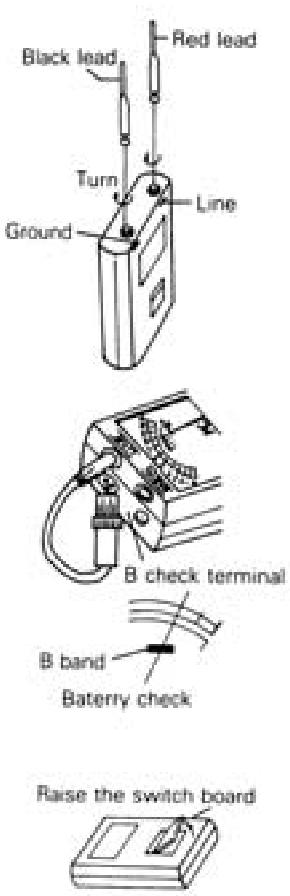
(2) Battery check
Make the head pin of the line-side probe touch the battery check terminal without pressing the switch. Do not fail to make the head pin touch both polarities. If the pointer deflects within the B mark on the scale, the battery can be used. If the pointer is out of the B mark, it shows that the battery is dead, so replace it with a new one.
Caution:
An accurate reading cannot be obtained if the switch is pushed before performing the battery check. Using method of pointer cap:
When it is impossible to use the head pin of the probe, insert the lead wire between the needle cap and probe cap, and fasten it with the pointer cap.

(3) Put the probe into contact with an object to be measured and press the switch at the center, and the pointer indicate its insulation.

(4) When reading the tester continuously for a long time, raise the switch board at the center, and the switch is locked at the ON position.

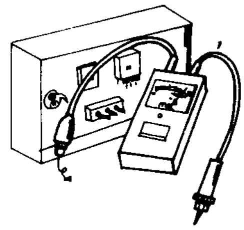
(5) Do not forget to turn off the switch after reading the megger tester.

Fig.6-80



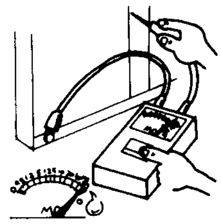
- Connect the ground terminal.

Fig.6-81



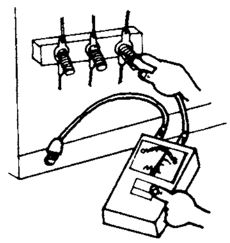
- Confirm the function of the megger tester.

Fig.6-82



- Measuring

Fig.6-83



6.8.2 Clamp meter

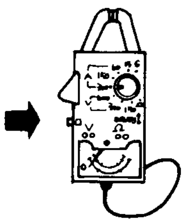
(1) Precautions

- Always check the range selection prior to measurement.
- When the current or voltage value of the circuit under test is unknown, always start checking from the highest range. When the correct range is ascertained, range down to it.
- Do not take measurements with over 1000A for over an extended period of time, or heat build-up within the core will affect reading accuracy. Therefore, it is better to take two or more measurements of short duration.
- Maximum circuit voltage rating for the instrument is 600V. For safety's sake, never measure AC current of over 600V in a circuit.
- When measuring current in the presence of a strong magnetic field, occasionally the pointer will deflect even though the clamp core is not clamped over a conductor. If possible, avoid such reading the tester meter where such conditions exist.
- Avoid storing the instrument in such locations where temperature or humidity is very high.

(2) Measuring procedure of AC

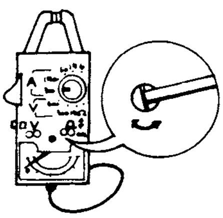
① Unlock the metering mechanism by sliding the meter lock switch to the right.

Fig.6-84



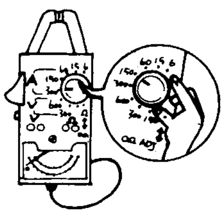
② Check whether the pointer rests at "0". If not, set it to "0" with adjusting screw.

Fig.6-85



③ Set the range selector to the highest current range.

Fig.6-86



④ Clamp the core over a single conductor, and place the conductor as near as possible to the middle of the clamp core.

Fig.6-87

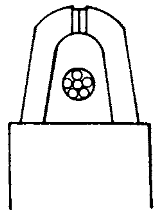
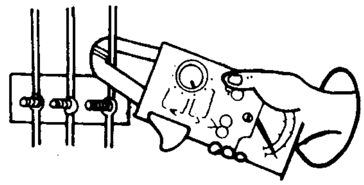


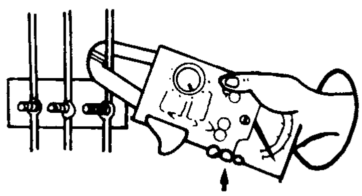
Fig.6-88



⑤ If the reading is low on the scale, range down by one step at a time until the proper range is obtained for accurate reading.

⑥ If the measurement is performed in such a place where it is difficult to get accurate reading, slide the metering lock switch to the left and get the reading later.

Fig.6-89



6.8.3 Voltage tester (HIOKI HI TESTER MODEL 3000)

In case of high power circuit area (distribution transformer and bus bar)

Before attempting any measurement, perform such check twice that the range switch is set to the correct position.

If the range is incorrectly set, a dangerous arc of explosion would occur.

(1) Precautions

① Prior to measurements, always make certain that the pointer is at the 0 mark of the scale. If not, adjust it using the zero adjusting screw.

② Check whether fuse is blown off by shorting the test lead probes together in the Ω range. If the meter is inoperative, be sure to check if fuse is blown off before taking any other action.

③ Make certain that the range selected is greater than circuit current or voltage prior to attempting a measurement. Also, when changing ranges always break contact from the circuit with one of the test leads.

④ Do not use this tester for measuring high voltages on an equipment operated at high frequency, e.g. microwave ovens etc. High frequencies reduce the dielectric strength of the meter to only a fraction of its specified rating at commercial frequency and can result in serious electrical shock to the operator.

⑤ Do not store the meter in a high temperature, high humidity environment.

Battery test:

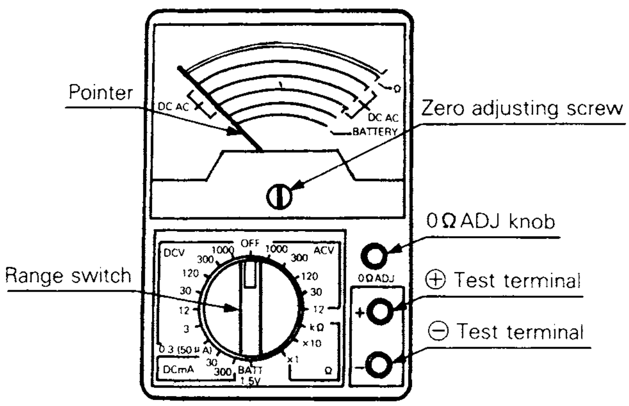
Battery voltage is measured with a 10Ω load applied to the battery. Battery condition can be determined by comparing the readings obtained using this method with those obtained using the DC 3V range.

The scale is graduated from 0.9 to 1.8V.

Note:

When set the tester as above, an internal "dummy" load of 10Ω has been introduced-thus an accurate battery check will be shown.

Fig.6-90

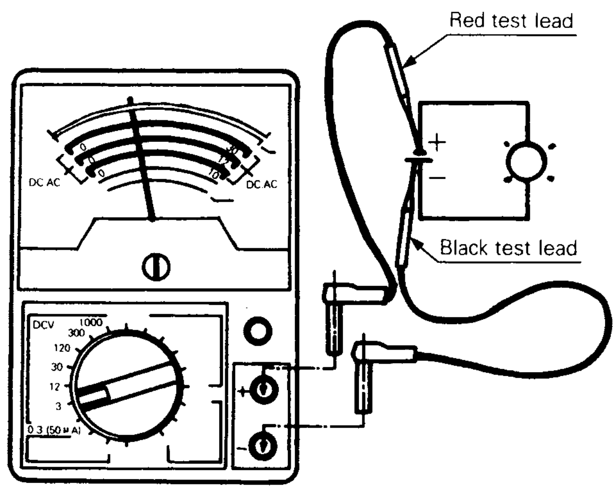


(2) Operating instructions

DC V

Position the range switch to the DCV range which is appropriate to the circuit to be tested. Plug the black test lead into the ⊕ test lead terminal and the red lead into the ⊖ terminal. Connect the meter in parallel with the load: with the black test lead on the negative ⊕ side and the red lead on the positive ⊖ side.

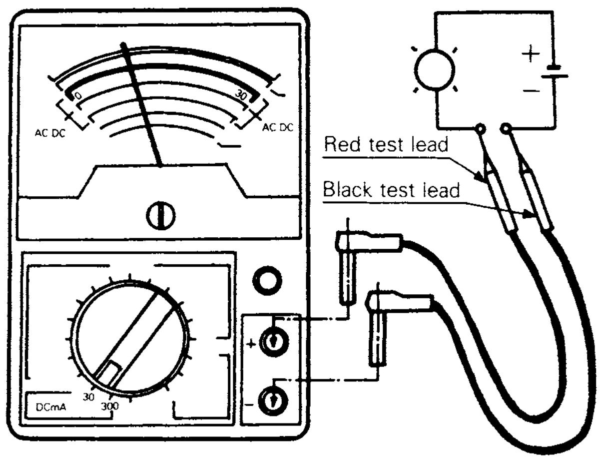
Fig.6-91



DC mA

Position the range switch to the DCmA range which is appropriate to the circuit be tested. Plug the black test lead into the ⊕ test lead terminal and the red lead into the ⊖ terminal. Cut off the power to the circuit to be tested and connect the meter in series with the circuit; with the black test lead on the negative ⊕ side and the red lead on the positive ⊖ side. Readings up to 50μ A are read off the 10 scale and multiplied by a factor of 5.

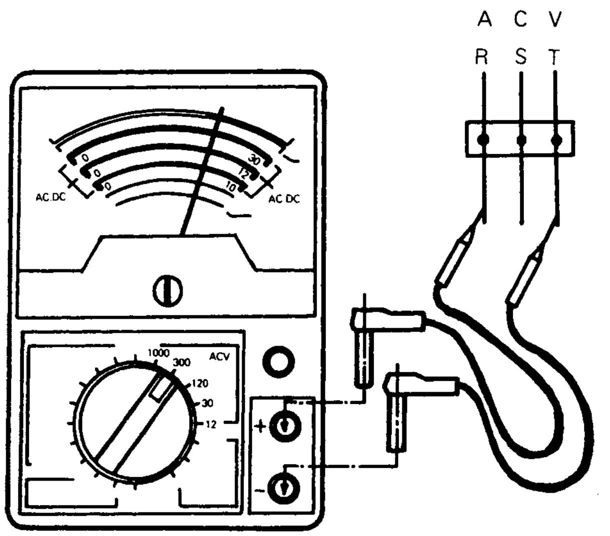
Fig.6-92



AC V

Position the range switch to the ACV range which is appropriate to the circuit to be tested and proceed with the work as in DCV measurements.

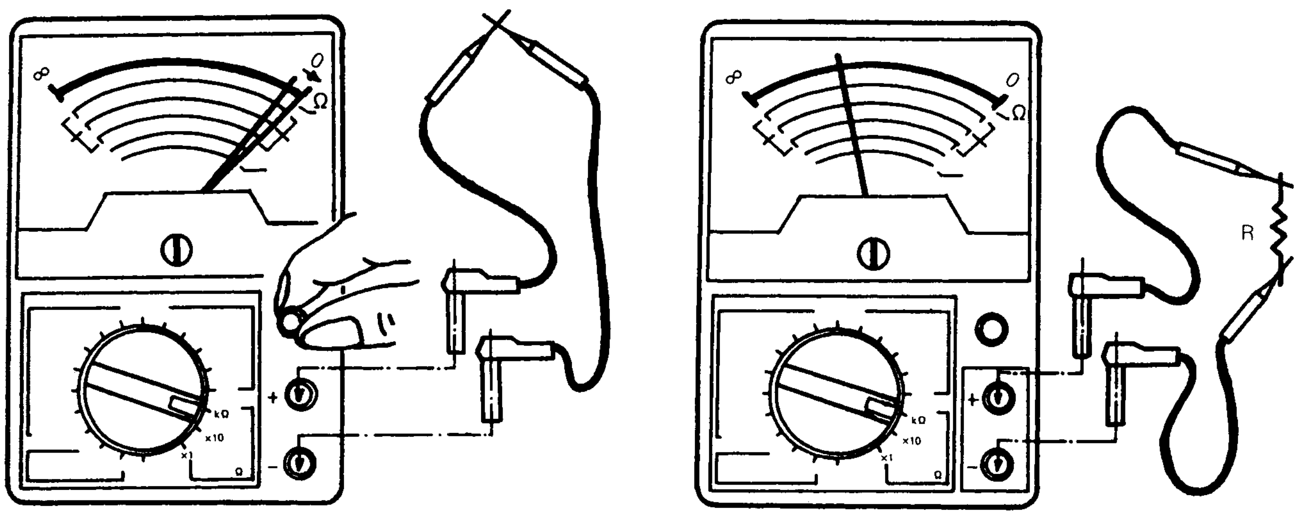
Fig.6-93



Ω

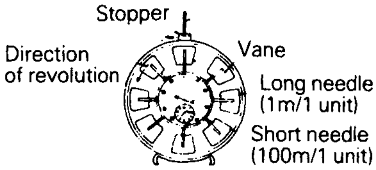
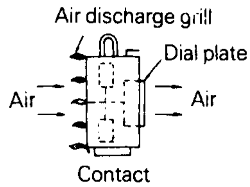
Position the range switch to the Ω range appropriately for the circuit or device to be tested. Plug the black test lead into the ⊕ test lead terminal and the red into the ⊖ terminal. Short circuit the two test leads together and adjust the pointer to 0Ω using the zero Ω ADJ knob. If the pointer will not deflect all the way over to 0Ω mark, replace the meter battery. Always cut off power to the circuit prior to making circuit resistance measurements.

Fig.6-94



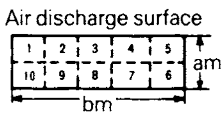
6.8.4 Anemometer

Application: Air velocity measurement(1~15m/s)

Work order	Points	Remarks
1. Inspection of anemometer	1. Check if vanes and casing are deformed. 2. Check if any other part is damaged.  	● Do not lubricate bearing.(Because abrasion of bearing should be constant.)
2. Preparing for measuring	1. Insert anemometer into holder, or place on a shelf which is made at a measuring point. 2. Set indicating needle to 0, and stop it by stopper.(Adjust short needle by attached handle and long needle by breathing upon the vanes.)	● Do not hold it by hand, because resistance differs. This increases error. ● Do not touch vanes, as error occurs.
3. Measuring	1. Place anemometer so that its indication needles are turned clockwise. (Vanes should be turned counterclockwise viewed from graduation side.) (Air should flow through it from its back to its front.) 2. Release stopper and measure air velocity for a certain period. ● Measure it at least for 20 seconds or more at a point and more than 1 hour in total. When locations of measuring are moved from one to other points; i.e. note the following items. ● Stop indication needles by stopper. ● Record measured values. (Recording is necessary when air distribution is unbalanced or measuring period is long or measuring points are many.) ● Move the anemometer to next measuring point and release stopper. ● Stop indication needles by stopper and read graduation for measuring period. (One graduation for short needle is 100m and that for long needle is 1m.) ● Measure air velocity at each measuring point.	 ● Do not measure air velocity higher than 15m/s. ● Protect the anemometer from water droplets. ● Short measuring increases error. ● Air velocity cannot be measured if the diameter of the air discharge outlet is under 11cm. ● Inspection standards for anemometer regulated by the Meteorological Agency are as follows. 1. Error should be less than 1~10m/s → ±1m/s. 2. Error should be less than 10~15m/s → ±10% Therefore, it is advisable to use anemomaster for accurate measurement. ● Anemometer cannot be used for measuring uneven distribution of air velocity.
4. Completion of measuring	1. Record Mfg No. of the anemometer and correction factor. 2. Put back the anemometer in its case.	

Caution for measurement:

a. Divide air distribution area as shown below and measure air velocity at many points. This applies to either anemomaster or anemometer, and obtain air flow rate by a sum of average air velocity and air discharge area.



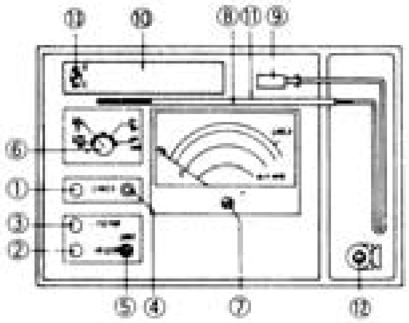
- Air velocity(V)= $\frac{(1)+(2)\ldots\ldots+(9)+(10)}{10}$ (m/sec)
- Air flow rate(Q)=a×b×V×60(m^3/min.)

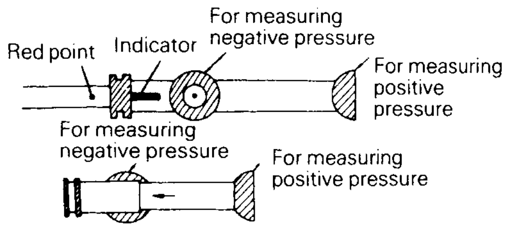
b. If is difficult to measure air velocity at the duct connection or the air distribution outlet, do it in the same manner at the air suction inlet.

6.8.5 Anemomaster

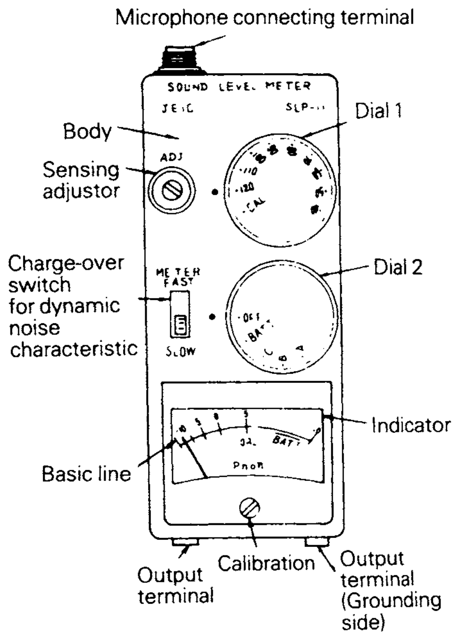
Application: Temperature measuring(-50~+150˚C),air velocity measuring (0~40m/s), static pressure measuring (0~500mmH_2O)

<table>
<tr><th>Work order</th><th>Points</th><th>Remarks</th></tr>
<tr><td>1. Calibration of indicator</td><td>1. Place this gauge in a horizontal position.
2. Confirm that indicator rests at 0 on temperature graduation.

(If necessary, adjust it by turning zero corrector ⑦ slowly.)
</td><td>Setting batteries:
Turn knob ⑬ of battery box ⑩ to 0 direction and remove panel. Insert 4 dry batteries (D.C.1.5V-leak preventive type) correctly with their poles placed in correct directions, put back spring as it was, and fasten knob ⑬ to C direction.
(If this instrument is not used for a long time, take out batteries as there is fear of electrolyte leak from them.)
① Check button switch
② VELO SP
③ TEMP.
④ Check knob
⑤ OADJ
⑥ Range switch
⑦ Zero corrector
⑧ Sensor
⑨ Element
⑩ Battery box
⑪ Safety switch
⑫ Static pressure adapter
⑬ knob</td></tr>
<tr><td>2. Voltage check</td><td>Check voltage before measuring.
1. Remove sensor ⑧ from holder.
2. Set measuring range by range switch ⑥ and press down VELO.SP ② or TEMP ③.
3. Turn check knob ④ to check mark, pressing down check button switch ①.
4. When button switch ① is released, this is ready for measuring.</td><td>Confirm battery check in the method of voltage check; i.e. so long as the indicator is at the right side of CHECK mark, voltage is correct.(Usable)
(Turn knob ④ clockwise fully. If indicator cannot be set at the right side of CHECK mark, voltage of battery is incorrect.)</td></tr>
<tr><td>3. Temperature measuring (-50˚C~+150˚C)</td><td>1. Set range switch ⑥ within measuring limit.
2. Press down button switch for TEMP ③, and this is ready for measuring temperature.</td><td>● If measuring is performed with almost no air velocity, swing sensor in air by approximately 1 m/s and read indicated point after indication becomes stable.
● Measuring range and setting range of range switch ⑥.
<table>
<tr><th></th><th>Measuring range</th><th>Setting of range switch</th><th>Setting range of range switch</th></tr>
<tr><td>Temp.</td><td>-50~+150˚C</td><td>50
0
50
100</td><td>-50~0˚C
0~50˚C
50~100˚C
100~150˚C</td></tr>
<tr><td>Air velocity</td><td>0~40m/s</td><td>VL
AH</td><td>0~5m/s
3~40m/s</td></tr>
<tr><td>Static pressure</td><td>0~500mmH_2O</td><td>SPL
SPH</td><td>0~50mm/WG
50~500mm/WG</td></tr>
</table>
</td></tr>
</table>

Work order	Points	Remarks
4. Air velocity	1. Attach static pressure adaptor ⑫ to sensor ⑧, and place them vertically (Detecting part is located upward). Stop up a hole on the side with a finger to shut out air draft. 2. Set range switch ⑥ at air velocity of either V.L. or V.H. 3. Press down VELO.S.P. ②, and measuring air velocity is ready to go and indicator is set to 0m/s. (If indicator is not set to 0m/s, turn OADJ ⑤ to set it to 0m/s.) 4. Remove static pressure adaptor, and direct air direction mark (red dot) of sensor to windward to measure air velocity	● When indication becomes stable, read graduation.
5. Static pressure measuring	1. Attach static pressure adaptor ⑫ to sensor ⑧ and place them vertically with detective part faced downwards. Stop up a hole with a finger to shut out air draft. 2. Place range switch ⑥ either on static pressure S.P.L or S.P.H. 3. Press down button for VEL O.S.P. ②, and measuring static pressure is ready to go and indicator shows 0mmH_2O (static pressure) (If indicator does not rest at 0 mmH_2O, turn 0 ADJ to set it to 0mmH_2O.) 4. After completion of measurement, make a hole of dia. 10mm in a measured point such as duct wall and press down sucking disk of static pressure adapter ⑫ vertically onto a hole to seal up and then measure static pressure.	● Set indicating line of static pressure adapter ⑫ to red dot of sensor and tighten up adapter. ● For measuring positive pressure, press down the head. For measuring negative pressure, press down the side. All in all, place this in a way air flows to the direction pointed by an arrow mark on static pressure adaptor. 
6. Completion of measuring	1. After completion of measuring, lightly press down TEMP button ③ or VELO.S.P. button ②, and these two buttons come out of their original positions. (At this time, the circuit is turnd off.) 2. Safety switch ⑪ is provided to turn off power when sensor is pressed into holder. Therefore, do not forget to press it down to holder. 3. Take out element ⑨.	

6.8.6 Portable noise meter

<table>
<tr><th>Work order</th><th>Points</th><th colspan="7">Remarks</th></tr>
<tr><td>1. Calibration of noise meter</td><td>1. Adjust indication needle at basic line by calibrator.</td><td colspan="7" rowspan="8">

* Note:
If defection of indication needle is so intense that one cannot read its indication, set the change-over switch for dynamic noise characteristic to SLOW.</td></tr>
<tr><td>2. Connection of microphone</td><td>1. Firmly connect microphone to terminal of noise meter body.
2. Set 120 phon on Dial 1 to the dot.</td></tr>
<tr><td>3. Battery check</td><td>1. Set BATT on Dial 2 to the dot.
2. If indication needle is within black line of BATT on graduation, battery capacity is correct.</td></tr>
<tr><td>4. Electric calibration</td><td>1. Set CAL on Dial 1 to the dot.
2. Set C scale on Dial 2 to the dot.
3. Adjust indication needle at red graduation. (location of CAL on indicator is adjusted with sensing adjustor)</td></tr>
<tr><td>5. Acoustic correction (C scale 115.5 phon)</td><td>1. Set 110 on Dial 1 to the dot.
2. Set C scale on Dial 2 to the dot.
3. Connect microphone to noise source corrector (SS-1…attached pitch pipe),and adjust noise source to 115.5phon with sensing adjustor and blowing pipe.</td></tr>
<tr><td>6. Using method and how to read noise level</td><td>1. Scales on Dial 2 are C → B → A. Measure noise in that order.
2. Turn Dial 1 from largest number (120phon) to smaller numbers gradually, looking at deflection of indication needle. When deflection of needle is within range, adjustment of Dial 1 is completed.
3. Dial 2 indicates scales (C, B and A) on it. Noise level is a total of reading of Dial 1+ reading of needle +correction factor.</td></tr>
<tr><td>7. Measurement</td><td>1. Be sure to measure background noise before measuring noise.
2. Direct microphone to an object to be measured.
3. Measure noise in the order of C, B and A.
4. Pay attention not to exceed the scale of needle.
5. Change-over switch for dynamic noise characteristic is normally set to FAST…*
6. Record ambient conditions and distance between measuring point and object to be measured as detailed as possible.</td></tr>
<tr><td>8. Storage</td><td>1. Remove microphone.
2. Set OFF on Dial 2 to the dot.</td></tr>
<tr><td rowspan="2">9. Correction for background noise</td><td>Compare noises when it is given out of an object to be measured with that when it is not given out.</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td></tr>
<tr><td>Correction factor</td><td>-3</td><td colspan="2">-2</td><td colspan="4">-1</td></tr>
</table>

6.8.7 Vibrometer (Handling method of TYPE 2040)

1. Measurement of vibration acceleration (ACC)

(1) Preparation-calibration

1-1 Set the power switch ⑥ to the BATT, and confirm that the battery voltage exists in the range of the indicator ③. (If it is beyond the limits of the BATT, replace the battery with the new one.)

1-2 Turn the level knob ① counterclockwise, and set it so that the display "SENS" is shown in the window ③ of the indicator.

1-3 Set the power switch ⑥ to the "ON".

1-4 Set the detection-form change-over switch ④ to the "P-P".

1-5 Now, the numerical value of ☐ mV/kgal mentioned on the pickup sensitivity table attached to this instrument is matched to the meter indication, turning the level regulator ⑤ for calibration. At this time, the scales to be matched are 120 to 80 graduated in the lower line.

(2) Measurement

2-1 Set the measurement-items change-over switch ② to the sides of "ACC" and "10Hz".

2-2 Turn the level knob clockwise, and set it to the position which is easy to read, provided that the meter indication is in the range of no shaking off.

2-3 The way of measurement-valve reading is as follows. The figures shown in the window of the indicator are the full-scale values. For instance, when the numerical value 100 is shown in the window and 5 is indicated, it can be read as follows.

50×10×500Gal =0.5G

Provided that the detection-form change-over switch ④ must be previously set to the "P-P".

×10 in the equation mentioned above is multiplying factor in the case of vibration acceleration.

2. Measurement of vibration velocity(VEL)

(1) Preparation-calibration

1-1 Set the power switch ⑥ to the BATT, and confirm that the battery voltage exists in the range of the indicator ③. (If it is beyond the limits of the BATT, replace the battery with the new one.)

1-2 Turn the level knob ① counterclockwise to set that the display "SENS" is shown in the window ③ of the indicator.

1-3 Set the power switch ⑥ to the "ON".

1-4 Set the detection-form change-over switch ④ to the "P-P".

1-5 Now, the numerical value of ☐ mV/kgal mentioned on the pickup sensitivity table attached to this instrument is matched to the meter indication, turning the level regulator ⑤ for calibration. At this time, the scales to be matched are 120 to 80 graduated in the lower line.

(2) Measurement

2-1 Set the measurement-items change-over switch ② to the sides of "VEL" and "10Hz" usually.

2-2 Turn the level knob clockwise, and set it to the position which is easy to read, provided that the meter indication is in the range of no shaking off.

2-3 The way of measurement-value reading is as follows.
The figures shown in the window of the indicator are the full-scale values. For instance, when the numerical value 300 is shown in the window and 2 is indicated, it can be read as follows.

200×1=200mm/S

Provided that the detection-form change-over switch ④ must be previously set to the "P-P".

×1 in the equation mentioned above is the multiplying factor in the case of vibration velocity (when on the side of 10Hz).

3. Measurement of vibration displacement

(1) Preparation-calibration

1-1 Set the power switch ⑥ to the BATT, and confirm that the battery voltage exists in the range of the indicator ③. (If it is beyond the limits of the BATT, replace the battery with the new one.)

1-2 Turn the level knob ① counterclockwise, and set it so that the display "SENS" is shown in the window ③ of the indicator.

1-3 Set the power switch ⑥ to the "ON".

1-4 Set the detection-form change-over switch ④ to the "P-P".

1-5 Now, the numerical value of □ mV/kgal mentioned on the pickup sensitivity table attached to this instrument is matched to the meter indication, turning the volume of the level regulator ⑤ for calibration. At this time, the scales to be matched are 120 to 80 graduated in the lower line.

(2) Measurement

2-1 When a measurement is made in the range of 10 to 100Hz of frequency, set the measurement-items change-over switch ② to the sides of "DIS" and "10Hz".

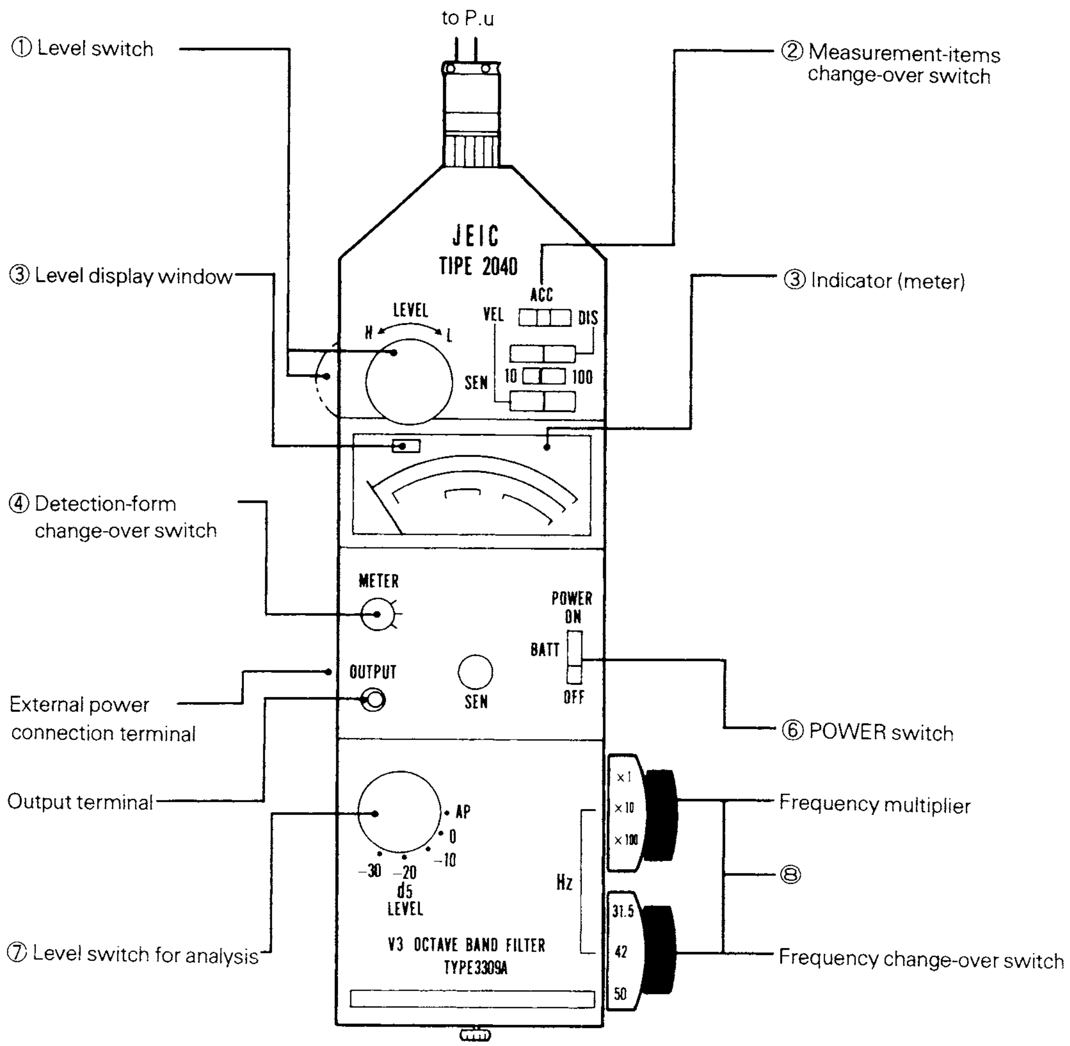
2-2 Turn the level knob clockwise, and set it to the position which is easy to read, provided that the meter indication is in the range of no shaking off.

2-3 The way of measurement-value reading is as follows.
The figures shown in the window of the indicator are the full-scale values. For instance, when the numerical value ③ is shown in the window and 1.4 is indicated, it can be read as follows.

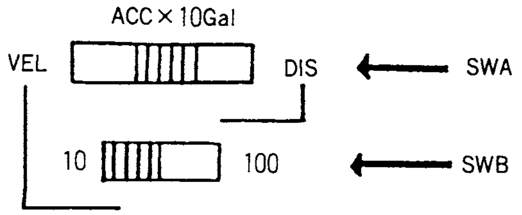
$1.4 \times 100 = 140 \mu m$

Provided that the detection-form change-over switch ④ must be previously set to the "P-P".
×100 in the equation mentioned above is the multiplying factor in the case of vibration displacement.

Fig.6-95



Supplementation 1
Measurement-items change-over switch ②



Here, let the upper switch be SWA and the lower one be SWB as mentioned above in the figure. By setting the SWA, the following measurements are possible.

When ACC vibration acceleration
When VEL vibration velocity
When DIS vibration displacement

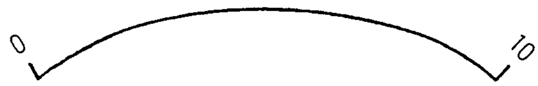
By SWA-SWB combinations, the frequency range and the measurement range can be shown as the following table.

SWA	SWB	Frequency range (Hz)	Measurement range
ACC (Acceleration)	10*	10~8,000	3~30,000Gal
	100	10~8,000	3~30,000Gal
VEL (Velocity)	10*	10~1,000	0.3~3,000mm/s
	100	100~8,000	0.03~300mm/s
DIS (Displacement)	10	10~100	30~100,000μ
	100	100~1,000	0.3~1,000μ

More, SWB marked with * is used many times in general.

Supplementation 2

Reading way of the indicated value (when P.U TYPE 2155 is attached)
As an example, the measurement of vibration acceleration (ACC) will be explained.

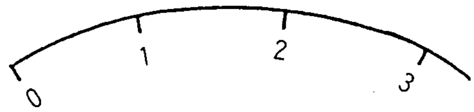


When "$^{100}{}_{110}$" is displayed in the level display window ③ by operation of the level switch ①, the full-scale "10" on this graduated scale becomes "100" of black figures. And, when calculating in consideration of ACC multiplying factor that is "×10Gal", the value of full scale is as follows.

100×10=1000Gal

When the scale "5" is shown, this is read as follows.

50×10=500Gal



When "$^{30}{}_{100}$" is displayed in the level display window ③ by operation of the level switch ①, the full-scale "3" on this graduated scale becomes "30" of black figures. And, when calculating in consideration of ACC multiplying factor that is "×10Gal", the value of full scale is as follows.

30×10=300Gal

When the scale "1.6" is shown, this is read as follows.

16×10=160Gal

6.9 Tools relating to new refrigerant R410A

6.9.1 Gauge Manifold for R410A

Fig.6-96

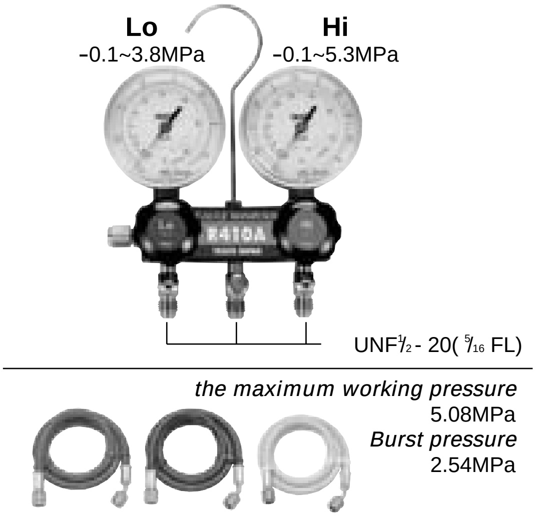
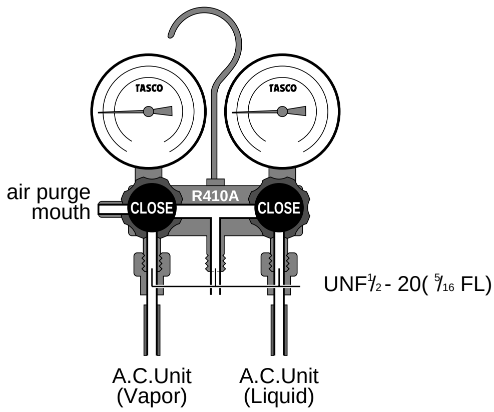
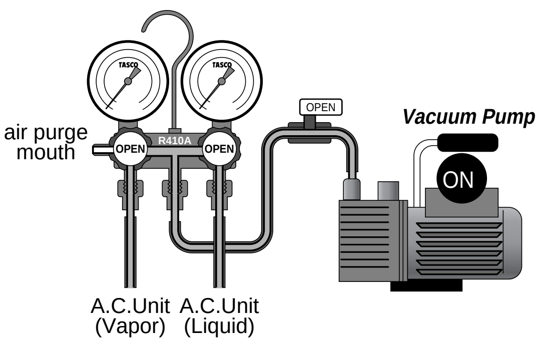


Fig.6-97



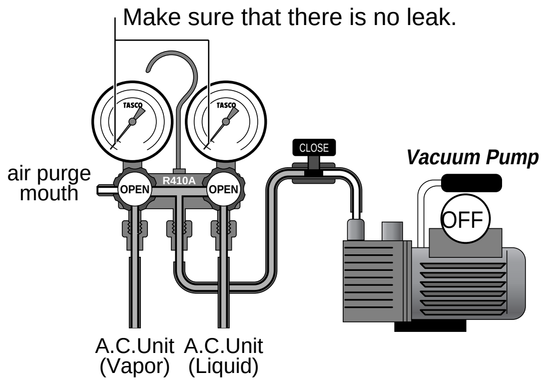
Vacuum

Fig.6-98



Leak Check

Fig.6-99



R410A is a refrigerant with about 1.6 times higher pressure compared to the conventional R22.Therefore, in order to prevent the damage and accident resulting in injuries or death caused by the incorrect charges of the apparatus, the standard radius of the service port was changed from 7/16UNF-20 threads (1/4flare) to 1/2UNF-20 threads (5/16flare).
Also, the quality for the majority of the refrigerating machine oil (synthetic oil) used for the HFC refrigerant machines differs greatly to the old refrigerating oil (mineral oil). If the two oils were to be mixed, an impure material would be made, which would cause great damage to the machines.
If the sealing material for conventional refrigerants is used for the HFC refrigerants, this would cause cracks and dissolution and this would inevitably lead to gas leakage. It is therefore necessary to use HNBR (high draw neoprene rubber) or the specially coated nylon for HFC-refrigerants.
R410A is a mixed refrigerant of R125 and R32. In order to avoid the change of component mixture, the refrigerant charge must be done in the liquid state.

Specifications

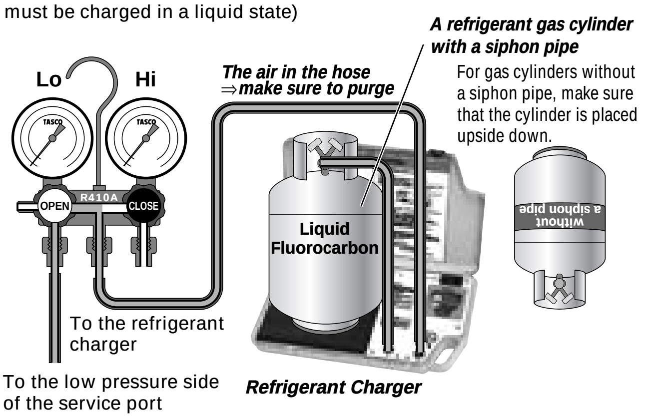
Gauge	LOW : -1.0~3.8MPa
	HIGH: -1.0~5.3MPa
Manifold Port Size for Service	1/2 UNF-20 (5/16FL)
Charge Hose	Environment type with stop valve
Gasket	HNBR for HFC

Instructions (on how to connect)

- Firmly connect the charging hose to the service port (1/2UNF-20) of the **R410A** unit. Please make sure that the valve of both High and Low of the gauge manifolds are closed.
- Moreover, please be sure to purge the air in the charge hose from the air purge mouth of the gauge manifold.
- The unit is now ready to measure the inside gas pressure of the AC unit.

Gas Charge

Lo : Low pressure valve ⇒**OPEN**
Open half of the valve, and charge half of the gas in a liquid state. (HFC must be charged in a liquid state)



6.9.2 Electronic Charging Scale & Weight Limiter

Fig.6-100 item no.TA101M

Measurable Gas	R410A, R407C/E, R404A, R507A, R134a, R12, R22, R502
Resolution	2g
Max Loading Weight	50kg
Usable Recovery Systems	TA110A, B, C, R
Usable Tanks	for charger : ~20kg tanks for weight limiter : ~20kg standard recover tanks
Table Measurement	L228 × W228
Display Measurement	L30 × W63 mm
Power Supply	
Operating Temp	—5~40˚C
Inlet/outlet Ports	IN(UNF7/16-20) × OUT(UNF7/16-20) with UNF1/2-20 adapters for R410A ball valve × 1, port for recovery operations
Dimension/Weight	L460 × W300 × D60(mm) / about 4.5kg

Fig.6-101 item no.TA101SX

Measurable Gas	R410A, R407C/E, R404A, R507A, R134a, R12, R22, R502
Resolution	2g
Max Loading Weight	50kg
Usable Recovery Systems	TA110A, B, C, R
Usable Tanks	for charger : ~20kg tanks for weight limiter : ~20kg standard recover tanks
Table Measurement	L228 × W228
Display Measurement	L30 × W63 mm
Power Supply	
Operating Temp	—5~40˚C
Inlet/outlet Ports	IN(UNF7/16-20) × OUT(UNF7/16-20) port for recovery operations × 1
Dimension/Weight	L460 × W300 × D60(mm) / about 4.8kg
Attachment	hose for accuracy charging(UNF7/16-20 female × UNF 7/16-20 female with valve core depressors) × 1 Adapters for R410A × 2, AC adapter × 1

Refrigerant Charger

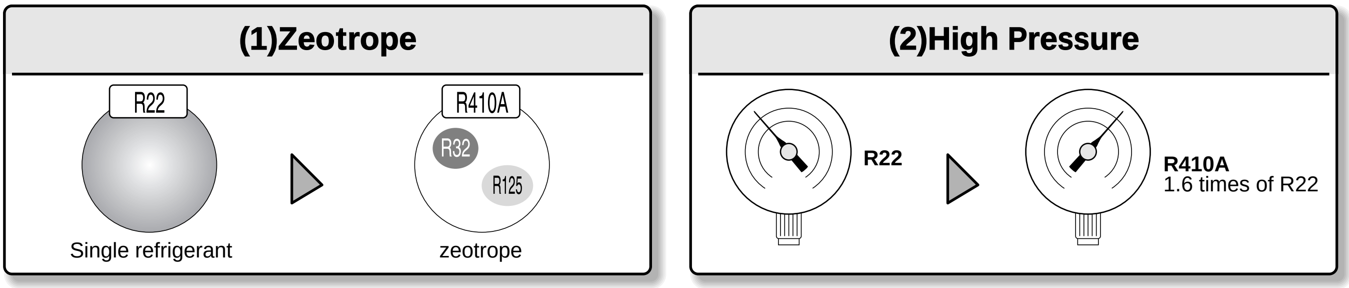
Notes

R410A is the refrigerant with which two kinds of refrigerant (R32 and R125) were mixed. If R410A is filled up with gas into an air-conditioning machine, this will cause a change to the composition and the apparatus won't demonstrate it's full capacity. Therefore, it is necessary to fill up R410A in a liquid state. Moreover, the amount of enclosure refrigerant of the latest air-conditioning apparatus is decreasing compared with before.

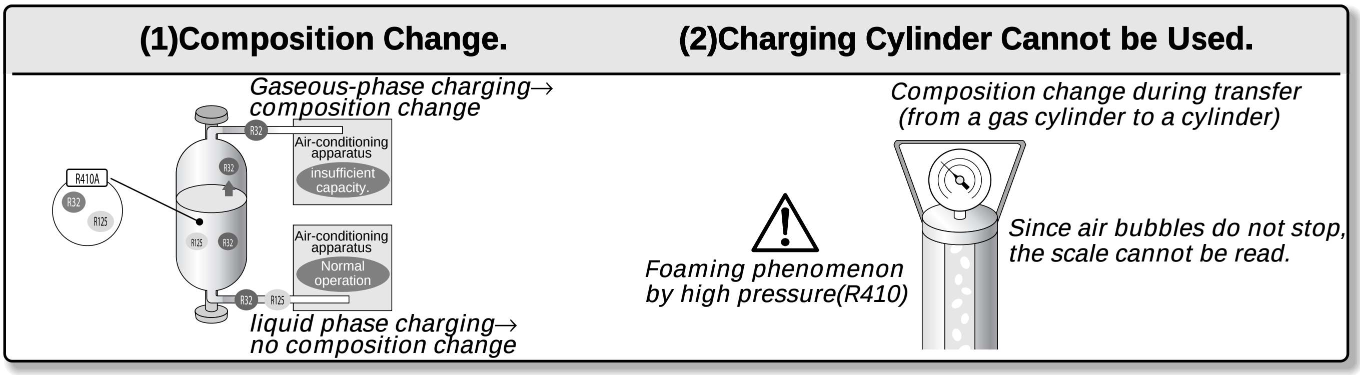
Therefore, few charging errors becomes the cause which has big influence on the capacity of apparatus.

Charger using a refrigerant meter with high (less than ±5g of charging errors) accuracy is required.

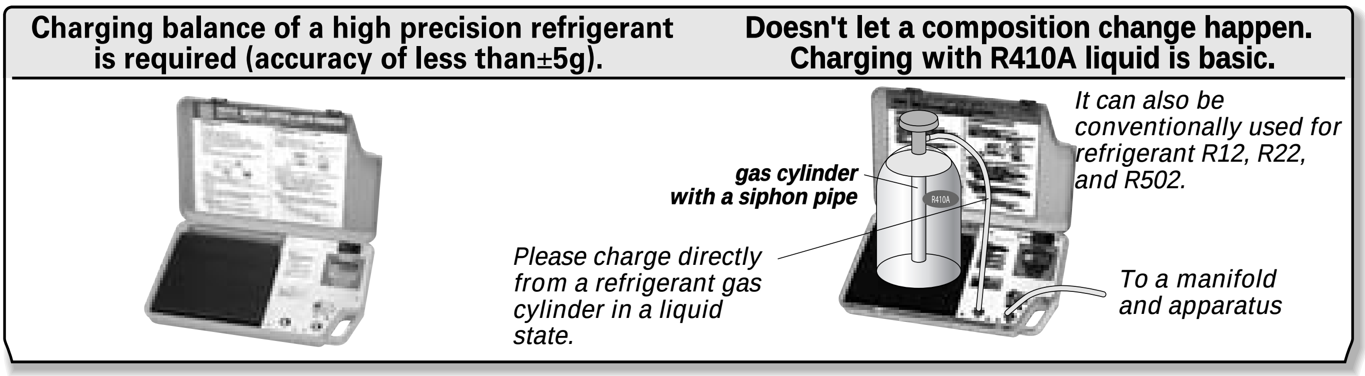
The Property of R410A



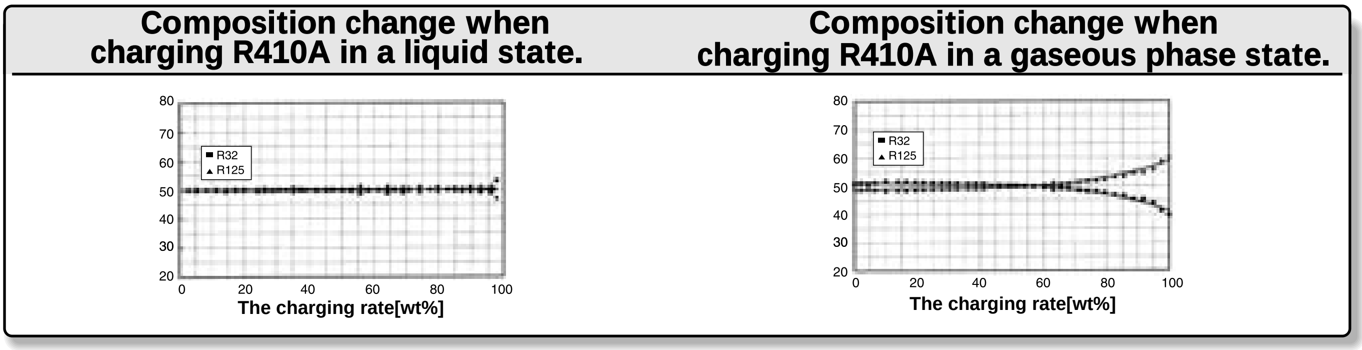
The Problem of Charging R410A



Measures



(Reference) Composition change of a liquid phase chase charging and gaseous-phase charging of R410AA refrigerant



The Feature for the Electronic Charger for R410A

Fig.6-102

<TA101M>

(a) Accuracy is less than ±5g.
A charger with especially high accuracy is needed for R410A.

(b) With a hose shake prevention port.
Since it is not necessary to attach the charge hose directly from a gauge to the gas cylinder during measurement, the charger isn't influenced and accuracy is maintained.

(c) A manual opening-and-closing valve
Since the opening-and-closing valve (ball valve type) is located under the digital indicator, closing of the valve can be performed with sufficient timing by looking at the charging numerical value (there is also an automatic charge type with a built-in solenoid valve).

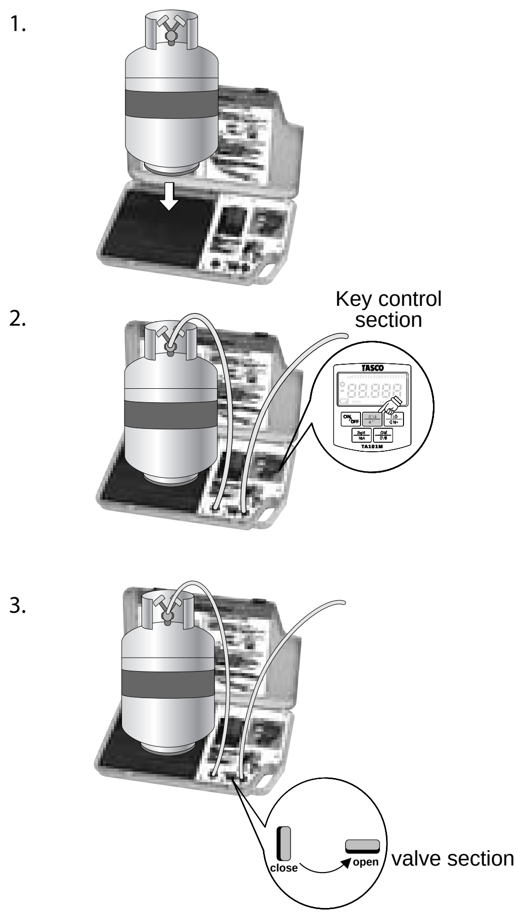
(d) A weight limiter function for recovery machines
If the sensor cord of a recovery machine is inserted in the sensor plug of (d), refrigerant recovery for general recycling can be performed cheaply.

(e) A tare influence function
By using a tare influence (weight in state where cylinder and charge hose were set being set to 0) the display shows the present amount of charge at a glance.

How to Use an Electronic Charger

(1) Manual Charging

Fig.6-103 TA101M type



Manual charging, weight limiter combination type

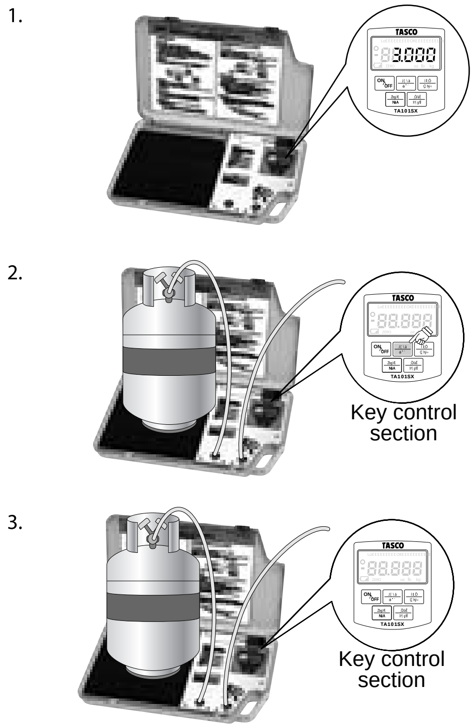
Fig.6-104

TA101M

1. A gas cylinder is put on the measurement stand.
2. Set charge hose and push the tare influence button.
3. Open the valve of the gas cylinder or the valve of the electronic charger, and fill with refrigerant.
4. When digital display reaches the charging value, close the valve. This will complete the process.

(2) Automatic Charging

Fig.6-105 TA101SX type



Automatic Charging and weight limiter combination type

Fig.6-106

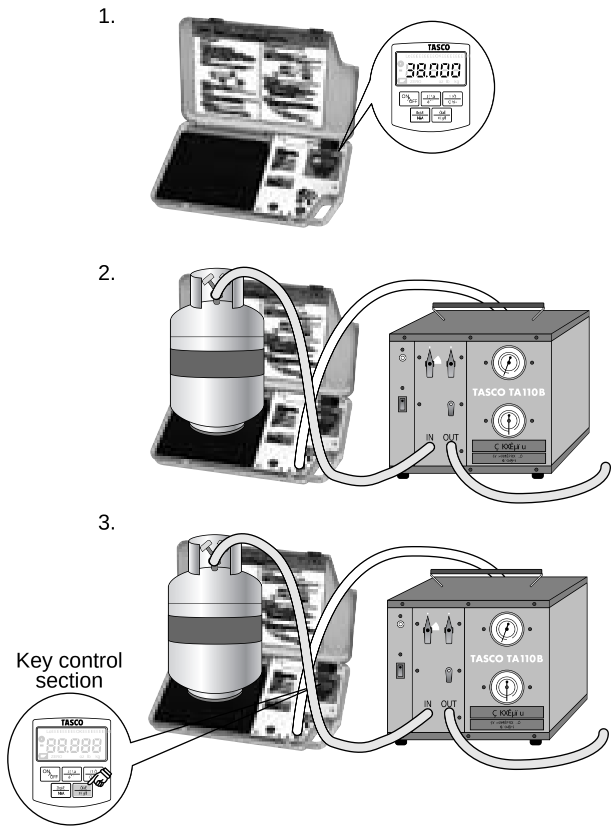
TA101SX

1. Set the charging value by the key control section.
2. Place the gas cylinder, the charging hose and push the tare influence button.
3. Push the start button and start the charge.
4. If digital display reaches a charging value, charging will be automatically stopped by the built-in solenoid valve.

(3) When Using as a Weight Limiter

Weight limiter.....
When recovering the refrigerant, the full liquid and cylinder weight is set beforehand, and when the cylinder is full, the weight limiter will automatically stop the recovery machine.

Fig.6-107 TA101SX, M type community



1. Set the gas limit value (the weight of recovery cylinder +85% of marginal amount of liquid) with the key control section.
2. Set the gas cylinder and charging hose, and then set the sensor cord of the recovery unit to the connector of the weight limiter.
3. Push the start button, turn on the recovery machine and recovery is started.
4. If the previously set numerical value is reached, the sensor cord will stop the operation of the recovery machine.
   *If the recovery unit is completed before it reaches the set point, it can succeedingly be used to the next time with the last set point.

6.9.3 Vacuum Pump

Correspondent to the new refrigerant apparatus

The Vacuum Influence
In the installation process of air-conditioner, the air in the pipes are all extracted after the attachment of pipes. (If not extracted, when operating, the inside of the cycle would show extreme high pressure.)
Evaporate the moisture in piping.(If ever a slight moisture remains, this will cause the degradation of the refrigerant machine oil, which would lead to the burning of the compressor.)
This work is called vacuum process and a vacuum pump is used as an apparatus .

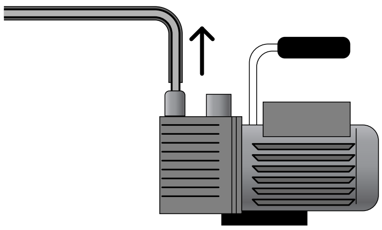
The Necessity for Counter Flow Prevention
After the vacuum process of the refrigerant cycle, the inside of the hose will be vacuumed after stopping the vacuum pump, and the vacuum pump oil may flow back. Moreover, if the vacuum pump stops during the operation by some reason, the same thing happens.
In such cases, different oil mixes in the HFC system refrigerant apparatus cycle, and becomes the cause of a refrigerant circuit trouble. Therefore, in order to prevent the counter flow from the vacuum pump, a check valve is needed.

Refrigerant Machine Oil for HFC Refrigerant Apparatus

Synthetic oil use
POE
PVE etc.

Mixing of Different Oils

Counter flow and mixing of vacuum pump oil (mineral oil)



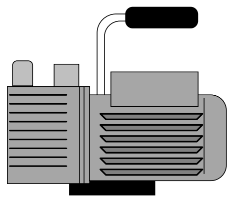
Problem outbreak

Since refrigerating machine oil (synthetic oil) and vacuum pump oil (mineral oil) turn into different oils, if mixed in the apparatus, they will become impurities and will lead to HFC freezing air-conditioning apparatus damage. (burning of compressors, clog of capillary)

Units to be used for such measures

A vacuum pump with an check valve
(it can also be used for conventional refrigerants.)

A vacuum pump for conventional refrigerants. + **Check valve (vacuum pump adapter)**



If the check valve (vacuum pump adapter) is connected to the vacuum pump for conventional refrigerants, this can also be used for new refrigerants (HFC).

- The refrigerant machine oil used for a HFC system refrigerating cycle has the high hygroscopicity of moisture. If moisture is mixed, it generates an acid substance. Therefore, sufficient moisture removal by the vacuum pump with which high vacuum is needed. ((More than) 0.5Torr=-0.0993MPa)

* For the air omission method at the time of apparatus installation for air discharge prevention of a refrigerant, it is recommended to stop using the gas purge system and use the vacuum system instead.

A Vacuum Pump with an Check Valve

Small Highly Efficient Two Stage Vacuum Pump

Fig.6-108 item no.TA150F

Exhaust Speed	50 liter/min(50Hz) 62 liter/min(60Hz)
Degree of Vacuum	5x10^{-3}Torr(5microns)

- Since a gas ballast valve is attached, the oil won't become easily filthy.
- Since it has a check valve, both new & conventional refrigerants can be used.

Rotor System	Two stage
Drive System	Direct
Rotation Frequency	2900r.p.m. (50Hz) 3480r.p.m. (60Hz)
A Power Supply and Motor	100V 240W
Size and Weight	250(H) × 290(W) × 150(D) mm 19.5kg
Inhalation Port	UNF7/16-2
Accessories	UNF1/2 -20 (for R410A) adapter M10P1.5 (for R134a) adapter

Micro Highly Efficient Two Stage Vacuum Pump

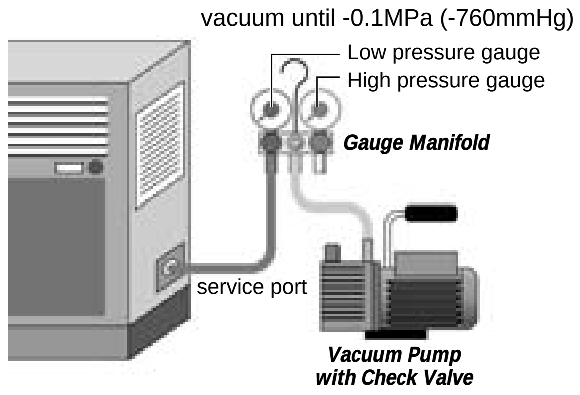
Fig.6-109 item No.TA150H

Exhaust Speed	22.5 liter/min(50Hz) 27 liter/min(60Hz)
Degree of Vacuum	5 × 10^{-3}Torr(5microns)

- Since it has a check valve, both new & conventional refrigerants can be used.

Rotor System	Two stage
Rotation Frequency	2750r.p.m. (50Hz) 3300r.p.m. (60Hz)
A Power Supply and Motor	100V 130W
Size and Weight	220(H) × 280(W) × 170(D) mm 6.8kg
Inhalation Port	UNF7/16-2
Accessories	UNF1/2 -20 (for R410A) adapter M10P1.5 (for R134a) adapter

Fig.6-110



Attention

An exclusive charge hose and gauge manifold should be used. The connection aperture of the R410A charge hose is set to UNF1 / 2-20. Please change the connection aperture of the vacuum pump by the attached adapter.

When you have a vacuum pump for former refrigerants (not HFC refrigerants).

Vacuum pump only for the former refrigerants

+

Check valve (vacuum pump adapter)

Check Valve (Vacuum Pump Adapter)

Fig.6-111 item no.TA159PA

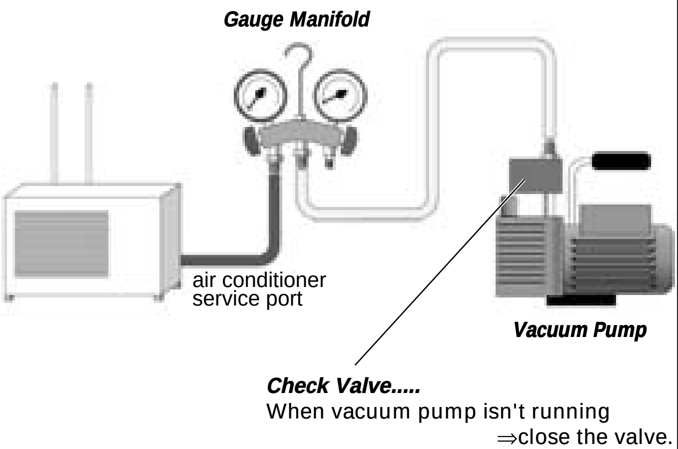
Power Supply	100V
Plug Socket	100V and below 6A
Connection Mouth to a Pump	UNF7 / 16-20
Inhalation Port	UNF7 / 16-20
Attached Adapter	UNF1 / 2-20 (for R410A) M10P1.5 (for R134a)
Main Part Size	58W × 80L × 52Hmm
Cord	3m

- Please use it for the vacuum pump which you already have.

Attachment

Fig.6-112

Fig.6-113



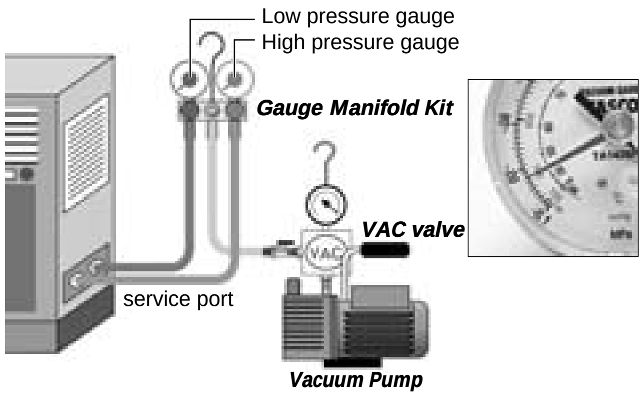
6.9.4 Vacuum Gauge

The compressor oil used for a HFC system refrigerating cycle has the high hygroscopicity of moisture. And if moisture is mixed, there is a characteristic which generates an acid substance. Therefore, it is a necessity to maintain the degree of vacuum as well as the complete remove of moisture.
With a normal gauge manifold the values on the vacuum range is limited. and is hard to identify the degree of vacuum. Therefore the vacuum gauge is recommended.

Vacuum Gauge Kit
(Directly Attached Vacuum Pump)

Fig.6-114 item No.TA142VK

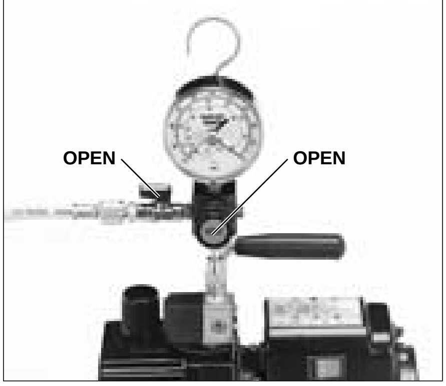
Fig.6-115



- A large 80ϕ gauge with easy to read numerical values.
- With [convenient for an airtight leak check] an installation needle.
- The diaphragm style Teflon sheet packing which has small resistance to the manifold valve used.
- Since it has a water evaporation temperature scale, the relation between outside temperature, water evaporation temperature, and the vacuum is quite obvious.

Pressure Range	0~-0.1Mpa
(Vacuum Region)	(0~-760mmHg) With water evaporation temperature scale
Attachment Screw	UNF7 / 16-20

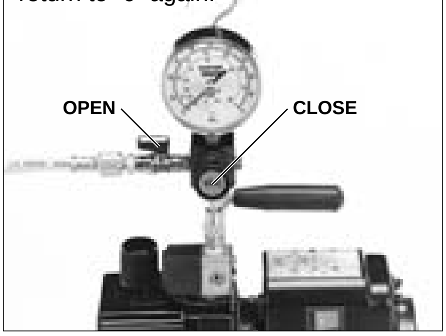
Vacuum Process



Needs the vacuum valve of more than -0.0993MPa (0.5Torr).

Airtight Examination

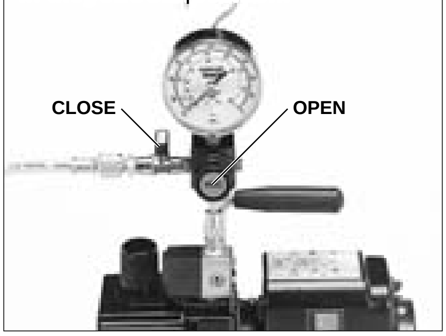
Make sure that the needle doesn't return to "0" again.



Please set the installation needle in the direction the gauge needle indicates.

Refrigerant Charge

Make sure that the valve is in the "CLOSE" position.



⚠ A gauge will break if the pressure of the refrigerant is applied

6.9.5 Gas leak detector corresponding to new refrigerant HFC

Since there is a high possibility of gas leakage out of a refrigerating cycle, stricter airtight management is needed. Moreover, because the detection capacity of a HFC refrigerant is difficult, a highly efficient gas leak detector is needed.

Features

Fig.6-116

- Correspondent Refrigerant
  .....R410A, R407C(E) R404A, R507A, R134a, R22
- Sensitivity Change (Lo / Hi)
- Auto Balance Function
  .....If a switch is changed to ON⇒OFF⇒ON, the leak concentration is automatically made to zero, and the function to react only to a high concentration leak is attached. This is useful to pinpointing the direct leakage.
- Leak Perception Amount Display Indicator
- Lo BATT.....Low Battery Display
- Small Powerful Suction Pump Inserted
  .....Since the powerful suction pump is inserted, it can detect sharply and there is no worry of the buzzer ringing endlessly.

Specifications

Correspondent Refrigerant	R410A, R407C(E) R404A, R507A, R134a, R22
Detection Sensitivity..... Hi	23g/year (R410A), 20g/year (R407C) and 14g/year (R134a)
Lo	23g / year (R22)
The Detection Display Method	A five-step indicator, buzzer
Function	• Auto balance function • Low battery indicator • Automatic inhalation pump
Warm Up Time	About 20 seconds
Operating Temperature	0 to 40˚C
Power Supply	Size AA battery
Dimension and Weight	254(H) × 78(W) × 34(D)mm, 395g (battery include)
The Set contents and Accessories	• Main unit • Extended nozzle • Storage case • Battery (AA cell × 6)

Fig.6-117

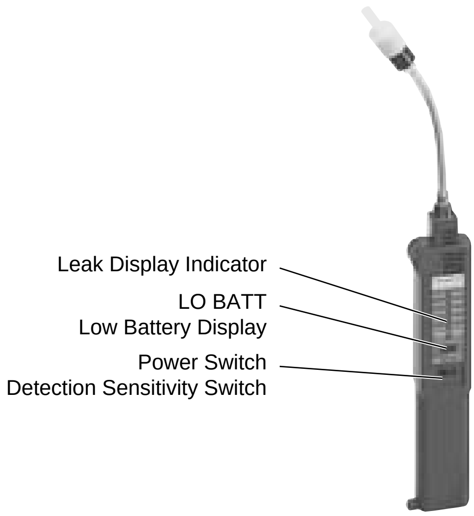
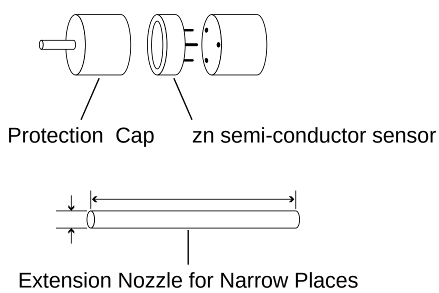


Fig.6-118



Leak detector

corresponding to new refrigerant HFC

New refrigerant apparatus

R410A
R407C/E
R404A
R507A

The property of a new refrigerant

- •Molecules are small.
- •Chlorine is not con-tained.

Problem

- •Leaks easily. High perception capacity is required.
- •Conventional leak detectors which detect chlorine cannot be used.

Measures

- •A leak detector of high sensitivity is required.
- •A leak detector which detects components other than chlorine is required.

Sensitivity ratio

.... Comparing the sensitivity of HFC refrigerant to the conventional leak detector, about 50 times are needed.

Refrigerant	HFC134a	CFC11	CFC12	HCF22	R502	R5404A	R407C	R410A
Sensitivity Ratio	0.042	2.958	1.25	1	1.5417	0.0375	0.029167	0.025

A sensitivity ratio is the numerical value when HCFC22 is set to 1.

With a HFC refrigerant...

Gas leak detection liquid, a gas leak detection spray → As molecule composition is small, it's hard to distinguish a leak.

Combustion equation gas leak detector → Because of the combustion reaction of chlorine and copper, HFC refrigerant with which chlorine is not contained is undetectable.

Leak detector for former refrigerants → Since a HFC refrigerant does not contain chlorine, the leak detector type which detects chlorine cannot be used.

Does a gas leak detector correspond to various refrigerants or not?
Perception capacity of a detector.

Detector	The detection method	CFC, HCFC		HFC			Leak detection capacity of a refrigerant (g / year)	
		CFC12	HCFC22	HFC410A	HFC407C	HFC134a	HCFC22	HFC410A
Gas leak detection liquid (spray type)	A leak is checked with bubbles.	△	△	△	△	△	500	500
Combustion equation gas leak detector	The combustion reaction of Cl (chlorine) and Cu (copper)	○	○	×	×	×	50	—
The leak detector corresponding to the conventional refrigerant	Cl (chlorine) detection system	○	○	×	×	×	14	—
The conventional refrigerant and R134a correspondence	Fluorine detection system	○	○	×	×	△	14	560
The leak detector corresponding to a new refrigerant	Hydrogen detection system	×	△	○	○	○	14	23
Leak detector correspondent for both conventional and new refrigerants.	Semiconductor sensor system (Heat diode)	○	○	○	○	○	14	24

6.9.6 Airtight examination

What is an airtight examination?
After completion of pipe, nitrogen is pressurized under the manufacturer's regulation pressure. By the motion of the needle, one can check if there is a leak or not.

Airtight leak tester
N2 pressurization kit for airtight examination

Fig.6-119 item No.TA385A

The contents of a set

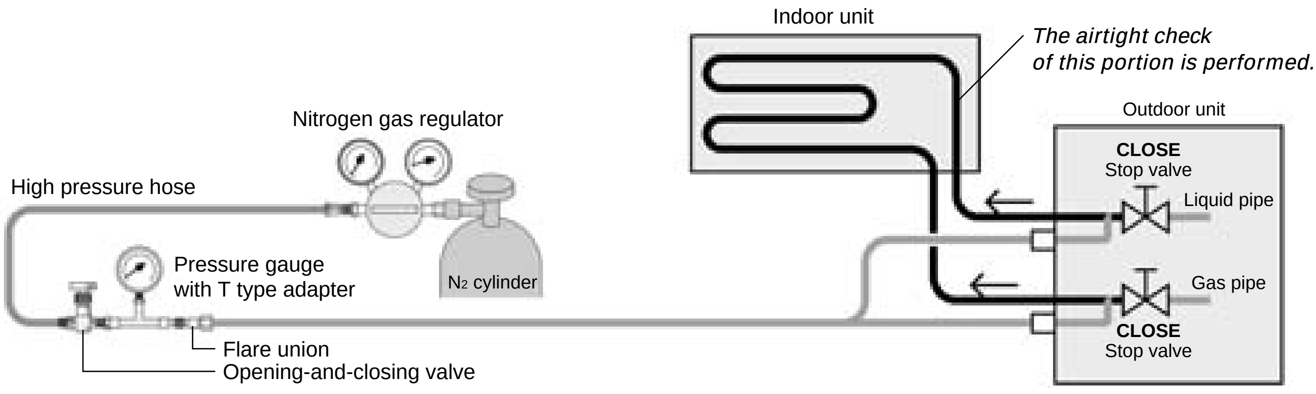
- Nitrogen Regulator.....Secondary side 0~8.0MPa ×1
- Pressure Gauge with T Type Adapter (placing with a needle)
  - · Pressure Gauge : 0~7MPa
  - · Hose Connection Mouth : 7/16UNF-20 female (with valve core depressors) × 7/16UNF-20 male (with valve core) × 1
- High Pressure Hose for Connection : 5m × 1
- Opening-and-Closing Valve :7/16UNF-20 × 2 (with valve core depressors) × 7/16UNF male × 1
- Gas Leak Detection Liquid × 1
- Flare Union for Pipe Connection :7/16UNF, 9/16UNF, and for 11/16UNF.....1 each
- Alcohol Thermometer × 1
- Storage case (480 × 250 × 230 mm) × 1

Cautions for the airtight examination

1. Please do not use any gas other than nitrogen (oxygen, combustible gas) by any means as pressurization gas.
2. Please perform with stop valve of the exterior unit closed.
3. Please be sure to pressurize both the liquid and the gas pipe.
4. After the test, Nitrogen should be extracted.
5. If 1˚C of ambient temperature changes, since pressure will change about 0.01 MPa (0.1 kg / cm^2), please rectify.
6. After brazing, if pressurized before piping temperature falls, this will decompress after cooling.

The Airtight Examination Method

Fig.6-120



As shown in the above figure, the liquid and gas pipe are pressurized with nitrogen from the service port.
*Please keep the stop valve of both outdoor units closed at this time. Please do not open by any means. Moreover, as there is possibility of mixing nitrogen in the exterior unit cycle, the valve rod should be shut tightly before pressurization.

Please proceed measures as follows and pressurize gradually.
*Please do not pressurize pressurization to regulation pressure at once, but perform it gradually.

Step 1 — **Stop pressurization at 0.5MPa (5 kg/cm^2), and leave for 5 minutes or more, and check that there is no fall of pressure.**

Step 2 — **Stop pressurization at 1.5MPa (15 kg/cm^2), and leave for 5 minutes or more again, and check that there is no fall of pressure.**

Step 3 — **Lastly, pressurize up to the regulation pressure(design pressure of apparatus) and make a note of ambient temperature and pressure.**

Leave for about 24 hours and if there is no fall of pressure, then all is successfully completed.
*If 1˚C of ambient temperature changes at this time, pressure will also change about 0.01 MPa (0.1 kg/cm^2).

Step 1, Step 2 : Big leak discovery
Step 3 : Small leak discovery

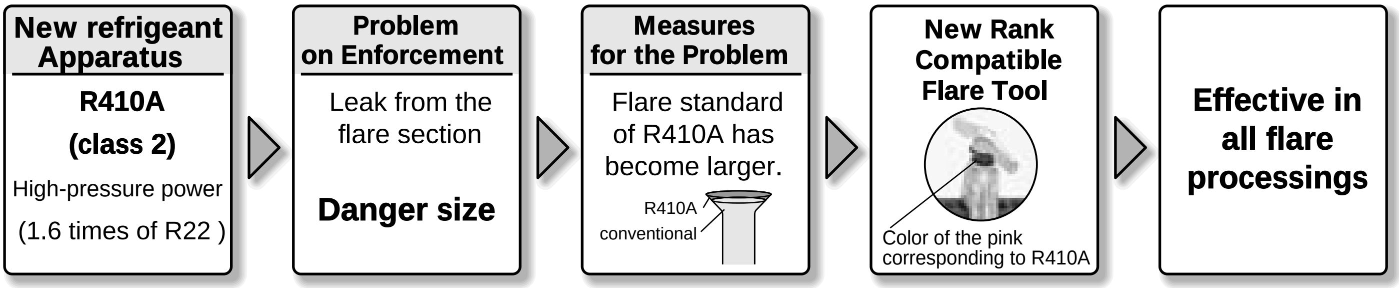
Discovery and the Correction Method

1. When there is fear of a leak, discover and fix by covering the welding section, the flare section, the flange section, each unit section, etc.
   ⇒Please make sure to perform a nitrogen blow when repairing by brazing.
2. If the leak cannot be easily discovered, mix the refrigerant gases, and pinpoint the leak roughly with a leak detector.
3. The pipe in a pit should tested of leaks before embedding.

6.9.7 Flaring Tool

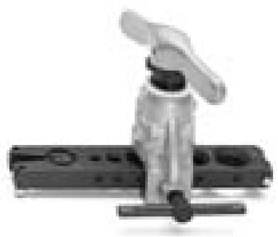
Compared to previous refrigerants, the components of a HFC refrigerant is small. R410A also has a higher pressure than other refrigerants, revealing it as a dangerous refrigerant. Therefore, in order to strengthen the intensity of the form and size of the flare section used for R410A (class 2) apparatus, unlike the specification of the conventional refrigerants, it was set up with different standards.

When carrying out flare processing, use a new rank compatible flare tool or a conventional flare tool. When using the later, use a flare gauge to take out the pipe from the gauge bar, adjust it, and then carry out the flare processing.



New Rank Compatible Flare Tool

Fig.6-121 item No. TA550N



- Flare processing for both the refrigerant and new refrigerant can be processed.
- When the flare is completed, the clutch will function, and the handle will idle, so the stress beyond necessity is not applied.
  conformity size 1/4", 5/16", 3/8", 1/2", 5/8", 3/4"

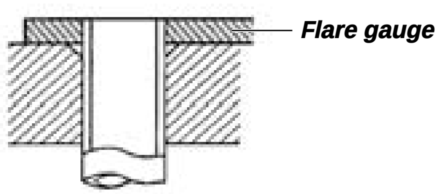
Flare Gauge (Adapter Corresponding to the New Rank)

Fig.6-122 item No. TA504G

Fig.6-123

Size 12mmx72mm

Thickness 1.0x0.5mm Each



Size from the dice surface to the copper tip (in mm)

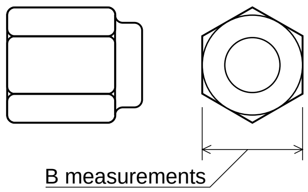
Name	Outer diameter	Wall thickness	New rank compatible flare tool	
			The conventional flare tool	The conventional flare tool
			Clutch type (Previous Refrigerant)	Clutch type (R410A)
1/4	6.35	0.8	0~0.5	1.0~1.5
3/8	9.52	0.8	0~0.5	1.0~1.5
1/2	12.70	0.8	0~0.5	1.0~1.5
5/8	15.88	1.0	0~0.5	1.0~1.5

6.9.8 Torque Wrench

In order to prevent the leak of the refrigerant by the weak tightening of the flare nut or to prevent the damage of the copper tube flare section by tightening too much, please bind the flare nut with a proper bolting torque.
If a torque wrench is attached with a regular bolting torque,the head will eventually break.

Opposite side size specification of a flare nut

Fig.6-124



Size		B measurements	
inch	mm	R410A	others
1/4"	6.35	17	
3/8"	9.53	22	
1/2"	12.70	26	24
5/8"	15.88	29	27
3/4"	19.05	36	

others*
=Meaning R407C(E),R404A, R507A, HFC134a refrigerants <mm>

R410A
high-pressure power
(1.6 times of R22)

A crack of the flare nut caused by over tightening.

The leak from the nut section

Measures
Specification of a flare nut (R410A)
1/2 : 24mm ⇒26mm
5/8 : 27mm ⇒29mm
(has become larger)

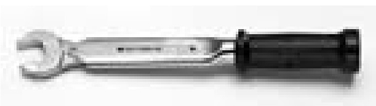
The adaptation table of the flare nut and the tightening torque. (Standard value by JISB 8607-1999)

copper tube size	#1)and former products <size(mm)×torque(N·m)>	#2)<size(mm)×torque (N·m)>
1/4" (6.35)	17 × 16	17 × 16
3/8" (9.53)	22 × 38	22 × 38
1/2" (12.70)	24 × 55	26 × 55
5/8" (15.88)	27 × 75	29 × 75
3/4" (19.05)	36 × 110	36 × 110

#1)R407C(E), R404A, R507A, HFC134a
#2)R410A

High Quality Torque Wrench

Fig.6-125

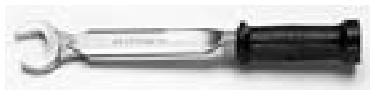


item no.	flare nut size	size(mm)×torque N·m (kgf·cm)	length (mm)
TA771A	1/4"	17 × 15.6 (160)	220
TA771B	1/4"	17 × 17.6 (180)	220
TA771H	3/8"	22 × 41.1 (420)	265
TA771J	3/8"	22 × 29.9 (300)	265
TA771L	1/2"	24 × 53.9 (550)	265
TA771R	5/8"	27 × 75.0 (765)	335
TA771S	3/4"	36 × 110.0 (1122)	403

For new refrigerant units with 1/4", 3/8", we recommend those of TA771B and TA771H.

High Quality Torque Wrench specifically for R410A

Fig.6-126



item no.	flare nut size	size(mm)×torq·ue N·m (kgf·cm)	length (mm)
TA771L-2	1/2"	26 × 53.9 (550)	265
TA771R-2	5/8"	29 × 75.0 (765)	335

- Colored by R410A colar (pink)
- 1/4", 3/8", 3/4" are the same as other refrigerants.

6.9.9 Charge Valve

- **Compared with R22, the R410A refrigerant has gas pressure as high as 1.6 times.**
- **In order to bear high pressure, the hose is specially coated with nylon.**

If a charge hose is not carefully removed after service of refrigerant charging etc, there is fear of injury by the dancing of the hose.

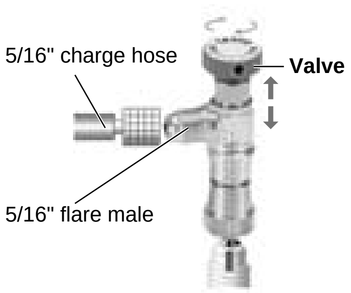
The desorption of a charge hose can be performed safely if a charge valve is used, since the valve opening and closing in the hose tip section will be attained.

R410A Charge Valve

Fig.6-127 item no.TA166

Diameter of Connection	UNF1/2-20 Male × UNF1/2 -20 Female
Full length	73mm
Use	When removing the charging hose, prevention of jet gas from both sides of unit.

Fig.6-128



↓ **OPEN**
The valve core on the service port will push and make way for an opening.

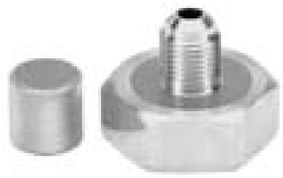
↑ **CLOSE**
The valve core on the service port will close the opening.

Gas Cylinder Adapter

Although the diameter of gas cylinder side of the connection of the R410A refrigerant is the same with former (W26-14), the diameter of charge hose side connection is set to UNF1 / 2-20.

R410A Gas Cylinder Adapter

Fig.6-129 item no.TA165AF



Gas Cylinder Connection Side	W26-14
Hose Connection Side	UNF1 / 2-20
Use	Connection between an R410A cylinder and a charge hose

- With a seal cap
- The band of color pink R410A is placed inside.

6.9.10 Fluorocarbon Recovery Machine

Fig.6-130 item no.TA110R

Applicable for both new and conventional gas refrigerants
R12,R22,R500,R502,R134a,R410A,R407C,R404A,R507A

Specifications

Power Source	100V 50/60HZ
Compressor	400W (1/2HP) Oil free
Recovery system	• Gas, Half-liquid,Liquid Liquid compression type refrigerant recovery system (it is the system which compresses and liquefies a refrigerant by the compressor and is enclosed in a gas cylinder) • Liquid Push-pull System (The system which pressurizes with the recovery system and collects in a liquid state.)
Noise Value of the unit	65dB
Level of Vacuum Attainment	-0.05MPa (Gauge)
Extra functions	Purging Function
Dimensions, Weight	300(H) × 260(W) × 430 (D)mm, 11.5kg
Operating Temperature Range	0~39˚C
The Connectable Recovery Gas Cylinders	~100kg (120liter), gas cylinder with gas cylinder (sold separately) • Weight Limiter (sold separately) Applicable gas cylinder=~20kg Standard recovery gas cylinder (sold separately)
Attachments	• 1/4 charging hose with flare valve 150 × 2 • 1/4 flare charging hose 30cm × 1 • R410A hose adapter 5/16 Ferule × 1/4 Male • Inlet filter × 1

Recovery Abilities

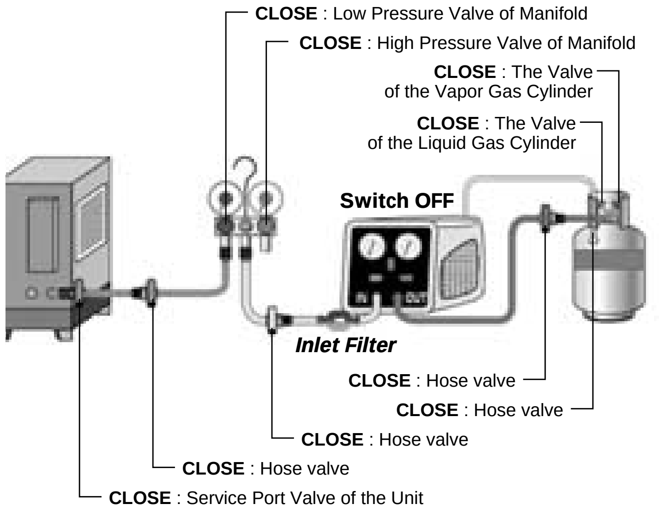
	Volume of Refrigerant Recovery (g) / min					
Recovery Method	**R12**	**R502**	**R22**	**R134a**	**R410A**	**R407C**
VAPOR(GAS)	100	120	120	100	130	120
HALF LIQUID (GAS LIQUID)	1200	1300	1300	1200	1100	1300
LIQUID(PUSH-PULLSYSTEM)	3800	4550	4630	3900	4780	4680

*This data of R22 is from RRC 7002. It's recognized at UL, ARI.

RECOVERY METHOD

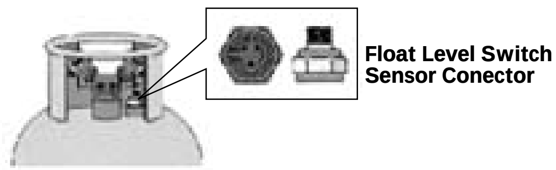
(1) Connecting Method

Fig.6-131



1. Please check that the apparatus side service port valve, the manifold valve, the hose valve, the recovery gas cylinder, and both valves of the liquid and gas are closed.
2. Please connect apparatus, manifold, the refrigerant recovery machine, and the recovery gas cylinder with the valve connected charging hose.
3. Firmly attach float level switch cord to the recovery gas cylinder to prevent over charging.
   *If the connection cannot be confirmed, the recovery machine will not operate.

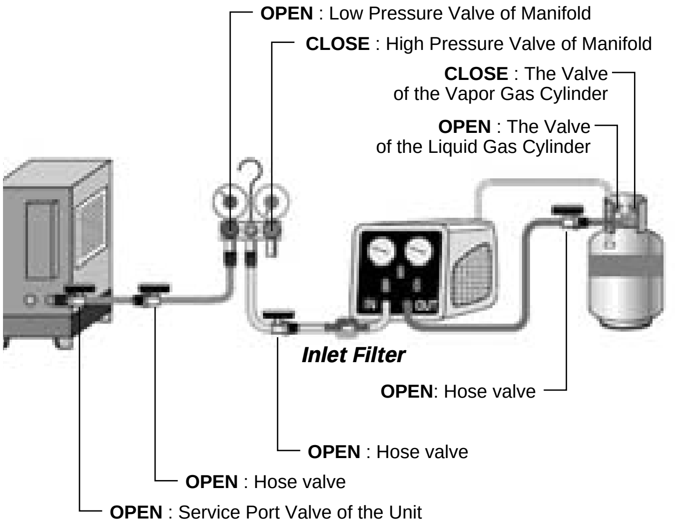
Fig.6-132



4. Please check that the operation switch of the recovery machine is turned off, and insert the power cord in the plug socket.
   - Please check that voltage is not rapidly dropping, as this will cause malfunction.
   - In this case, please secure voltage by the rise transformer.

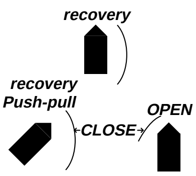
(2) Starting Preparation

Fig.6-133



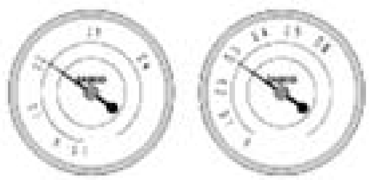
1. After completion of each apparatus, please open each valve of the recovery machine as shown in the figure.

Fig.6-134



2. Do not open the blue valve to full extent, but open it a little, so that the valve stops around the middle. The cycle is opened when the blue valve is opened, which will let the refrigerant flow in. Please make sure that the needle of the low pressure gauge and the high pressure gauge is going up.

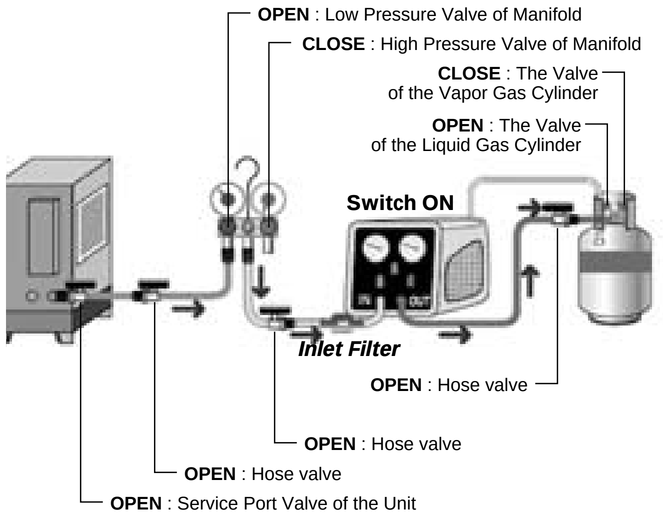
Fig.6-135



*If the pressure doesn't rise, it is possible that the blue valve is not fully opened, or that the service port, the manifold valve, and the hose valve are closed.
(Please also check that there is some refrigerant left in the apparatus)

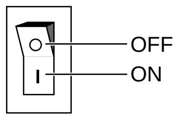
(3) Recovering mode

Fig.6-136



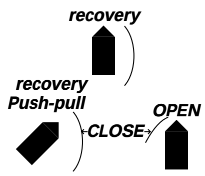
1. Please turn the recovery unit switch on (I side)

Fig.6-137



2. Slowly and gradually open the blue valve.
   If the compressor makes a strange knocking sound, then immediately close the valve again. This sound means that the unit was recovering liquid refrigerant.

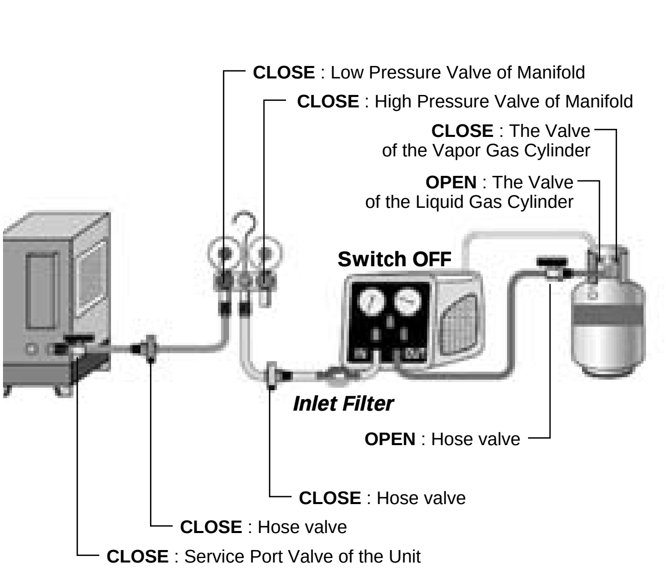
Fig.6-138



*Please check all conditions while opening the blue valve.

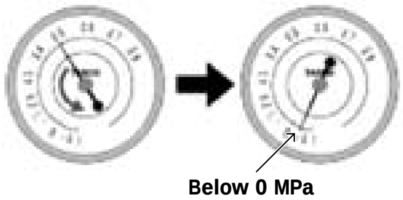
(4) End of Recovery Operations

Fig.6-139



1. When recovering, the numerical value of the suction side of the pressure gauge will gradually fall.

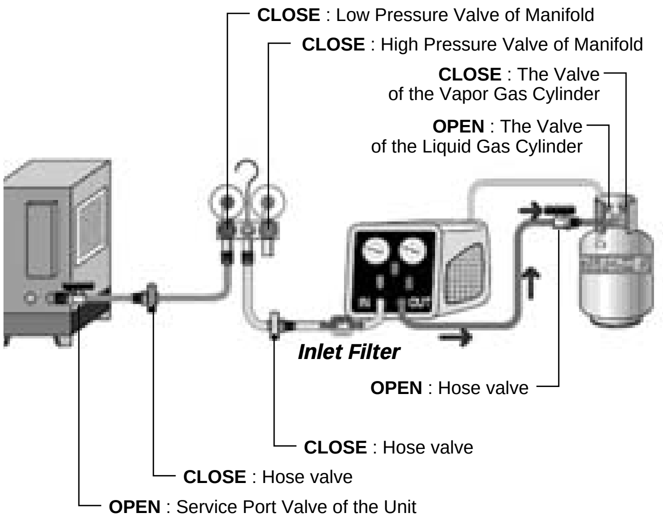
Fig.6-140



2. If the numerical value on the pressure gauge goes below 0MPa, this would indicate that the recovery process is almost finished.
3. Turn the switch OFF.
4. Leave the recovery unit for 5 to 15 minutes. If the needle on the pressure gauge doesn't go over 0.1MPa, then this would indicate the end of the recovering process.
   If the needle shows a value higher than 0.1MPa, then turn on the switch again, and restart the whole process again.

(5) Purging the Recovery Unit

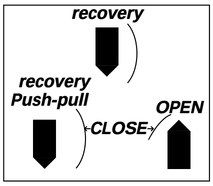
Fig.6-141



This process evacuates all the liquid refrigerant inside the condenser into the gas cylinder. Without this procedure, the refrigerant left inside will come out when taking the charging hose off the unit, and this would also mix the refrigerant with the next recovery operation, causing a mixed refrigerant.

1. Turn the valve as shown in the figure.

Fig.6-142



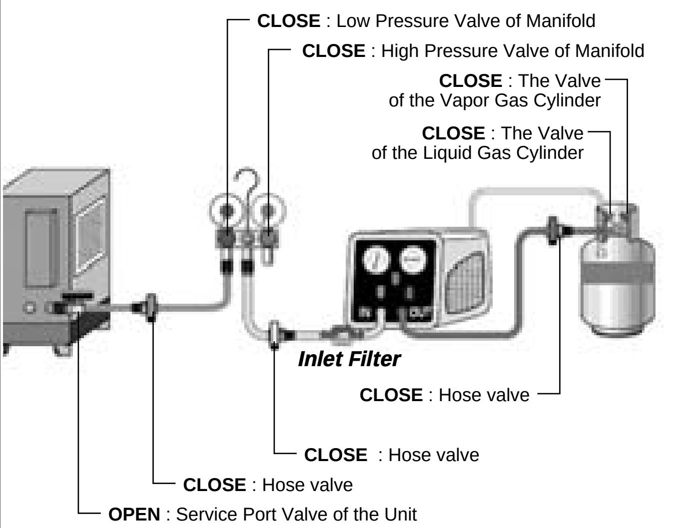
At this time, allow the unit to run until the inlet gauge indicates that there is an adequate vacuum present.

Fig.6-143

2. Turn the switch ON.

(6) End of Purging

Fig.6-144



1. When the inlet valve gauge indicates a value below 0.1MPa, turn the switch to the OFF position.
2. Close the valve of the liquid gas cylinder.
3. Close the charging hose valve.
4. Take the hose off the valve.
5. Open the hose valve and discharge all of the remaining gas out the discharge port.

(7) End of Process

Turn the valve to thegCLOSEhposition.

6.9.11 Refrigerant Cycle Cleaning Machine

Fig.6-145 item no.TA353-400

Purpose of Use

When changing the burnt compressor to a new one.

Contamination, degradation oil, pieces of metal, chips, etc. remains in apparatus and connection piping.

If used continually, there is a high possibility that the apparatus will be damaged. For example, this may cause the blocking of the capillary and the burning of compressors.

This would inevitably be necessary to wash the inside of apparatus and piping.

Specifications

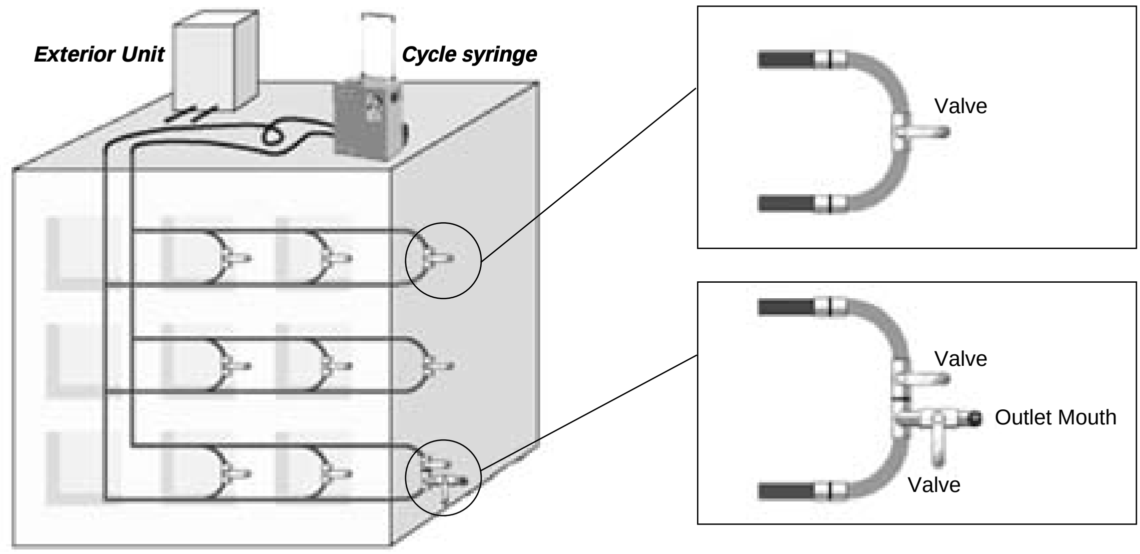
Power Source	100V 50/60HZ
Motor Output	400W
Maximum Output Pressure	1.5MPa(15kgf/cm^2) 50Hz/60Hz
Maximum Output Quantity	4.0 liter/min (60Hz) 3.2 liter/min
Pump	Pressure Cylinder System
Inside Tank Volume	12 liter
Pressure Gauge..... Outlet	0~0.2MPa
Inlet	0~2.0MPa
Connection Port	• Port Outlet Por × 1 • Return Port × 1 • Connection Port for N_2 Outlet × 1
Port Diameter	1/4"Flare (5/16 UNF-20)
Cleaning Section	• Metal Mesh Type Strainer × 1 • Filter × 1
Set Contents	• Unit × 1 • Connecting hose 1.5m × 3
Unit Size (Handle Not Included)	305 (w) × 443 (d) × 540 (h) mm
Weight	43 kg
Temperature Range	0~40˚C
Washing Liquid	R141b, R225

INSTRUCTIONS

(1) Preparation for Cleaning

1. Please remove the compressor, the accumulator, and the oil separator of the refrigerating cycle, open the expansion valve and the electric valve in the cycle, and lower the pipe as much as possible.

Fig.6-146



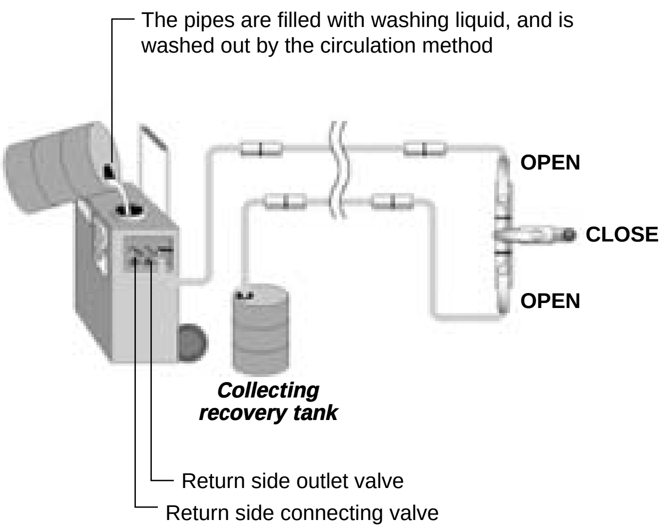
■ Washing Liquid (How to determine the quantity)

$$Y = \frac{(\text{Pipe Diameter mm})^2 \times 3.14 \times (\text{Length of Pipe})}{1000}$$

Specific gravity × 1.23 (R141b)
Specific gravity × 1.55 (R225)

(2) Preliminary Washing

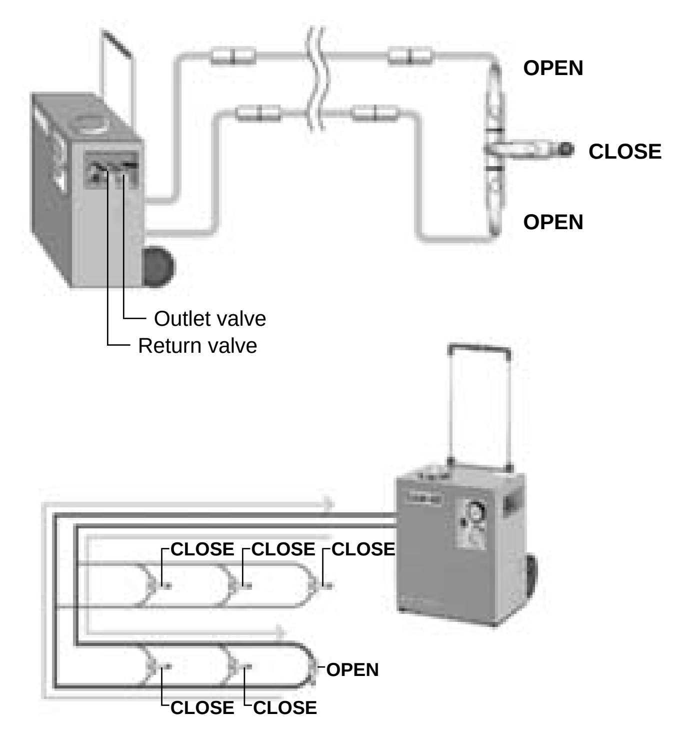
Fig.6-147



1. Attach the outlet hose of the cleaner to the pipe end where the exterior unit was removed.
2. Pour in the washing liquid to the cleaning machine (unit).
3. After pouring in the washing liquid, take the black cap (located at the back of the main unit) off, and push the valve core for 3 to 5 seconds with a driver. Liquid comes out and air omission is completed.
4. Turn the switch of the cleaning machine on, and let the detergent circulate. (If the liquid doesn't flow back to the tank from the return nozzle, add more washing liquid to the tank)
5. Since several liters of the washing liquid which returned first is extremely filthy, please remove with a hose and discard it into another container.

(3) Cleaning

Fig.6-148



1. Connect the return hose to the return valve, and turn the switch to the gonh position on the cleaning machine.
2. Open each valve at a time, and the cleaning out will be carried out for each course/channel.
   (Washing time changes with each air-conditioning apparatus manufacturer specification, diameter of piping, length and resistance) Please check condition of the washing liquid by looking at the filth.

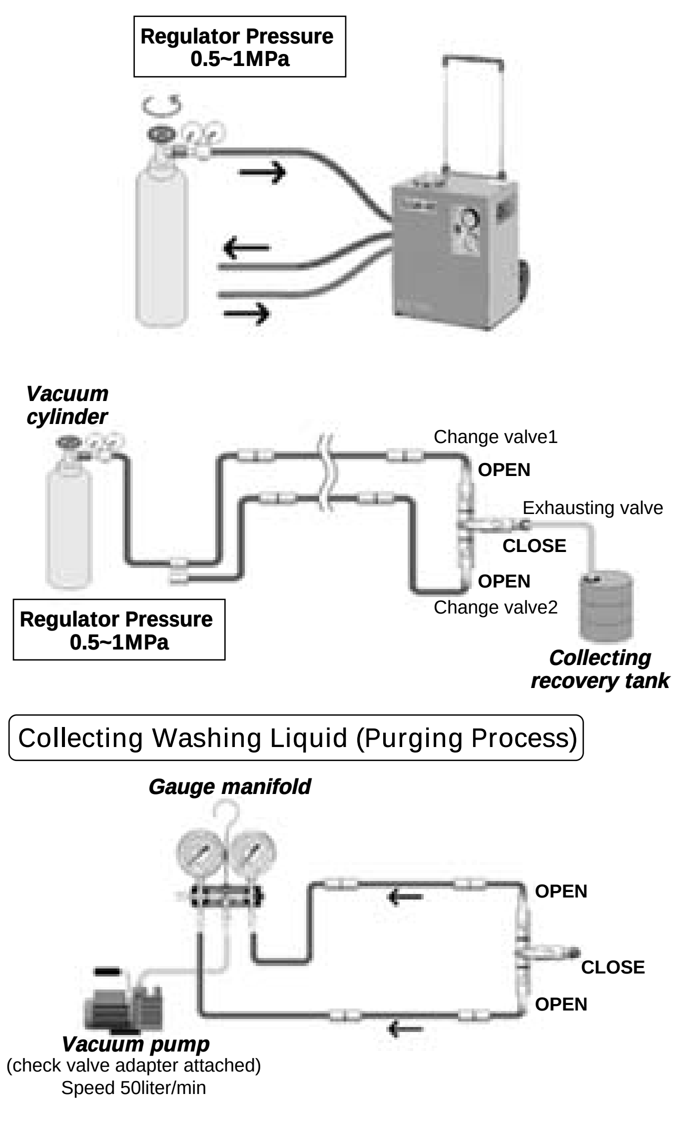
   <Cleaning Time Length>
   - Maximum Pipe

   $$\frac{\text{Pipe capacity (liters)}}{\text{Pump Outlet Quantity (liters/min)}} \times 10 + 30 \text{ (minutes) cleaning}$$

3. When the washing is completed, attach the nitrogen gas cylinder with the regulator in the nitrogen valve. (For the cleaning discharge in piping)

(4) After Cleaning

Fig.6-149



Please open the nitrogen valve and return washing liquid to the tank of the cleaning machine. If more washing liquid was added, please prepare another tank and collect there. Moreover, if there is a pressure difference is in piping, please discharge from drain valve of the lowest layer.

*Please be careful that there is no cleaning detergent left in the pipes as this will become the cause of capillary clog or compressor failure.

- By performing nitrogen blow, the quantity of residua washing liquid can be reduced and the vacuum time can be shortened.

1. Attach the vacuum pump and the gauge manifold like the diagram on the left.
2. After the gauge pressure reaches -0.1MPa, continue the process nonstop for 30 minutes, and the vacuum is completed.
3. Stop the vacuum pump for 20 minutes.
4. Repeat the 2→ 3 procedure three times.

6.10 Service Checker

6.10.1 Service Checker TYPE III

Fig.6-150

Monitors Air-conditioning Systems.

The Service Checker displays operation data
of air-conditioning systems on personal computers.
The Daikin's Service Checker TYPE-III is designed for the DIII-NET
and is capable of monitoring large-scale
and complicated air-conditioning systems.
Limited to air conditioners conforming to the DIII-NET.
It cannot monitor beyond the range of the DIII-NET Expansion Adapter (DTA109A51).

6.10.1.1 Simple guide for connection

PCB CONNECTION

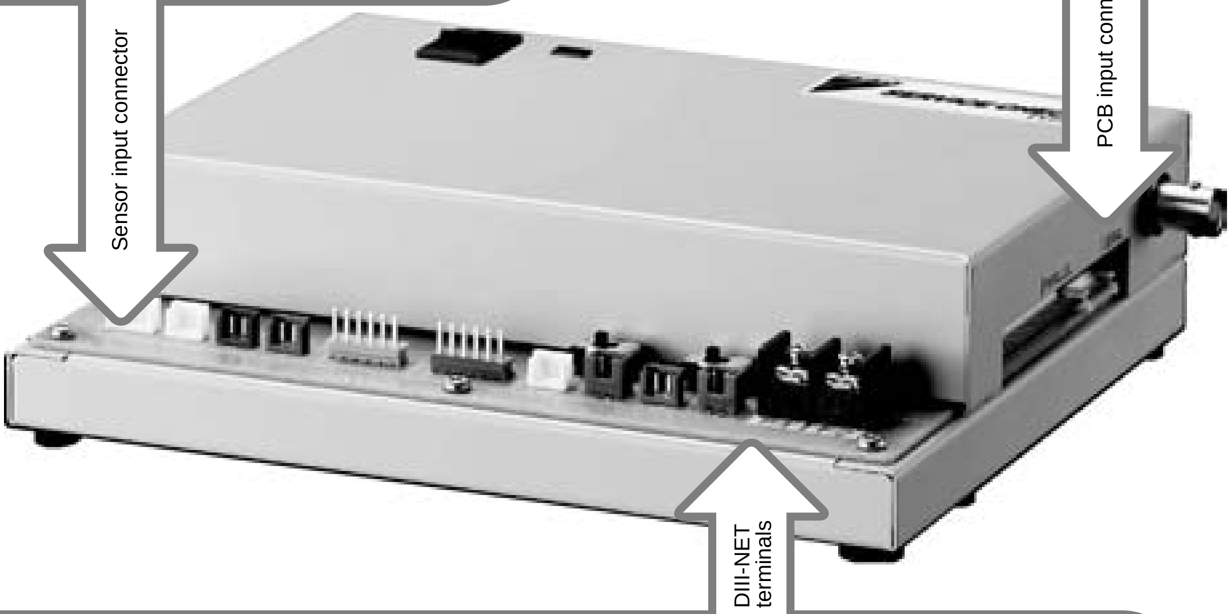
Like conventional Service Checkers, connect to the PCB of an outdoor unit. Operation conditions of an outdoor unit can be monitored once every 5 seconds.

- VRV-system air conditioner for building (other than EXL [G, H, K])
  Use for VRV-system air conditioner for building cable supplied with the TPYEIII as standard accessory.
- VRV-system air conditioner for building (EXL [G, H, K])
  Use optional EXL [G, H, K] cable.
- Super Multi room air conditioner
  Use optional M5, RA cable.

*Connect the room air conditioner to an indoor unit.
Not possible to use when using the HA option.

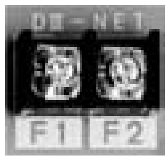
SENSOR INPUT

Using the optional sensor kit,temperatures can be measured at 6 points (one for discharge pipe)and pressured (high and low) can be measured at 2 points.Throuth these measurements,operation conditions can be recorded for air conditioners not conforming to DIII-NET or PCB connection.
Possible to use in combination with DIII-NET or PCB connection
Two sensor input connectors of the 6 temperature measurement points can be switched for voltage signals (0 to 1V or 0 to 5V) from other measuring instrument and, therefore, voltage or current of commercial power supply can also be measured using other measuring instrument.

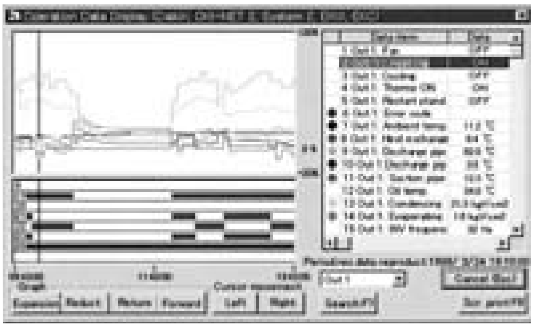


FOR DIII-NET

- Connect to the DⅢ-NET terminals(F1 and F2)on the PCB of an indoor or outdoor unit.
  (In case of an indoor unit, be careful not to create sub-branching.)
  *When the Service Checker TYPE-III is connected to the DIII-NET for the first time, air conditioners on the DIII-NET will be set to restart standby for several minutes.
  They will not be set to the standby state from the second time on unless PCBs are replaced or the number of air conditioners has changed.
- More than one operation data of air conditioners on the DIII-NET can be recorded simultaneously (under the same DIII-NET)



Network Map Display Screen



Operation Data Display Screen

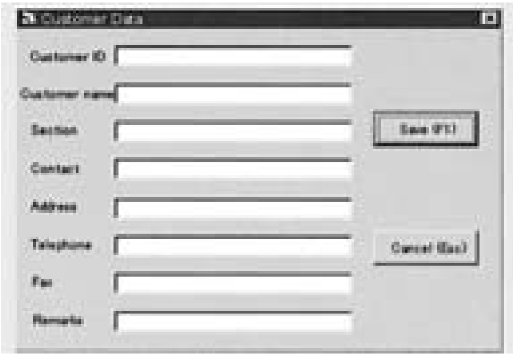
6.10.1.2 CSV OUTPUT

Files are output in CSV format.Detailed analysis can be made using a calculation software for personal computer.

6.10.1.3 CUSTOMER INFORMATION

The software of Type III manages the operation data of every customer.

Fig.6-151



6.10.1.4REQUIRED DEVICES

Prepare a personal computer with the following specifications.

CPU	Pentinum (75MHZ or higher)
Memory	16Mbytes or larger
Hard disk	Empty space of more than 20 Mbytes
RS-232C	19200 bps or higher
Basic software	Windows95/98/Me/NT4.0/2000/XP

6.10.1.5 APPLIED MODELS

Service Checker TYPE III software (English Version) Ver.1.06
Support models
(As of May 31, 2003)

DIII : DIII-NET connection
PCB : PCB connection

VRV series-R22			Connection	
Type		Model	DIII	PCB
VRV "G" series	Cooling Only	RSX8G,10G (Y1,YAL)		○
	Heat Pump	RSXY5-10G (Y1,YAL)		○
	Heat Recovery	RSEY8G,10G (Y1)		○
VRV "H" series	Cooling Only	RSX5-10H (Y1)		○
	Heat Pump	RSXY5-10H (Y1,YAL,TAL)		○
VRV "K" series	Cooling Only	RSX5-10K (Y1,TAL)	○	○
		RSX5-10K (UY1)	○	○
	Heat Pump	RSXY5-10K (Y1,YAL,TAL)	○	○
		RSXY5-10K (7W1)	○	○
	Heat Recovery	RSEY8-10K (Y1)		○
		RSEY8-10KL (Y1)	○	
VRV plus series	Cooling Only	RX16-30K (Y1,YAL) (C unit)	○	○*1
	Heat Pump	RXY16-30K (Y1,YAL) (L unit)	○	○*1
		RXY16-30KA (Y1,YAL)	○	
	Heat Recovery	REY16-30K (Y1) (R unit)	○	○*1
	Condenser Unit	RXE2-3KVAL *2	○	
VRV system for Hi-outdoor temp.use		RSNY8KTAL	○	○

*1.Connect to a functional unit.
*2.VRV Plus(Cooling only,Heat pump)For high outdoor temperature use up to 50 C. Condenser Unit

VRV series-R407C(HFC)			Connection	
Type		Model	DIII	PCB
VRV "K" series	Heat Pump	RSXYP5-10K (JY1)	¡	¡
	Heat Recovery	RSEYP8-10K (JY1)	¡	
VRV plus series	Cooling Only	RSXP16-30K (Y1)	¡	
	Heat Pump	RSXYP16-30K (JY1)	¡	
	Heat Recovery	RSEYP16-30K (JY1)	¡	
VRV "L" series	Heat Pump	RSXYP5-10L (JY1,Y1,YL)	¡	
VRVIII "M" series	Heat Pump	RXYQ5MY1B-RXYQ48MY1B	¡	¡

VRV series R410A (HFC)			Connection	
Type		Model	DIII	PCB
VRV II series	Heat pump	RXYQ5~48MY1B	¡	

PA series			Connection	
Type		Model	DIII	PCB
Sky Air	Super Inverter	RZP71,100,140D (V1) RZP71,100D (VAL),RZP125,140D (TAL)		¡*3

Multi series			Connection	
Type		Model	DIII	PCB
Super Multi	2MK, 3MK	2MK58FV1N, 3MK75FV1N		¡*3
	4MK	4MK75FV1N		¡*3
Multi H series	4MX, 4MK	4MX80HV (1NB), 4MK90HV (1NB)		¡*3
	2MX, 3MK	3MX68HV (1NB), 2MX52HV (1NB)		¡*3
QA Multi	RMX, RMK	RMX140JVM (C, T), RMK140JVM (C, T)		¡*3

*3.Optional M5,RA cable is required.

6.10.1.6 Specifications of Service Checker TYPE III

Item	Specifications
External dimensions (excluding projecting sections)	180 (width) × 150 (depth) × 45 (height) mm
Weight	Approx. 700g
Power supply	9VDC, 300mA (Outside:+) (Use an AC adapter or battery of [TYPE3 Power Unit (220V)]).
Power consumption	Approx. 1.2W
Battery drive time	Approx. 8 hours after complete charging (when using a battery attached to [TYPE3 Power Unit (220V)]).
Temperature and humidity conditions	-10 to 55˚C (-10 to 35˚C for AC adapters), 95% RH or less (no condensation)
RS232C interface	Asynchronous (19200bps), D-sub 25-pin female (straight connection to a personal computer)
Sensor input section	Temperature at 6 points(one point for discharge pipe), pressure at 2 points (high pressure and low pressure) Two out of the 6 points can be switched to receive to voltage signals (0 to 1V or 0 to 5V).

6.10.1.7 Standard configuration

<table>
<tr><th>Product name</th><th>Parts number</th><th colspan="2">Description</th></tr>
<tr><td>Checker TYPE3</td><td>999135T</td><td colspan="2">Service Checker TPYEIII
Cable for VRV-system air conditioner for building
Serial connector conversion cable
(Used when connecting M5, RAcable to the Service Checker)
RS-232C cable for personal computers
(D-sub 25-pin male/D-sub 9-pin female straight)</td></tr>
<tr><td rowspan="3">TYPE3 Power Unit (220V)*1</td><td rowspan="3">999142T</td><td>AC adapter</td><td>Input: 220VAC, 50Hz
Output: 9VDC, 500mA (Outside: +)
Temperature condition: -10 to 35˚C</td></tr>
<tr><td colspan="2">Battery: Ni-Cd battery</td></tr>
<tr><td colspan="2">Charger: 220VAC input, 50/60Hz (Complete charging: approx. 16 hours)</td></tr>
<tr><td>TYPE3 Software (English)</td><td>999143T</td><td colspan="2">Compatible with English-version Windows95/98/Me/NT4.0/2000/XP</td></tr>
<tr><td>TYPE3 Instruction Manual (English)</td><td>999144T</td><td colspan="2">Instruction manual of TYPE3 software (English)</td></tr>
</table>

Purchase the above four items (total of 181,000yen).

6.10.1.8 Optional Items

Product name	Parts number	Description
M5, RA cable*1	999140T	Used when connecting to a Super Multi or room air conditioner via PCB connection. No need to purchase this cable if customers have TYPE2 Expansion Kit (999112T).
Sensor Kit*1	999107T	High temperature thermistor (-30 to 150): 1pc. Low temperature thermistor (-30 to 70): 3pcs. Air thermistor (-10 to 50): 3pcs. High pressure sensor (0 to 30kg/cm^2G): 1lot Low pressure sensor (0 to 10kg/cm^2G): 1lot

6.10.1.9 Accessories

Product name	Parts number	Description
TYPE3 cable for VRV-system air conditioner for building*1	999141T	A set of cable of VRV-system air conditioner for building cable and serial connector conversion. Attached to the Checker TYPE3
TYPE2 spare battery*1	999113T	Used to drive the Serivce Checker TPYE III. Attached to the TYPE3 Power Unit (220V)

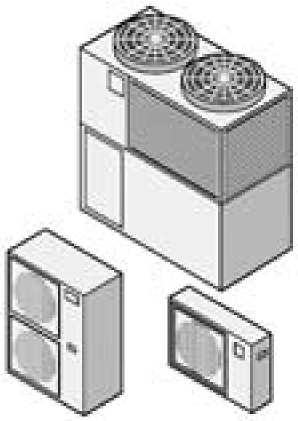
- Please follow Daikin's purchasing procedure.
- Pentinum is a registered trademark of Intel Corporation.
  Other product names mentioned above are trademarks or registered trademarks of respective companies.
- The above specifications may be modified for improvement without any advance notice.

Note :

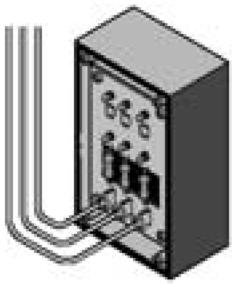
Refer to the operation manual of Service Checker Type III for more details.

6.10.2 Inverter Analyzer RSUK0917

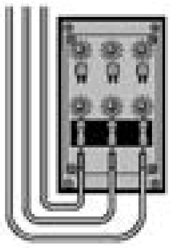
Fig.6-152



Any
inverter model



Quik
connection



Easy
Analysis

Compatible with all
models of inverter products.

(It can be used for air conditioners made by other manufacturers or non-airconditioning products.)

If an abnormal stop occurs during the compressor operation or at the start of compressor operation, It is difficult to judge whether the compressor has faulted or the PC board has faulted.

The Inverter Analyzer offers a function to easily pimpoint the specific cause of trouble, which can elominate unnecessary replacement of parts.

3-Step Startup

Step 1 : Turn the power supply off.
Step 2 : Disconnect compressor wire and connect the Inverter Analyzer.
(Do not connect the wire to the compressor at the same time, otherwise it may result in incorrect detection.)
Step 3 : Turn the power supply on and run the air conditioner.
Check if the LED is lit.

Easy Checkup

Check LED for turning on and off

When all LEDs are lit uniformly

↓

Output from inverter board is OK

Easy diagnosis

Light weight and compact size

No additional power supply or no battery is required

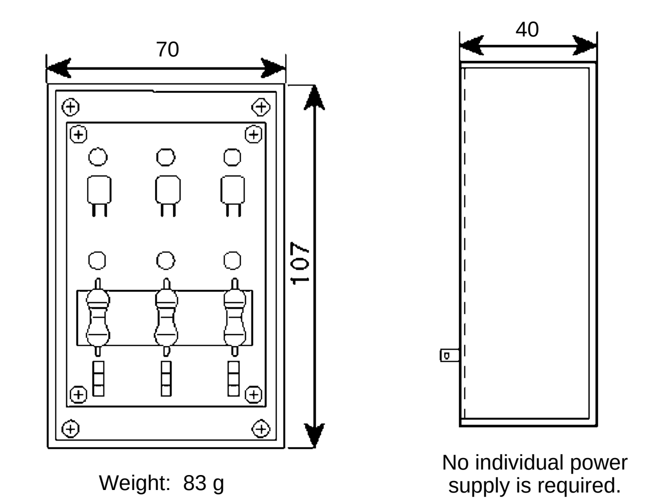
Lighting of the LED is unbalance. (Some LEDs are not lit, others are still lit.)

↓

Inverter output failure (Electric failure on control board, inverter board, power transistor and so on.)

■ **External Dimensions**

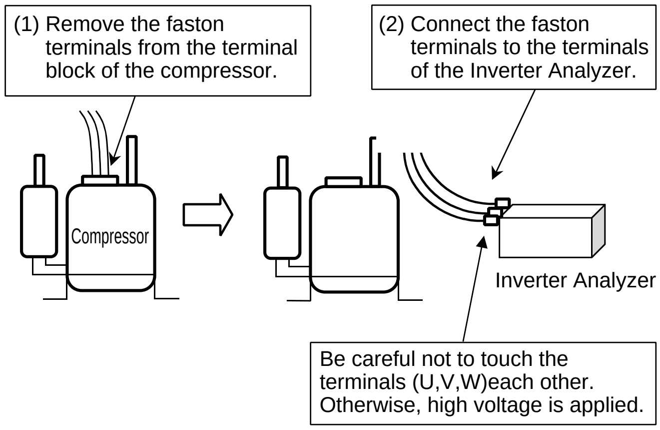
Fig.6-153



The Inverter Analyzer is applicable to all inverter products. (It can be used with other manufacturer's air conditioners and products other than air conditioner.)

1. **Characteristics**
   If abnormal stop occurs due to compressor startup failure or overcurrent output when using inverter unit, it is difficult to judge it results from the compressor failure or other failure (control PC board, power transistor, etc.). The inverter analyzer makes it possible to judge the cause of trouble easily and securely. (Connect this analyzer as a quasi compressor instead of compressor and check the output of inverter)

2. **Operation Method**
   1) Be sure to turn the power off.
   2) Install the Inverter Analyzer instead of a compressor.
   Note: Make sure the charged voltage of the built-in smoothing electrolytic capacitor drops to 10 VDC or below before carrying out the service work.



   Reference
   If the connector terminal of compressor is not a fasten terminal (difficult to remove the wire on the terminal), it is possible to connect a wire available on site to the unit from output side of PC board. (Do not connect it to the compressor at the same time, otherwise it may result in incorrect detection.)
   3) Turn the power on and operate the air conditioner.

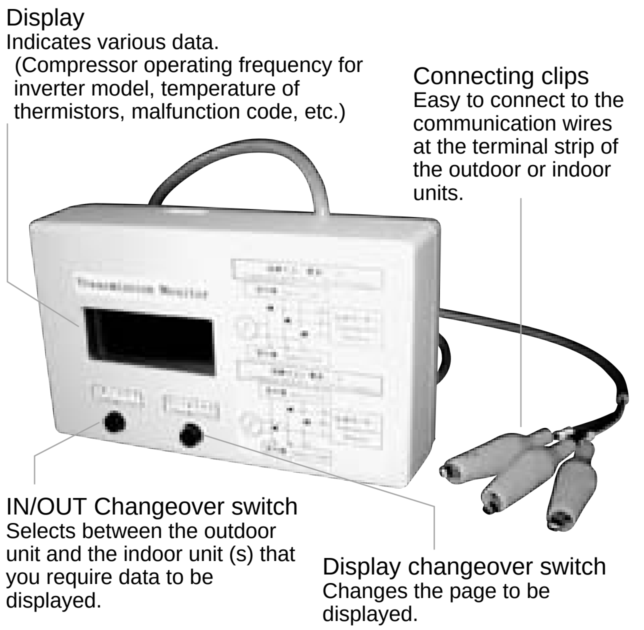
3. **Diagnose method (Diagnose can be made according to 6 LEDs lighting status as follows:)**
   (1) When all LEDs are lit uniformly, → Compressor malfunction (to be replaced)
   (2) When some of LEDs are not lit (LEDs are not lit or go off, etc.) :
   Check the individual power transistor. (Refer to the service manual)
   * When the power transistor and control PC board are integrated : → Replace the control PC board.
   * When the power transistor can be checked individually:
   ↓ Check the resistance value. (Refer to the relevant service manual)
   If NG : → The power transistor may have a failure. (Replace the power transistor).
   If the power transistor is normal, check if there is any solder cracking on filter PC board.
   * If any solder cracking is found : → Replace the filter PC board (or repair the soldered section).
   * If filter PC board is normal : → Replace the control PC board.

Note :

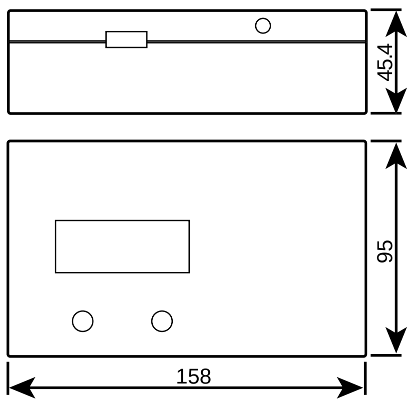
Refer to the operation manual of Inverter Analyzer RSUK0917 III for more details.

6.10.3 Transmission Monitor RSUK0919

Transmission Monitor RSUK0919 enables technicians to monitor information such as compressor operation frequency, temperature sensors and malfunction codes. Information exchanged between indoor and outdoor units.
The Monitor RSUK0919 allows you to conduct trouble shooting for both indoor and outdoor units.



■ **Outside dimension**



Weight: 522 g
Electric power: Supplied from air conditioner

1) **Outline**

Daikin's air conditioners carry out communication between indoor and outdoor units. The communication data can serve as very useful information when conducting problem diagnosis. Transmission Monitor RSUK0919 received the data to indicate it on LCD. The Transmission Monitor is featured as follows.

(1) Since the power supply is provided from the product to be monitored, no extra power supply, battery, etc. is required.
(2) Applicable to voltage ranging from 100V to 240V (50/60 Hz).
(3) Since the changeover of transmission methods is automatically judged, users are only required to connect the Transmission Monitor to the product.
(4) IN/OUT Changeover Switch : Serves to switch the sender (Outdoor or Indoor unit · · Maximum four indoor units may be connected depending on the circumstances) of data to be displayed.
(5) Display Changeover Switch : Serves to switch pages displaying the data.
(6) The data can be displayed in Japanese or English, which can be switched by an internal jumper. (Factory setting is English)

2) **Applicable models**

The Transmission Monitor is applicable to products performing the data transmission between indoor and outdoor unit through three- wire system among sprit & multi air conditioners and Skyair units developed by Daikin Industries, Ltd.

- Representative models of applicable/non applicable models are shown in the list in the next page. All models cannot be described in the list. To judge whether the model is applicable or not, confirm the wiring diagram of product.
- Reference wiring diagram is shown in page 209.
- Fig. 6-154 and 6-155 (page 209) show examples of applicable model. 6-156 (page 209) shows an example of non applicable model.
  Even the product performs data transmission through 3-wire system, it cannot be determined as an applicable mode when ON/OFF operation is controlled by relay circuit.
- The models carrying out transmission of digital communication with transmission circuit and receiving circuit using photo-triac and photo-coupler (see Fig. 6-154) are applicable models.

Applicable/non-applicable model list

Example of applicable model (room air conditioner)	
Model Name	Sales start
2/3/4MK to FV	1997
2/3/4MX to HV	1999
CDK25 to 60HA	2001
CDK25 to 60HV	1999
CTK to FV	1997
FTK(D) to JV	2001
FTX35/50HV	1998
FTX50HA	2000
FTY50GA	2001
FTY to 3B	1994
FTY to 3C	1992
FTY to D7	1993
FTY25 to 60F (G) V	1998
FVY to 3C	1992
MY to C (J)	1994
RKD50 to 71JV	2000
RX50JV	2000
RX35/50HV	1998
RY	1994
RY to C	1992
RY to D7	1993
RY25 to 60F(G)V	1998
RY50GV	2001

Example of applicable model (room air conditioner)	
Model name	Sales start
FAY71 to F	1996
FHK to F	1996
FHK35 to 71FV1	2000
FHYB to DA	1994
FVY to DA	1992
FHYC to DA	1992
FHYK to DA	1992
FHY to DA	1992
FHYC to KVE	2000
FHYC50 to 125K	2001
FUJ71 to 125FJ	1999
FUY71 to 125FJV1	2000
R125 to 250KU	2001
R71 to F	1995
RY to F	1995
R71 to KU	2000
RY35 to FV	2000
RY to DA	1994
RY35 to 60C	1992
RY to D	1992
RY50 to GV1A	2000
Double/twin/triple	2001

Example of applicable model (room air conditioner)	
Model Name	Sales start
ANW to GV1	1999
ARW to GV1	1999
FHC to C	1993
FL13HV	1999
FT to 1B	1995
FT to C	1992
FT to F	1997
FT to EB	1997
FT25G	1998
FT50GAVE	2001
FT60CV	1991
FTY to A(B)	1991
FV to CJ	1993
MA to CJ	1993
MA to E	1998
MA28 to 90C	1992
MY to B	1992
R to E	1995
R to FV1	1995
R to F	1997
R25G	1998
R13HV	1999
R50GV	2001

Example of applicable model (room air conditioner)	
Model name	Sales start
FAY71B	1994
FH to 60F	1995
FH35 to 60FV	1999
FHB35 to 60FV1	2000
FH to C	1992
FHC 71 to C	1995
FHJ to B	1991
FHC to FU	1997
FHC35 to 60KVE	2000
FHK to BB	1992
FHY to LE	1992
FV to B	1992
FHS to BA	1992
R to 60B (-K)	1996
R to C	1992
R to BB	1992
RU to J	1992
R to DA7	1993
R to FU	1997
R35 to 60GV1	2000
R to 60F	1995
RY to DTGU	1994

Fig.6-154 Applicabe product

FVY223CV1
FVY353CV1
FVY453CV1

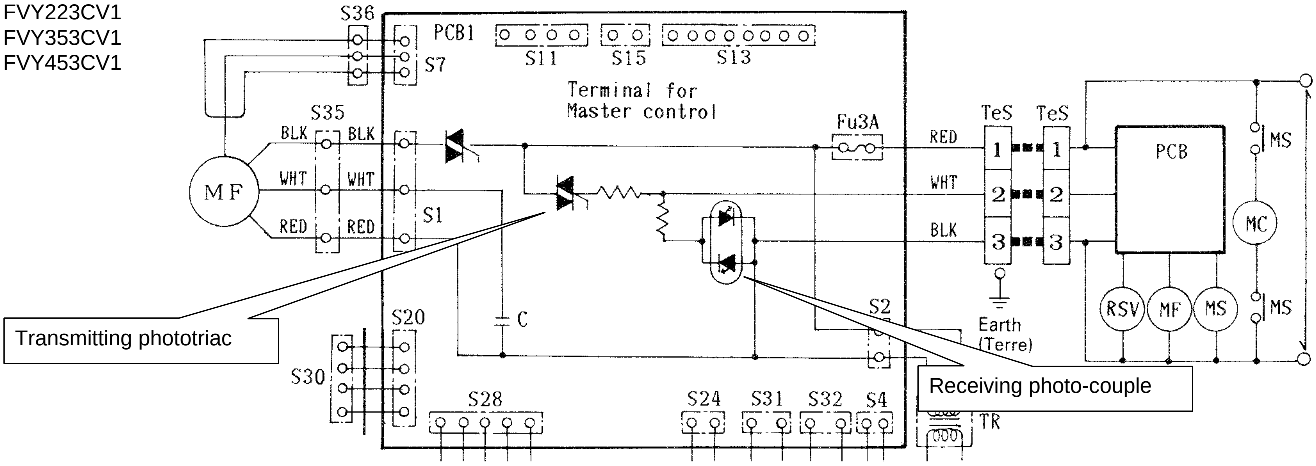


Fig.6-155 Applicabe product

FHYC71KVE
FHYC100KVE
FHYC125KVE

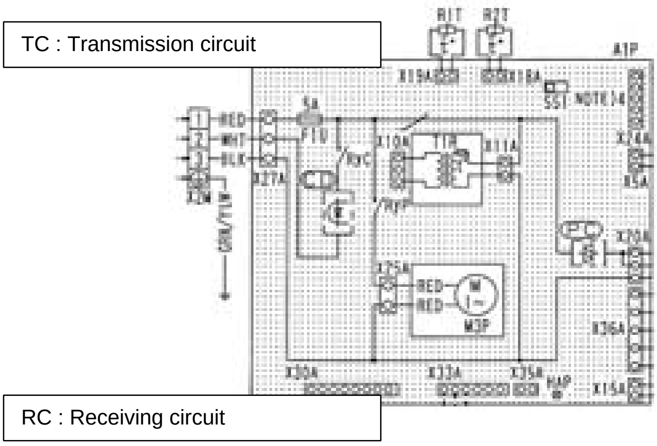
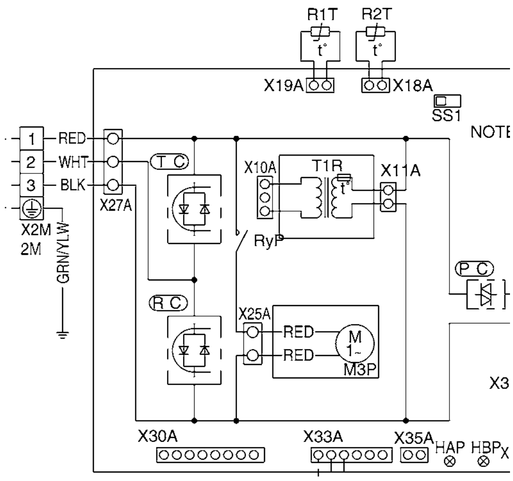


Fig.6-156 Non Applicabe product

FHC35KVE
FHC50KVE
FHC60KVE



3) Connection method to product

Basically, Transmission Monitor should be connected to the communication wires (3 wires) of indoor and outdoor units. As for some RA products produced in and after 2001, assignment of transmission wire has been changed from No. 2 to No.3 of the terminal block. Therefore, the connection method should be selected from the following two methods according to the models applied.

It is recommended to measure the voltage to determine the connection method. Take Connection method 1 when the power supply voltage is impressed between connection wire 1-3, and Connection method 2 when the power supply voltage is impressed between connection wires 1-2. However, since connection method cannot be determined with voltage measurement when any malfunction in communication wiring or in transmission is occurred, it is required to confirm with wiring diagrams or those in service manual.

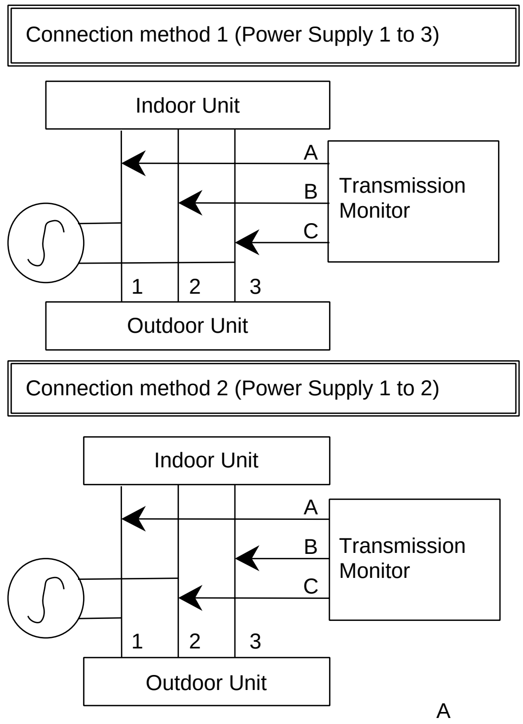
1. Connection method 1 (Power Supply1 to 3)
   When power supply 1 to 3.

Connection wire/ No. of product	Transmission monitor wiring	Meaning of wiring
1	A (Red)	Power supply
2	B (White)	Signal (between connection wire 2 to 3)
3	C (Black)	Power supply

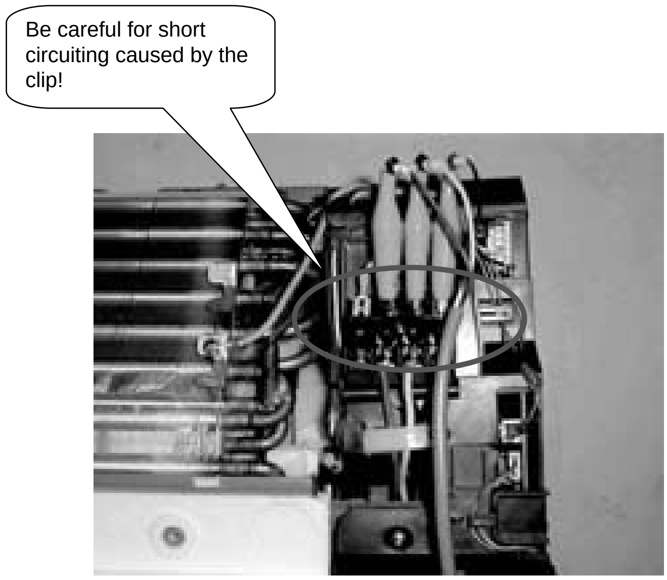
2. Connection method 2 (Power Supply1 to 2)
   When power supply 1 to 2.

Connection wire/ No. of product	Transmission monitor wiring	Meaning of wiring
1	A (Red)	Power supply
2	C (Black)	Power supply
3	B (White)	Signal (between connection wire 2 to 3)

Fig.6-157



Caution : Incorrect connection (incorrect wiring) may not damage the Transmission Monitor or the product itself but may cause transmission error. The short-circuited clip of Transmission Monitor could result in damage of the components of product. Therefore, care should be taken for the positive connection.



Example of connection to indoor unit

Note :

Refer to the operation manual of Transmission Monitor RSUK0919 for more details

Chapter 7 Installation

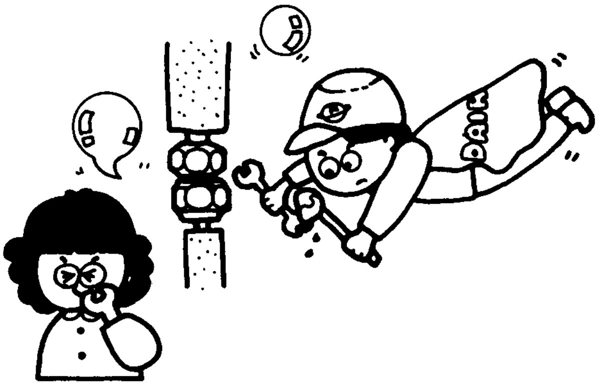
Chapter 7 Installation

7.1 Troubles related with the installation work

No matter how good the air conditioner is, if it is installed improperly, it cannot exhibit the utmost capacity. Wrong installation of the air conditioner may cause various troubles, which require service call as a result. The following five illustrations show typical troubles which are apt to occur caused by improper installation.

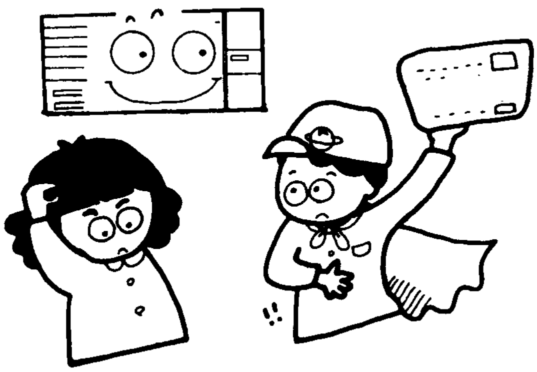
(1) No or insufficient cooling
- Refrigerant leak

Fig.7-1



(2) Improper operation
- Insufficient explanation how to operate the air conditioner to a customer.

Fig.7-2

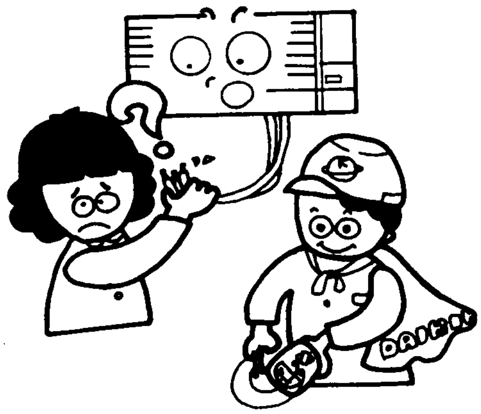


(3) Water leak
- Drain pipe is improperly connected.
- Piping is improperly insulated.

Fig.7-3

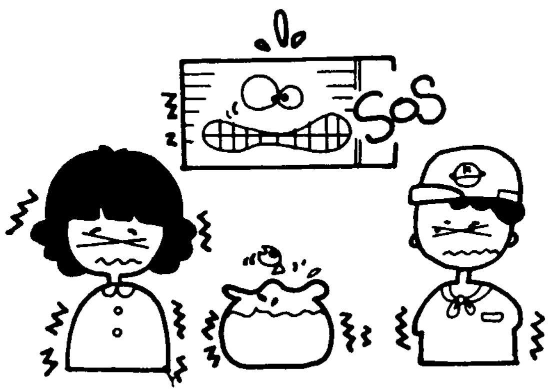
(4) Inoperative
- Field wiring is improperly connected.
- Voltage is wrong.

Fig.7-4



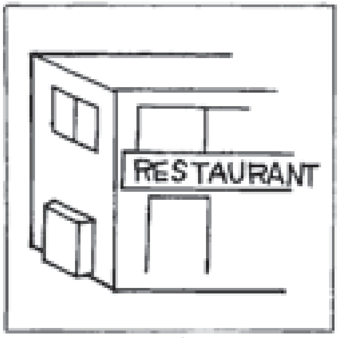
(5) Noisy operation
- Both or either of fan coil (indoor) or condensing (outdoor) unit is improperly installed.
- Field piping is improperly provided.

Fig.7-5

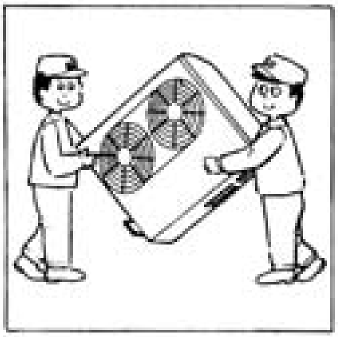


7.2 Procedure of installation

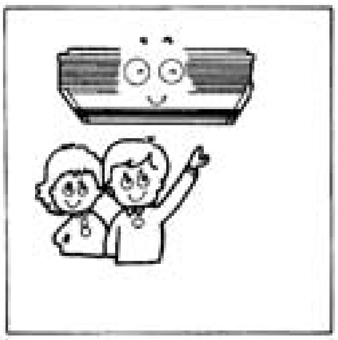
The followings are the order of the installation works. It is natural that the order of installation works differs with models, so read carefully the installation manual supplied with each product.



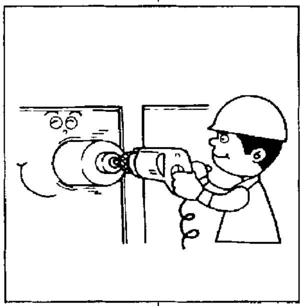
(1)Selection of a suitable installation places See 7.3



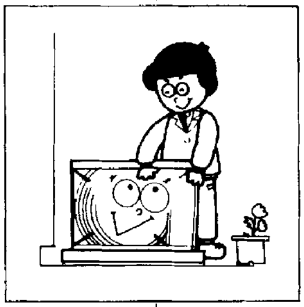
(2)Bringing in the A/C units See 7.4



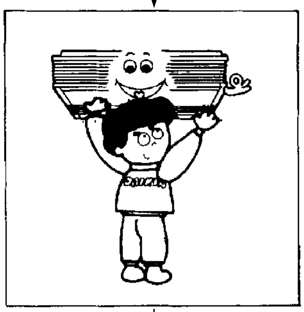
(3)Determination of an installation position for the fan coil (indoor) unit See 7.5



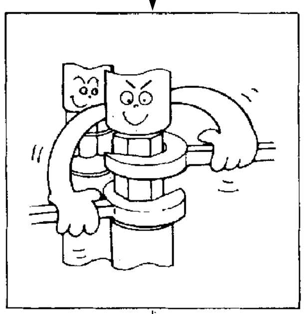
(4)Making a pipe hole See 7.6



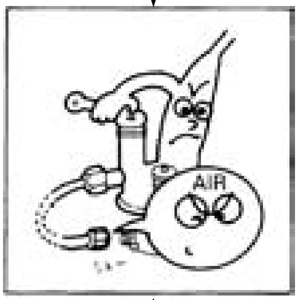
(5)Installation of the condensing (outdoor) unit See 7.5



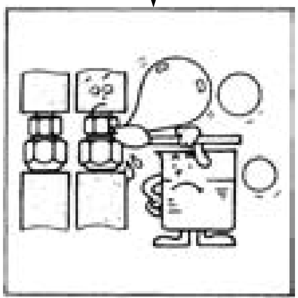
(6)Installation of the fan coil (indoor) unit See 7.5



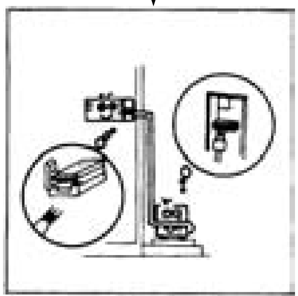
(7)Connecting the piping See 7.7



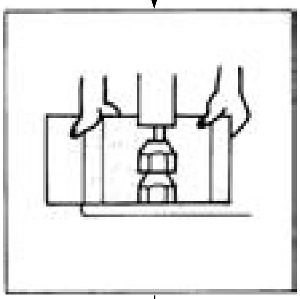
(8)Evacuation See 7.7.5



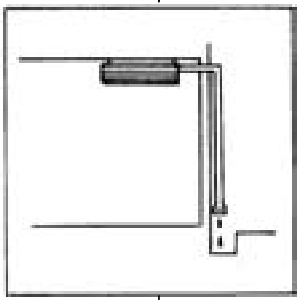
(9)Leak test See 7.7.4



(10)Field wiring. See 7.8

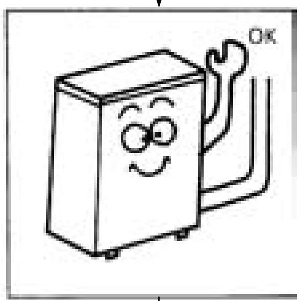


(11)Insulating See 7.9

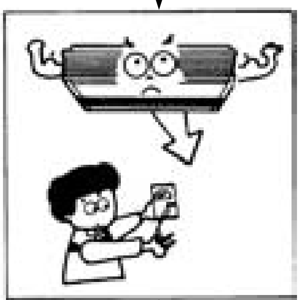


(12)Drain piping. See 7.10

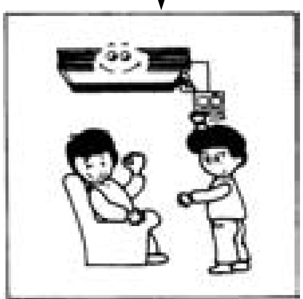
(13)Finishing work. See 7.11



(14)Final check. See 7.12



(15)Test operation See 7.13



(16)Commissioning Explain to your customer how to operate the product correctly in accordance with the operation manual.

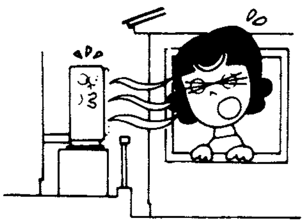
7.3 Selection of suitable installation places

7.3.1 Condensing (Outdoor) units

Select a suitable place for condensing (outdoor) unit in consideration with the following conditions.

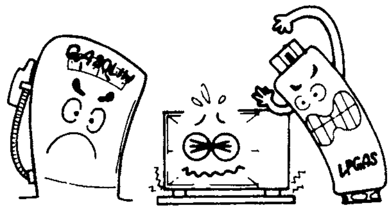
(1) A place where the discharge air doesn't disturb the neighbors.

Fig.7-6



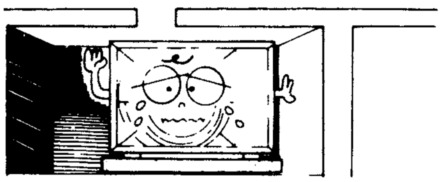
(2) A place allowed by government regulations.

Fig.7-7



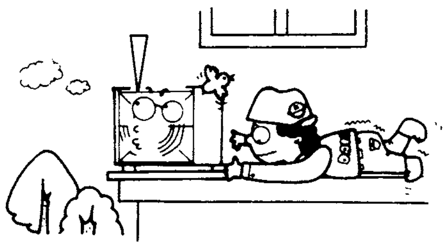
(3) A place where there is no obstacle in the air ways in and out of the condensing (outdoor) unit.

Fig.7-8



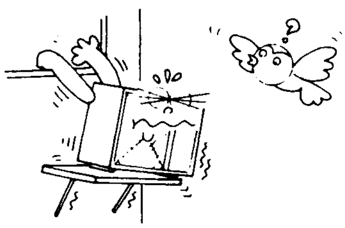
(4) A place easily accessible for servicing.

Fig.7-9



(5) A place where the condensing (outdoor) unit can be installed firmly.

Fig.7-10

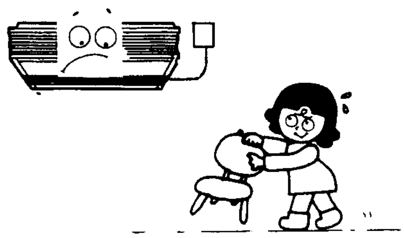


7.3.2 Fan coil (Indoor) units

Select a suitable place for fan coil (indoor) unit in consideration with the following items.

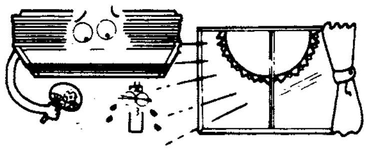
(1) A place from where the fan coil (indoor) unit can be operated easily.

Fig.7-11



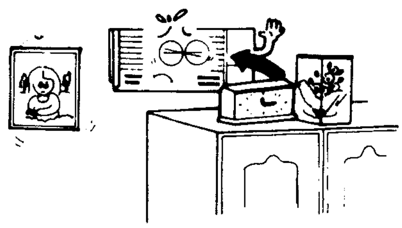
(2) A place where the remote controller cannot be affected by direct sunlight.

Fig.7-12



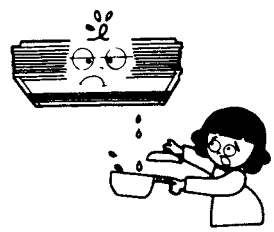
(3) A place where the air discharged by the fan coil (indoor) unit is not drawn in again.

Fig.7-13



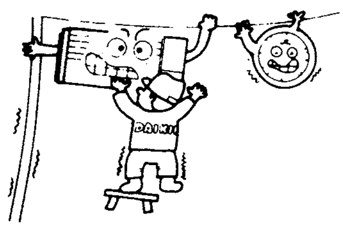
(4) A place from where drain water can be extracted outdoors easily.

Fig.7-14



(5) A place which is strong enough to support the unit.

Fig.7-15



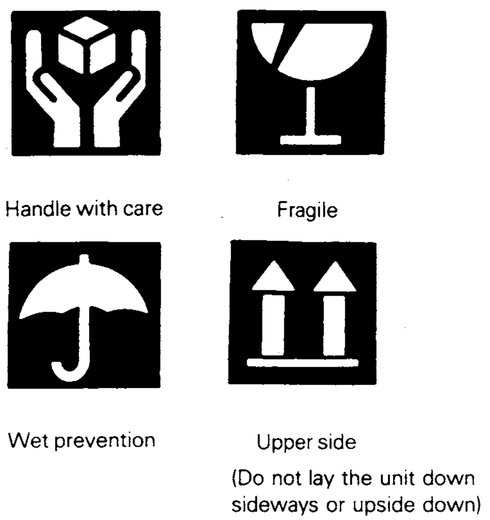
7.4 Bringing in

The general informations for bringing in will be explained in this chapter. Before bringing in the product, determine the method of bringing in and then carefully bring it in, referring to the installation manual and technical manual.

(1) Bring in the unit in the packing as near as possible to the site with care not to damage the unit inside.

(2) The following are representative symbols of transportation, which indicate respective cautions required. So handle the product in consideration with the caution shown by the symbol on a packing.

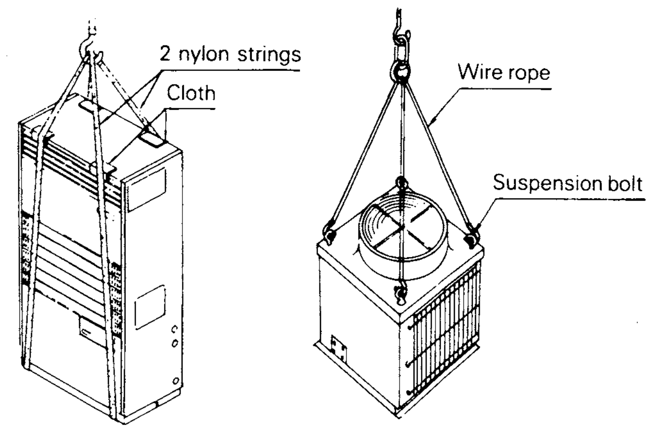
Fig.7-16 Symbols of packing



(3) Do not lay down the unit, in which the compressor is mounted.

(4) In case nylon strings (or wire ropes) are used for bringing in, hang the unit as shown in the Fig.7-17

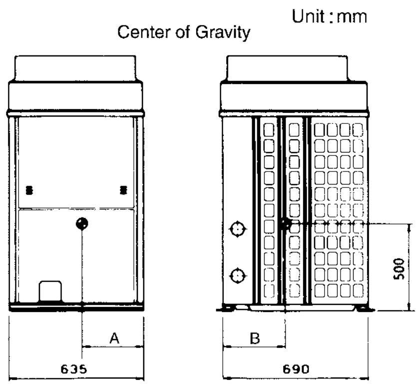
Fig.7-17 Example



* Each product is so designed to be brought in safely and correctly so long as you follow the instructions shown in the respective installation and operation manuals or technical manual.

The data of " Center of Gravity " are available in the engineering data. If referring to the data when hanging the equipment, the safer work will be promised.

Fig.7-18



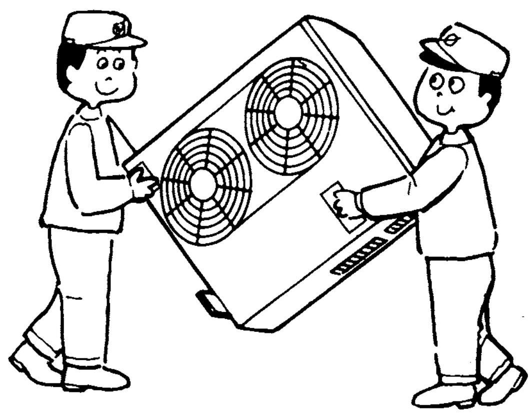
Model	A	B
RSX(Y)5K	315	325
RSX5KU	265	290
RSX6KU	265	290

(5) Since the positions to be grasped are indicated to bring in a small product, do it in accordance with the instruction.

Example

- Use the handles on the right and left and bring in as shown in the figure. (The compressor is on the right side.)

Fig.7-19 Example



(6) When unpacking, check that the accessories are correctly encased and then store them carefully so as not to lose any of them.

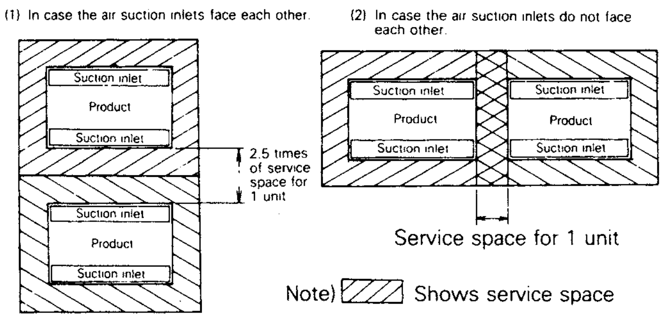
7.5 Cautions for installation

Before installing the unit actually at the predesigned position, make sure to leave the service space indicated on the respective installation and technical manuals around the unit, and at the same time, examine various surrounding conditions.

7.5.1 Service space

- In general, space for installation works is over 600mm and space for service works is over 1200mm. With regard to the details, see the technical manual.
- In case two air cooled condensing units are installed in parallel.
  Minimum service space is shown below.
  However, the minimum service space differs with models, so follow the respective installation or technical manual as for the details.

Fig.7-20

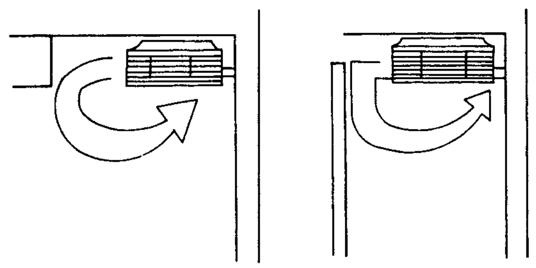


7.5.2 Installation of units

- Consider air distribution of a room based on structure of a room and arrangement of occupants and furniture.
- Install the unit in such a place where wall or obstacles do not interrupt the air ways in and out of the unit. (If the air way is disturbed, predesigned cooling efficiency is not obtainable, and furthermore dew forms on the casing, which may be resulted in water leakage.)
- Avoid installing the unit in such a place which is near the door or kitchen so as not to draw unnecessary volume of air or stale air.
- In case the unit is mounted in a wall, carefully install it not to transmit operation vibration to the wall. Leave a sufficient space for providing after-sales service.

Examples of bad installation
If distributed air is short-circuitted, cooling or heating capacity will be greatly reduced.

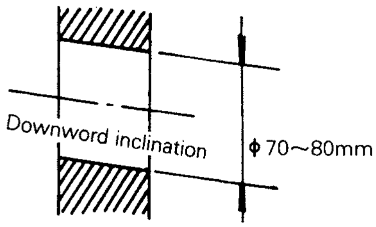
Fig.7-21



7.6 Making a pipe hole

Make a hole in the wall. In case of room air conditioners, suitable hole diameter is 70~80mm.
The location of a hole should be lower than the drain outlet so that drain water can be smoothly extracted outsides. In addition the hole should be inclined downwards to the outdoor as shown in the figure below.

Fig.7-22



7.7 Refrigerant piping

7.7.1 Refrigerant piping work

● Operational steps	Install indoor unit ➡ Cut pipes to size ➡ Fit pipes provisionally ➡ Replace nitrogen ➡ Solder ➡ Flushing ➡ Air tight test ➡ Vacuum dry

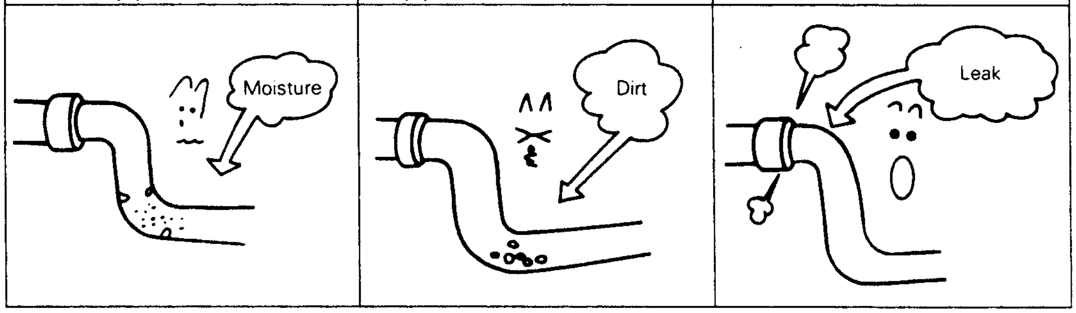
1) The 3 principles of refrigerant piping

The "3 principles of refrigerant piping" must be strictly observed.

	Cause of problem	Action to avoid problem
Dry	• Rainwater, work water, etc. gets into pipes from outside • Moisture generated inside pipes due to condensation	Pipe covering ➡ Flushing ➡ Vacuum drying See page 225
Clean	• Formation of oxides inside pipes during soldering • Dirt, dust or other extraneous material gets into pipes from outside	Replace nitrogen / Pipe covering ➡ Flushing
Air tight	• Leak from soldered area	Use the proper materials (copper pipe, solder, etc.) → Air tight test Adhere strictly to standard soldering work practice → Air tight test
	• Leak from flared area	Adhere strictly to standard flaring work practice → Air tight test
	• Leak from flange area	Adhere strictly to standard flange connection work parctice → Air tight test See page 224 and 339.

The 3 principles of refrigerant piping

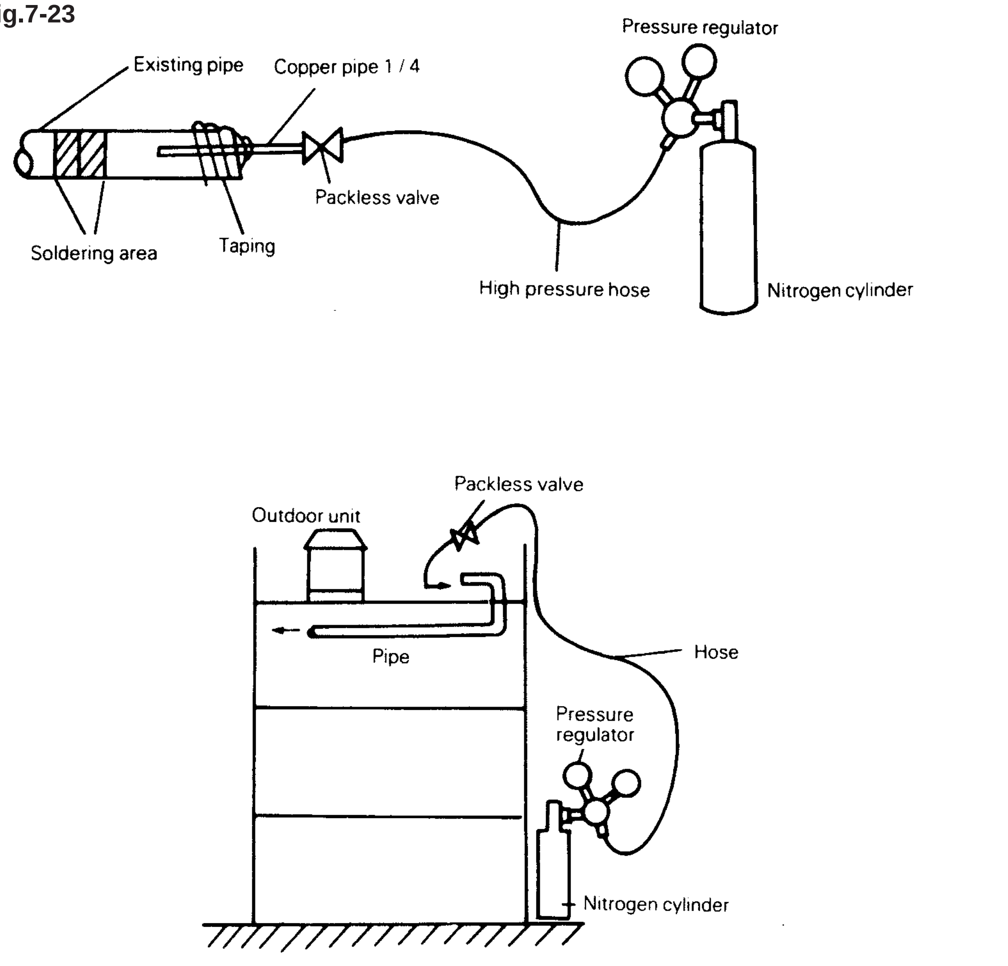
Dry	Clean	Air tight
Make sure there is no moisture inside the pipes	Make sure there is no dirt inside the pipe	Make sure the refrigerant does not leak out



<table>
<tr>
<td>2) Method for replacing nitrogen (soldering)</td>
<td>
If soldering work is carried out without passing nitrogen gas through the pipes which are being soldered then this allows the formation of oxidation bubbles on the inside surface of the pipes. These oxidation bubbles are then carried along inside the pipes to cause damage to various members of the system such as valves or compressors and the system ceases to function properly.

In order to avoid this problem nitrogen is passed through the pipes while the soldering work is being carried out. This operation is known as nitrogen replacement. (Air is replaced by nitrogen)

This is standard work practice for all soldering work.

Fig.7-23


Important points:
①The gas used must be nitrogen (oxygen, carbon dioxide and flon gas are inappropriate)
②A pressure regulator must be used.
</td>
</tr>
</table>

3) Covering of refrigerant pipes

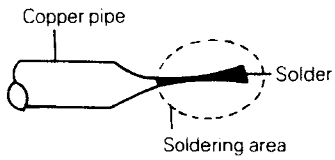
Covering is an extremely important operation as it prevents water, dirt or dust from getting inside the pipes. Moisture inside the pipes was a constant source of trouble in the past. The utmost care is required to nip this problem in the bud.

The end of each pieces of pipe must be covered. "Pinching " is the most effective method but "taping " is an simple alternative which may be used according to the work area and term of work.

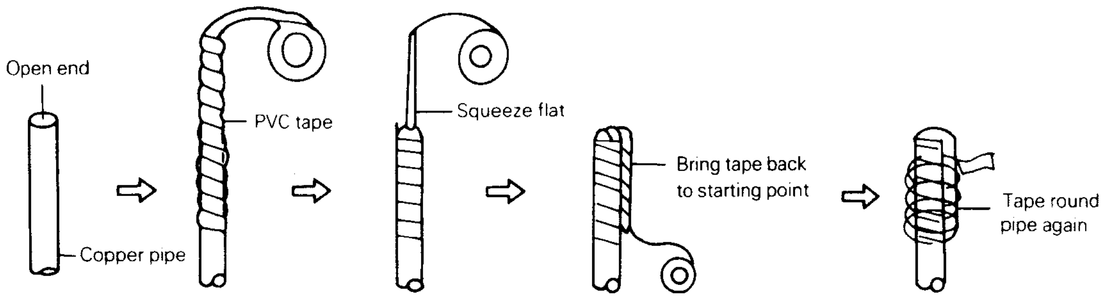
Location	Term of work	Covering method
Outdoors	3 months or more	Pinching
	Less than 3 months	Pinching or taping
Indoors	Irrelevant	Pinching or taping

① Pinching method
The end of the copper pipe is squeezed together and the gap soldered.

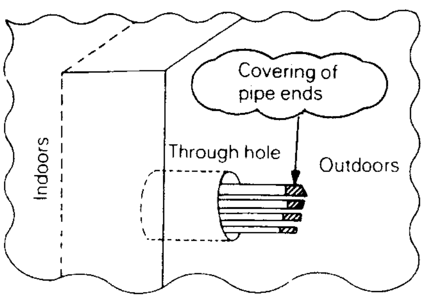
② Taping method
The end of the copper pipe is covered with PVC tape.

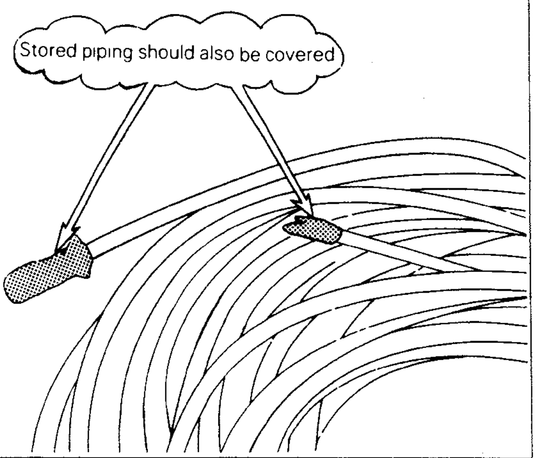


〈Taping method〉



Particular care should be taken during the following operations:
- When passing copper pipe through a through hole (Dirt easily gets into the pipe).
- When copper pipe is pushed through to outside (Rainwater gets in)
  (Special care is needed when the pipes are standing vertically outside)

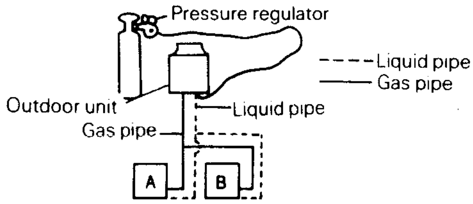




4) Refrigerant pipe flushing

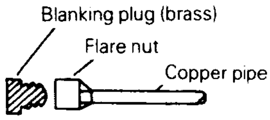
Flushing is a method of cleaning extraneous matter out of pipes using pressurized gas.
[3 major effects]
① Removal of oxidation bubbles formed inside copper pipes when "nitrogen replacement is insufficient" during soldering work
② Removal of extraneous material and moisture from pipes when covering has been insufficient
③ Checks connections in pipes linking outdoor and indoor units (Both liquid and gas pipes)

[Example of procedure]
① Set pressure regulator on nitrogen cylinder.
※ The gas used must be nitrogen.
(There is a danger of condensation if fluon or carbon dioxide are used and oxygen carries the risk of explosions.)

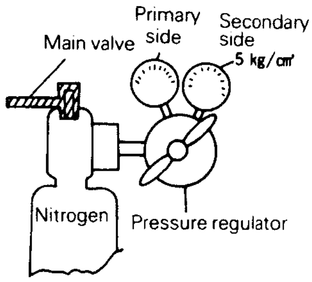


② Connect the charge hose from the pressure regulator to the service port on the liquid pipe side of the outdoor unit.

③ Fit blanking plugs to all indoor units (B) other than unit A.

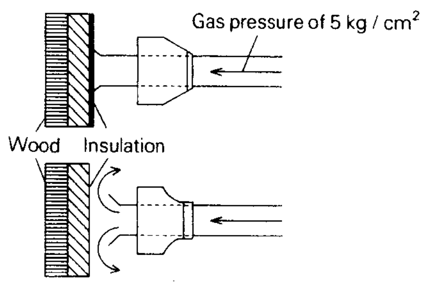


④ Open the main valve on the nitrogen cylinder and set the pressure regulator to 5 kg/cm².



⑤ Check that the nitrogen is passing through the unit A liquid pipe.

⑥ Flushing
• Block the end of the pipe with the insulation of your hand.
↓
• When the gas pressure becomes too great to contain remove insulation quickly.
(First flush)
↓
• Block the end of the pipe with insulation again.
↓
(Carry out second flush)

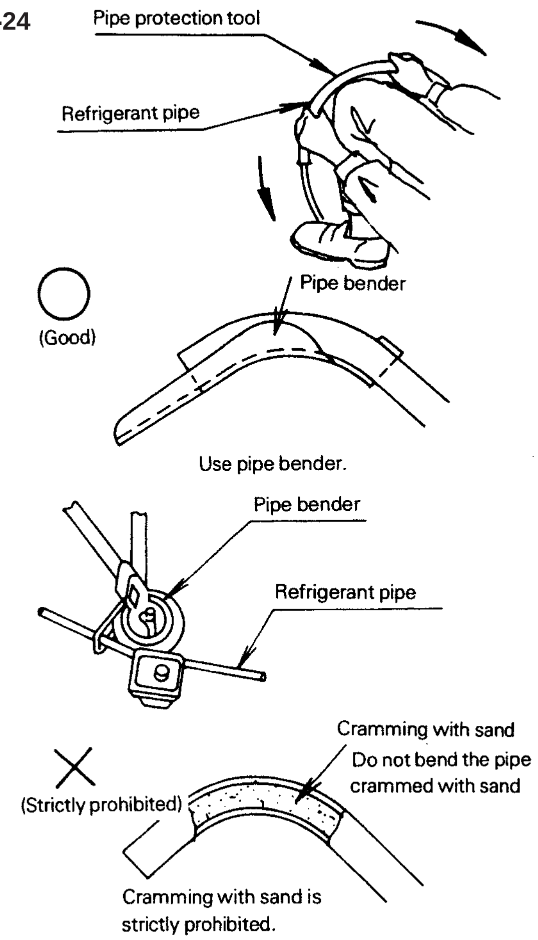


(The nature and amount of the extraneous material inside the pipe can be checked during flushing by placing a rag lightly over the end of the pipe. In the unlikely case that even a small quantity of moisture is found then the inside of the pipe should be dried out thoroughly.)
Action:
(1) Flush the inside of the pipe with nitrogen gas.
(Until such time as the moisture disappears.)
(2) Carry out a thorough vacuum drying operation.
⑦ Close the main valve on the nitrogen cylinder.
⑧ Repeat the above operation for unit B.
⑨ When the liquid pipe operations have been completed then do the same with the gas pipes.

5) Refrigerant pipe bending

- Decrease the number of the bending places as few as possible.
- Increase the length of the bending radius as large as possible.
- When bending without using a bender, a pipe protection tool must be used not to damage the pipe as shown below.

Fig.7-24



- Avoid the useless riser or down pipe.
- Be careful not to exert the excessive force on the pipe or the connecting part.
- When the piping is long, install the support as shown below.

Outside diameter	Clearance between supports (max.) m
ϕ22.2 or less	2.0
ϕ25.4 ~ ϕ38.1	2.5
ϕ44.5 ~ ϕ50.8	3.0

- Avoid to trap thoughtlessly in the course of the piping.
- The piping system should pass the place where it is not affected by other heat source.
- The piping on the passageway should be covered.

7.7.2 Allowable piping length and level difference

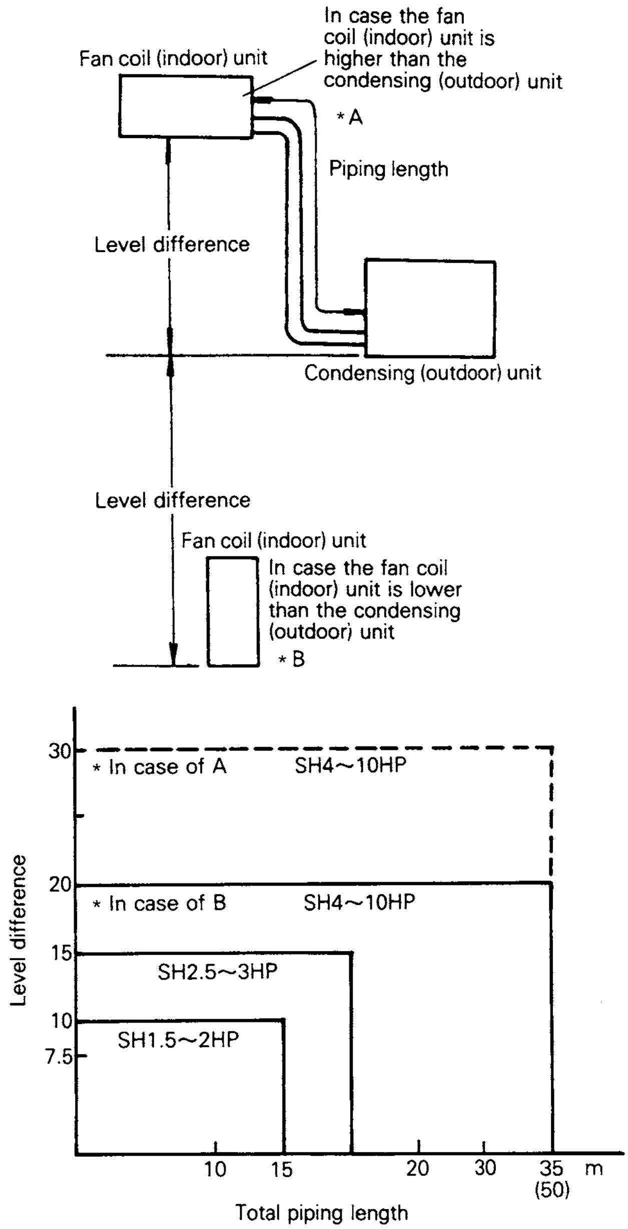
The longer the piping is, the lower the capacity of the air conditioner becomes. So lay the refrigeration piping as short and straight as possible.
In the following reasons, it is necessary to provide the refrigeration piping shorter and lower than the allowable values shown in the installation or technical manual.

- Allowable level difference
  If the level difference between the fan coil (indoor) unit and the condensing (outdoor) unit is larger than the allowable range, lifting head becomes excessively large. So flash gas (mixture of liquid and gaseous refrigerant) is generated before reaching to the highest part of the piping, which hinders refrigeration operation.
- Allowable length
  If piping length is longer than the allowable range, pressure loss through the piping becomes large, which reduces capacity. In addition refrigeration oil is deposited in the piping, which may cause burning of the compressor motor.

Notes:

1. In case the actual piping length exceeds the standard piping length, it is necessary to charge the refrigerant additionally.
2. The allowable difference differs from the positions of the fan coil (indoor) unit; i.e whether the fan coil (indoor) unit is located higher (*A) or lower (*B) than the condensing (outdoor) unit.
3. How to read the table:
   In case the unit is SH 4HP and the condensing (outdoor) unit is located lower than the fan coil (indoor) unit, the allowable refrigeration piping is 35m (L) in overall length and 30m (H) in level difference.
4. The parenthesized figure shows equivalent piping length.

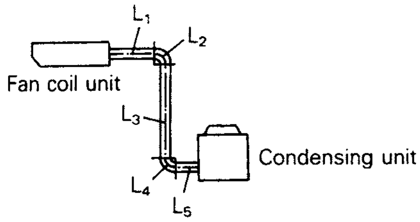
Fig.7-25 Example



7.7.3 Actual piping length and equivalent piping length

- Actual piping length
  Length of piping center line: LA
  $LA = L_1 + L_2 + L_3 + L_4 + L_5$

Fig.7-26



- Equivalent piping length
  Joints, bends, etc. provided in the actual piping are converted to the lengths of straight piping, which are added to piping length.
  Equivalent piping length = Actual piping length
  $+ N_L \times L_L + N_T \times L_T$
  L_L : Equivalent length of pipe per L joint
  L_T : Equivalent length of pipe per trap bend
  N_L : Numbers of L joints
  N_T : Numbers of trap bends

Table 7-1 Equivalent length of various fittings

(Unit: m)

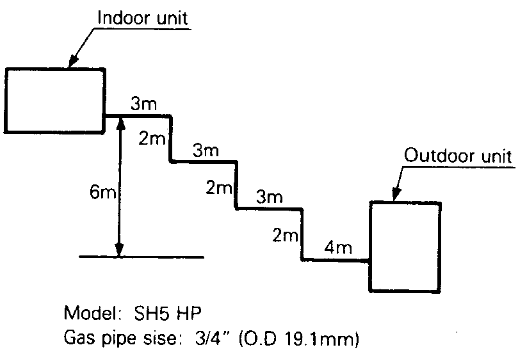
Pipe size	L joint 	Trap bend 
⅜" (OD 9.5mm)	0.18	1.3
½" (OD 12.7mm)	0.20	1.5
⅝" (OD 15.9mm)	0.25	2.0
¾" (OD 19.1mm)	0.35	2.4
⅞" (OD 22.2mm)	0.40	3.0
1" (OD 25.4mm)	0.45	3.4
1¼" (OD 31.8mm)	0.55	4.0

Notes:
1. Equivalent piping length is obtained with actual length of gas piping.
2. 90° bend of piping is equivalent to L joint.

Example

- Calculate the actual piping length and equivalent piping length of the following figure.

Fig.7-27



Solution

- Allowable total piping length: 35m
- Allowable level difference : 30m
- Max. equivalent piping length: 50m (From Fig. 7-25)

(1) Level difference ...... 6m<30m
(2) Actual piping length (LA)
    LA = 3 + 2 + 3 + 2 + 3 + 2 + 4 = 19m < 35m
(3) Equivalent piping length (LE)
    LE = 19 + 6 × 0.35 = 21.1m < 50m

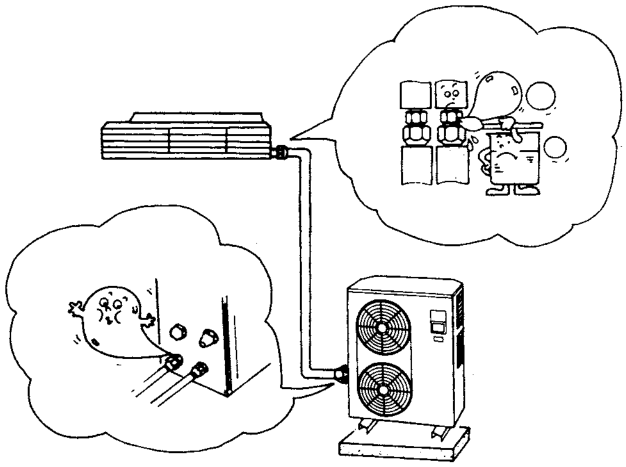
7.7.4 Leak test

Since refrigerant leakage from the refrigerant piping may cause trouble, it is necessary to check air tightness of the piping provided on the site before charging the refrigerant and performing the insulation work.
Check the piping for refrigerant leakage with one of the following methods.

(1) Soap-and-water solution
(2) Halide torch refrigerant leak detector
    - Alcohol type
    - LP gas cylinder type
(3) Electric type refrigerant leak detector

* As for the operation method, see 6.4.2 of Chapter 6.

Fig.7-28 No refrigerant leaks



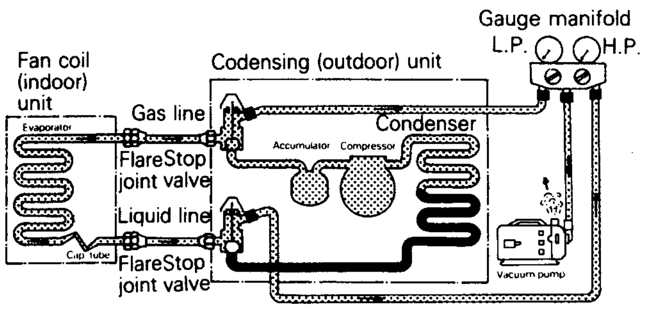
The following two methods of air tight tests are available depending on kinds of products. So carefully read the installation or technical manual before performing the leak test.

(1) Method to utilize gaseous pressure of the refrigerant
(2) Method to raise refrigerant pressure to the predesigned one (with nitrogen)

7.7.5 Evacuation

If air or moisture gets in the refrigerant piping, trouble may occur. So it is necessary to evacuate the piping by means of vacuum drying.
Since the evacuation method differs from products, refer to the installation or technical manual as for the details.

Fig.7-29



7.7.6 Refrigerant charge

The recent air conditioners require excessively smaller amount of the refrigerant to exhibit the utmost capacity. On the contrary, however, capacity is greatly affected by whether the refrigerant is over-charged or short. In this regard, it is necessary to charge the accurate volume of the refrigerant after finishing vacuum drying.
It is considered that the refrigerant is charged in the following two cases.

- The predesigned volume of the refrigerant is charged.
- The additional refrigerant is charged.

1. The predesigned volume of the refrigerant should be charged in the following two cases.
   - As the refrigerant has not been charged at the factory, it is charged on the site.
   - After repairing the refrigerant piping, the refrigerant is recharged.

   In any case, perform the vacuum drying before charging.
2. The refrigerant should be charged additionally when piping length exceeds the standard piping length.
   Additional charging volume of the refrigerant differs with diameters of the liquid refrigerant pipes, piping length and models. Calculate the additional charging volume in accordance with the instruction of the installation or technical manual.

Example

Obtain the additional charging volume of the refrigerant by use of the example in 7.7.3, "Actual piping length and equivalent piping length".

Solution

From Technical manual

		FH5HP +R5HP
Additional refrigerant charge	kg/m	0.02
Liquid pipe diameter	mm	12.7

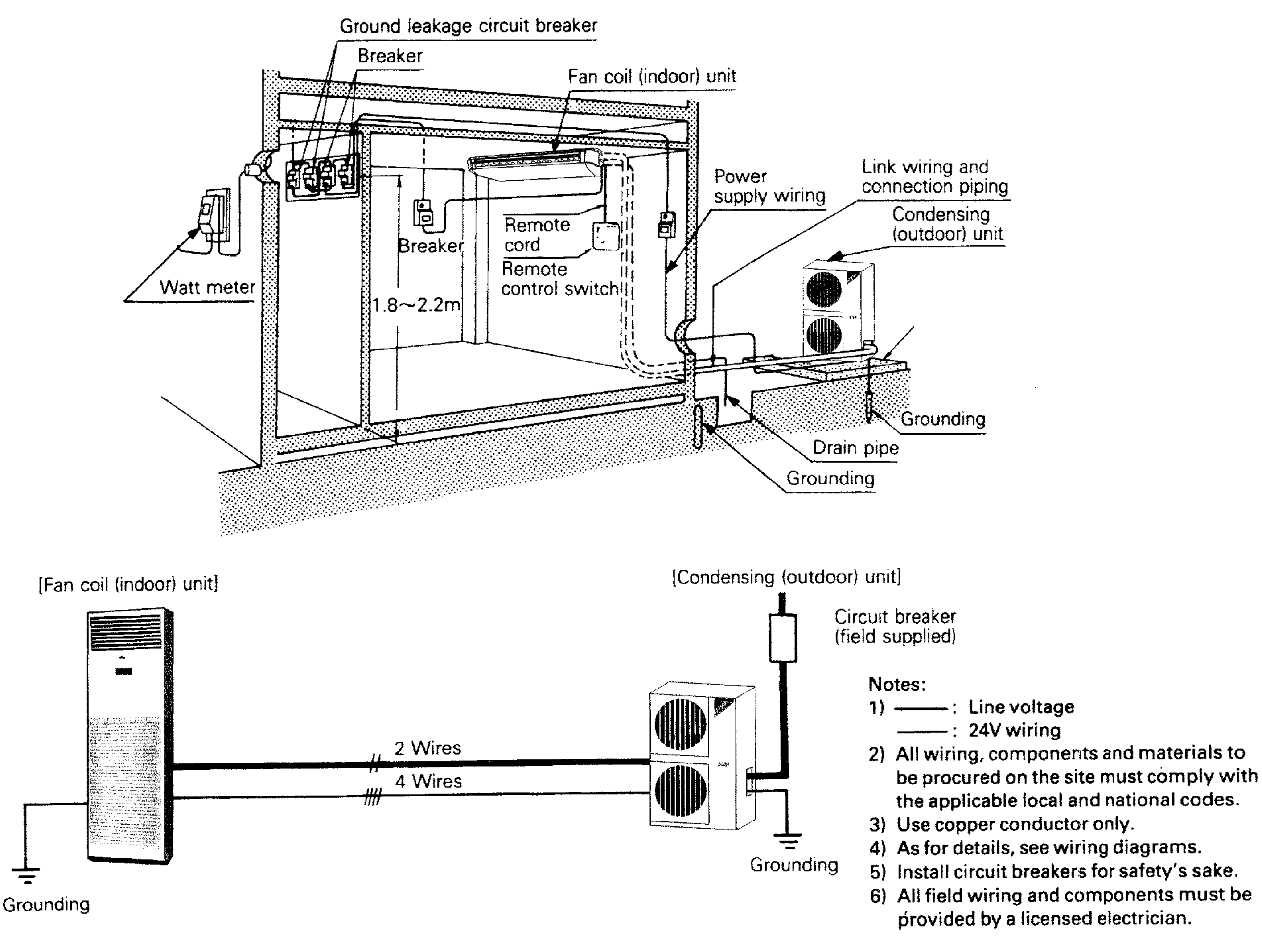
*Additional refrigerant should be charged, if the refrigerant piping length (LA) is longer than 5m.

Actual piping length (LA) =19m
Additional volume =(19-5)×0.02
=0.28kg=280g

7.8 Connect the power source wiring and link wiring

7.8.1 An example for split system air conditioners

Fig.7-30



7.8.2 Thickness of electric wires

The minimum thickness of wires is decided by the following items.

1) Mechanical strength
2) Allowable current
3) Voltage drop

(1) Mechanical strength
Thin wires are forbidden to be used for the electric circuit even if they seem thick enough in order to avoid thin wire snapping due to vibration or impact, wires of 1.6mm thick minimum are essential for all circuits, because thin wires are easily broken or snapped due to vibration and impact.

(2) Allowable current
When the current passes through a wire, heat is produced depending on flowing current and resistance of the wire. If very high current flows through a very long and thin wire, heat produced increases and the allowable current must be greater than the maximum load current. Calculation method of allowable current is as tabulated on the right.

Table 7-2 Allowable current of vinyl insulated wire

Conductor		Allowable current (A)
Dia, of solid wires (mm)	1.6	27
	2.0	35
	2.6	48
	3.2	62
	4.0	81
	5.0	107

Conductor		Allowable current (A)	Conductor		Allowable current (A)
Sectional area of stranded wires (mm^2)	2.0	27	Sectional area of stranded wires (mm^2)	80	257
	3.5	37		100	298
	5.5	49		125	344
	8.0	61		150	395
	14	88		200	469
	22	115		250	556
	30	139		325	650
	38	162		400	745
	50	190		500	842
	60	217			

Allowable current for insulated wires, the ratings of which are 0~2,000V, 60˚~90˚.
In case less than three wires are laid in a conduit or cable or buried in the ground based on the ambient temperature of 30˚C (86˚F).

Table 7-3

Size	Rating temperature of wires			
	60°C (140°F)	75°C (167°F)	85°C (185°F)	90°C (194°F)
AWG MCM	†TRUW, †T, †TW, †UF type	†FEPW, †RH †RHW, †RUH, †THW, †THWN, †XHHW, †USE, †ZW type	V, MI type	TA, TBS, SA, AVB, SIS, †FEP †FEPB, †RHH, †THHN, †XHHW, * type
	Copper			
18	......	......	......	14
16	......	......	18	18
14	20†	20†	25	25†
12	25†	25†	30	30†
10	30†	35†	40	40†
8	40	45	50	55
6	55	65	70	75
4	70	85	90	95
3	80	100	105	110
2	95	115	125	130
1	110	130	145	150
0	125	150	165	170
00	145	175	190	195
000	165	200	215	225
0000	195	230	250	260
250	215	255	275	290
300	240	285	310	320
350	260	310	340	350
400	280	335	365	380
500	320	380	415	430
600	355	420	460	475
700	385	460	500	520
750	400	475	515	535
800	410	490	535	555
900	435	520	565	585
1000	455	545	590	615
1250	495	590	640	665
1500	520	625	680	705
1750	545	650	705	735
2000	560	665	725	750

Table 7-4 Correction factor

Correction factor					
Ambient temperature °C	When ambient temperature exceeds 30°C, multiply the allowable current stated above by the following correction factor in order to determine the max.				Ambient temperature F°
31—40	.82	.88	.90	.91	86—104
41—45	.71	.82	.85	.87	105—113
46—50	.58	.75	.80	.82	114—122
51—60	......	.58	.67	.71	123—141
61—70	......	.35	.52	.58	142—158
71—80	......	......	.30	.41	159—176

The rating load current for the wires marked with † do not exceed 12A in case of 14AWG, 25A in case of 12AWG, and 40A in case of 10AWG for copper.

(3) Voltage drop

Voltage drop of low voltage wiring should be within 2%.

Main and branch circuits

- Since the length of wiring is very long, voltage drops. So it is necessary to determine the length of wiring as well.

The following table shows the max. length of wire.

Table 7-5 3phase 3wires (voltage drop: 2V) (copper wire)

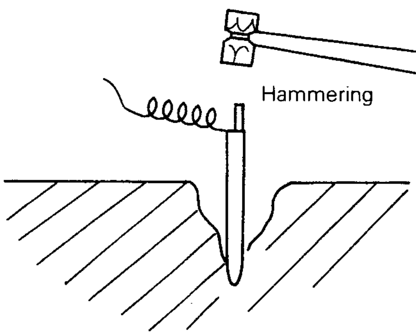
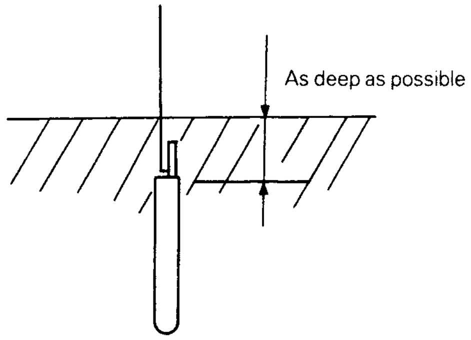
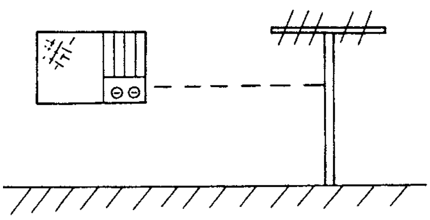
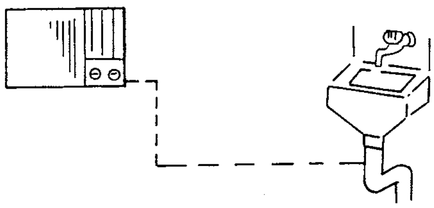
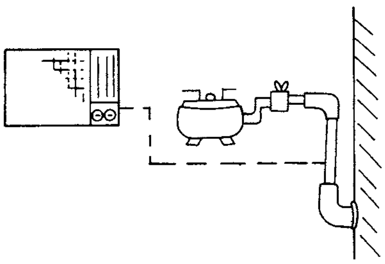
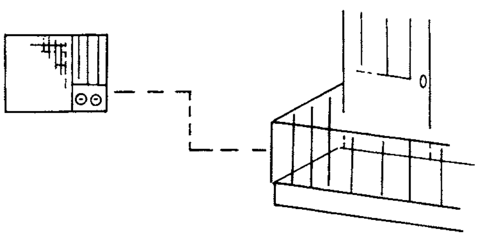
Current (A)	Solid wire (mm)				Stranded wire (mm^2)					
	1.6	2.0	2.6	3.2	14	22	30	38	50	60
	Max. length of wires									
1	129	204	345	522	888	1400	1850	2370	3050	3800
2	65	102	172	261	444	701	926	1180	1520	1900
3	43	68	115	174	296	467	617	788	1020	1270
4	32	51	86	131	222	351	463	592	762	951
5	26	41	69	104	178	280	370	473	609	760
6	22	34	57	87	148	234	309	394	508	634
7	18	29	49	75	127	200	264	338	436	543
8	16	26	43	65	111	175	231	296	381	475
9	14	23	38	58	99	156	206	263	339	422
12	11	17	29	44	74	117	154	197	254	317
14	9.2	15	25	37	63	100	132	169	218	272
15	8.6	14	23	35	59	93	123	158	203	253
16	8.1	13	22	33	55	88	116	148	190	238
18	7.2	11	19	29	49	78	103	131	169	211
25	5.2	8.2	14	21	36	56	74	95	122	152
35	3.7	5.8	9.9	15	25	40	53	68	87	109
45	2.9	4.5	7.7	12	20	31	41	53	68	84

Current (A)	Stranded wire (mm^2)								
	80	100	125	150	200	250	325	400	500
	Max. length of wires								
1	5030	6430	8000	9800	12500	16100	20600	25700	31200
2	2510	3210	4000	4900	6260	6070	10300	12800	15600
3	1670	2140	2660	3270	4170	5380	6870	8550	10400
4	1260	1610	2000	2450	3130	4030	5150	6410	7810
5	1000	1290	1600	1960	2500	3230	4120	5130	6250
6	837	1070	1330	1630	2080	2690	3440	4280	5210
7	718	918	1140	1400	1790	2310	2950	3660	4460
8	628	803	1000	1230	1560	2020	2580	3210	3900
9	558	714	888	1090	1390	1790	2290	2850	3470
12	419	535	666	816	1040	1340	1720	2140	2600
14	359	459	570	700	894	1150	1470	1830	2230
15	335	428	533	653	834	1060	1370	1710	2080
16	314	401	500	612	782	1010	1290	1600	1950
18	279	357	444	544	695	896	1150	1430	1740
25	201	257	320	392	500	645	825	1030	1250
35	144	184	228	280	357	461	589	733	893
45	112	143	178	218	278	359	458	570	694

Notes: 1. If the voltage drop is 4V or 6V, multiply 2 or 3 by the figure in the chart.
2. If the current is 20A or 200A multiply 1/10, 1/100 by the figure of 2A.
3. Power factor is one.

7.8.3 Procedure for grounding work

In case the air conditioner is grounded so as to allow leaking electric current to escape to the ground, there is only small danger of electric shock as the human body has comparatively large electric resistance.

Procedure	Description	Note
1. Decide a place where the grounding rod is to be buried.	Wet or humid ground is preferable. Avoid such places where gas, water or electrical piping may be buried under the ground.	Sand or gravel is also unsuitable because of its high grounding resistance. All air conditioners must be independently grounded. Do not share the grounding with telephone systems.
2. Hammer the grounding rod into ground	 	
3. Connect ground wire.	Fasten the ground wire with staples. * In case of short lead wires attached to the grounding rod, solder an extension wire to the lead wire and wrap around the connection with insulation tape.	The part to be connected by an extending wire with the grounding wire should be above the ground. (Corrosion prevention)
4. Examples of wrong grounding work	Grounding connected with TV antenna.  Grounding connected with water piping.  Grounding connected with gas piping.  Grounding connected with guardrail of veranda. 	

7.9 Heat insulation

After finishing leak test and vacuum drying, provide heat insulation around the piping as shown in the figures.

- Reasons why heat insulation is required around the piping.
  1) In order to protect the refrigerant vapor from being super heated extremely while passing through the suction piping, heat insulation is provided around the suction piping, heat insulation is provided around the suction piping. If not, capacity reduces and the compressor may be burnt.
  2) In order to protect dew from forming around the suction piping, heat insulation is provided around the suction piping.
  3) In order to protect persons from being burnt when contacting the discharge piping for refrigerant vapor, because temperature of the discharge refrigerant vapor is very high (Approx. 70˚C~100˚C.)

Table 7-6

Necessity of heat insulation		Gas piping	Liquid piping
Split type:	In case of capillary tube located in condensing (outdoor) unit	Necessary	Necessary
	In case of expansion valve located in fan coil (indoor) unit	Necessary	Necessary (Note 1)
Remote condenser type		Unnecessary (Note 2)	

*Material whose thermal durability is over 120˚C is used.
(Ex. glass fibre.)
Notes:
1.Protect the piping which is affected by direct sunlight with galvanized iron plate.
2.Protect the piping which contacts directly with objects or human body mistakenly with galvanized iron plate.

Fig.7-31 Example insulation

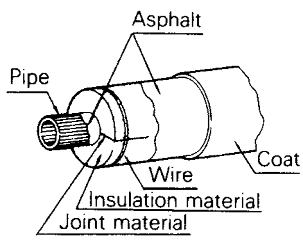


Fig.7-32 Heat insulation around a bent pipe

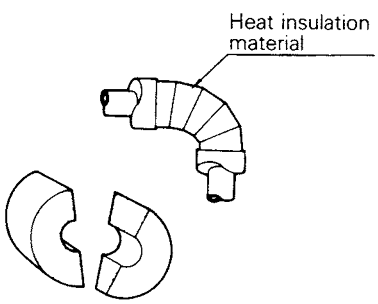
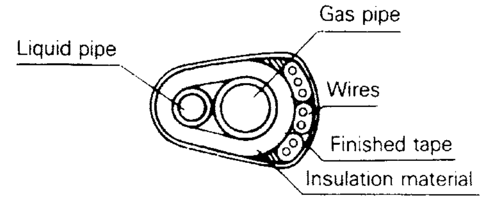
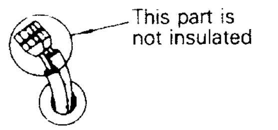


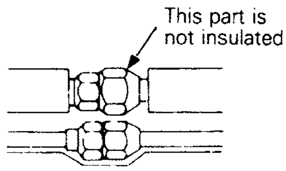
Fig.7-33 Points of heat insulation work

- Example of bad work
- Do not insulate gas piping and liquid piping together

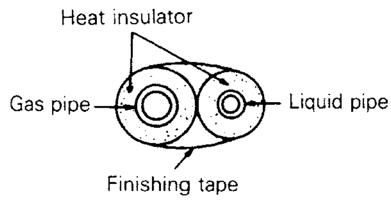


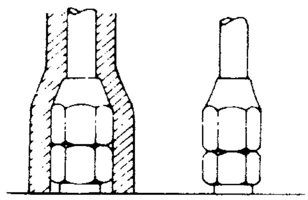
- Thoroughly insulate around pipe connections

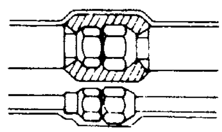




- Example of good work







7.10 Drain piping

Provide the drain piping short with a downward inclination, and do not make any air trap through it.

Fig.7-34

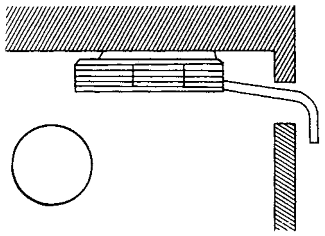


Fig.7-35

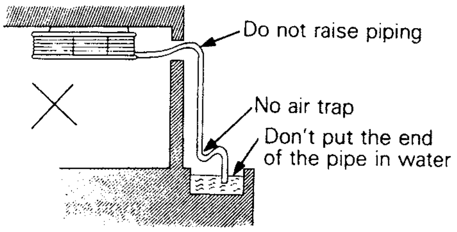
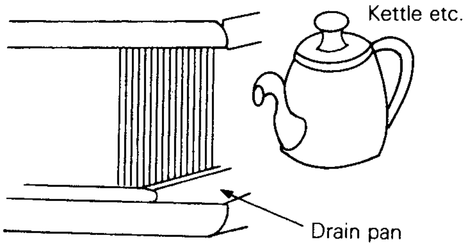


Fig.7-36

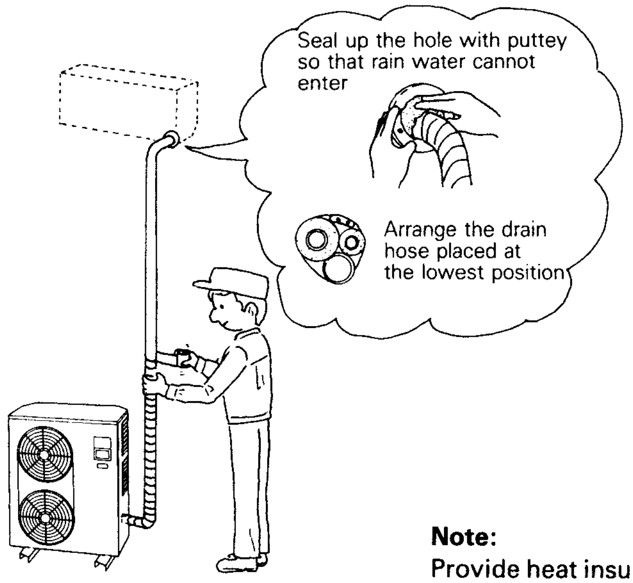


Check whether water is extracted smoothly outdoors.

7.11 Finishing work

- Provide the finishing work accurately so that rain water does not invade into the room.

Fig.7-37



Note:
Provide heat insulation and tape on the flare nut of the condensing unit.

7.12 Final check

- Remove the shipping plate.
- Check the ground connection.
- Check that screws are not loosened.
- Completely open the stop valves in the gas and liquid lines.

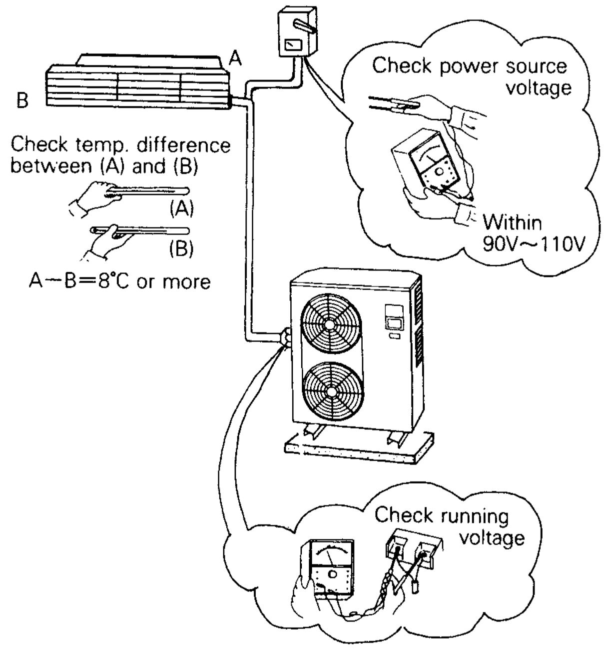
7.13 Test run

- Check the following items.

1. Check that the temperature difference between the suction air and the discharge air is over 8˚C.
2. Check that the power source voltage is correct.

- Check that running voltage is correct.

Fig.7-38



* As for the details, see Chapter 8.

7.14 Check points of installation (Summary)

1. General check points

- Prior to the installation (or the operation), did you get the legal permission?
- Is the temperature of the cooled (or heated) objects or the usable limit of the main machinery appropriate?
- Is the water quality proper for air conditioning?
- Do the surroundings have no adverse effect on the equipment?
- Is the service space ensured?

2. Equipment

(1)Main machinery

- Is the drain trap attached?
- Is the water-seal dimension of the trap equal to or more than the blower static pressure?
- Did you confirm the state of flowing out of the drain by the way of pouring water in the drain pan?
- Do you consider countermeasures to the snow or the strong wind?
- Is there no object fallen in the blower?

(2) Auxiliary machinery

■ **Cooling tower pump**

- Is the pump installed on the level below the water level of the cooling tower?
- Is the drain ditch provided around the cooling tower and the pump?
- Is the cooling tower positioned at the level higher than the main machinery?

■ **Hot water heater, steam heater**

- Are there possibilities of air purging and drainage?
- Do you consider the anti-freezing measures?

■ **Electric heater, Pan humidifier**

- Is the interlock for the blower set?
- Is the water supply to the humidifier obtained from the tap water?
- Is the strainer mounted?

3. Piping work

(1) Refrigerant piping

- Is the piping within the allowed length and height specified for the main machinery?
- Does the protection against heat follow the instruction mentioned in the specification for the main machinery?
- When the length of riser pipe is higher than 10m, is the specified trap mounted?
- Did you perform the gas-tight test as legally specified?
- When the piping length is longer than the standard length specified for the main machinery, is the designated refrigerant filled after the vacuum drying?

(2) Water piping

- When the plural number of main machineries share one cooling tower, is there a port so that the chemical cleaning of single machinery is possible?
- Is there a drain valve at the lowest part of the piping (both going and returning)?
- Can the water throughout the system be drained from the drain valve?
- Is the piping provided with the pipes having the same diameter as the cooling tower side not with the pipes having the same diameter as the main machinery side?

4. Duct work

- Is there an access door at the necessary place (return section, F, V, D positions)?
- Is the internal dirt cleaned out?
- Is the connection with the machinery made of canvas or the like so that the vibration does not travel to the machinery.
- Are the circumstances of the outside air intake proper?
- Are the insulating materials for the equipment and tool easy to be attached or detached for inspection?

5. Electrical work

- Does the power source conform to the equipment specification (voltage, phase number, frequency)?
  Do the thickness of the wire outside the machinery and the switch capacity follow the specification?
- Is the capacity of the phase advance capacitor of the auxiliary machinery proper?
  What are the wire size, the wiring position, and the installed position?
- Is the auxiliary machinery (cooling tower, pump) interlocked with the main machinery?
- Are all main and auxiliary machineries grounded?
- Is the insulation measurement performed for the whole equipment?
- Is there no valve for water piping directly above the equipment?

6. Others

■ Smell

(1) The growth mechanism

The chief materials used for the air conditioners are metal such as aluminum, copper, iron, ect., and resin such as ABS resin, styrene resin, expanded polystyrene, ect. The smell does not develop from these materials.

The growth of the smell is caused by the air circumstance where the air conditioner is installed. The mechanism of the smell growth is considered as follows.

(2) Countermeasure

There is no completely preventive measure as long as the air conditioner is used in the condition mentioned above. But it is the most effective preventive measure to take care fully of the ventilation using a ventilating fan. When the smell still worries you after taking the above measure, wash inside of the air conditioner each time the smell develops. It is a matter of course that the maintenance of air filter and exterior of the air conditioner should be conducted usually to keep out any dirt.

(3) Others

In some cases, the smell of the outdoor ditch may enter from the tip of the drain hose. Therefore, check fully the conditions in the field of the installation, too. In this case, check that the trap is provided in the drain piping.

Table 7-7

	Beauty saloon	Eating house	Mah-jong saloon	Building materials
Sulfurous compounds such as hydrogen sulfide	Permanent (hair)	Food processing		
Nitrogenous compounds such as Ammonia	Hair dye	Food processing		
Fatty acid such as nitric acid or nitrous acid	Shampoo, Spray	Food processing		
Aldehyde such as formaldehyde				Adhesive for the interior
Pyridine, Ammonia			Tobacco smoke	

⇩

The particles of the above mentioned objects are in suspension in air.

⇩

Pass through an air conditioner

⇩

Grow smell

Smelling particles adhere to deposit there, and change with the passage of time

General tendency

- During the cooling operation (thermostat ON), the smell is not strong comparatively because the fin surfaces of the heat exchanger is covered with the dehumidification water.
- During the fan or heating operation, the smell is comparatively strong because there is no dehumidification water on the fin surfaces and they are exposed.

Chapter 8 Test run

Chapter 8 Test run

8.1 Inspection before test run

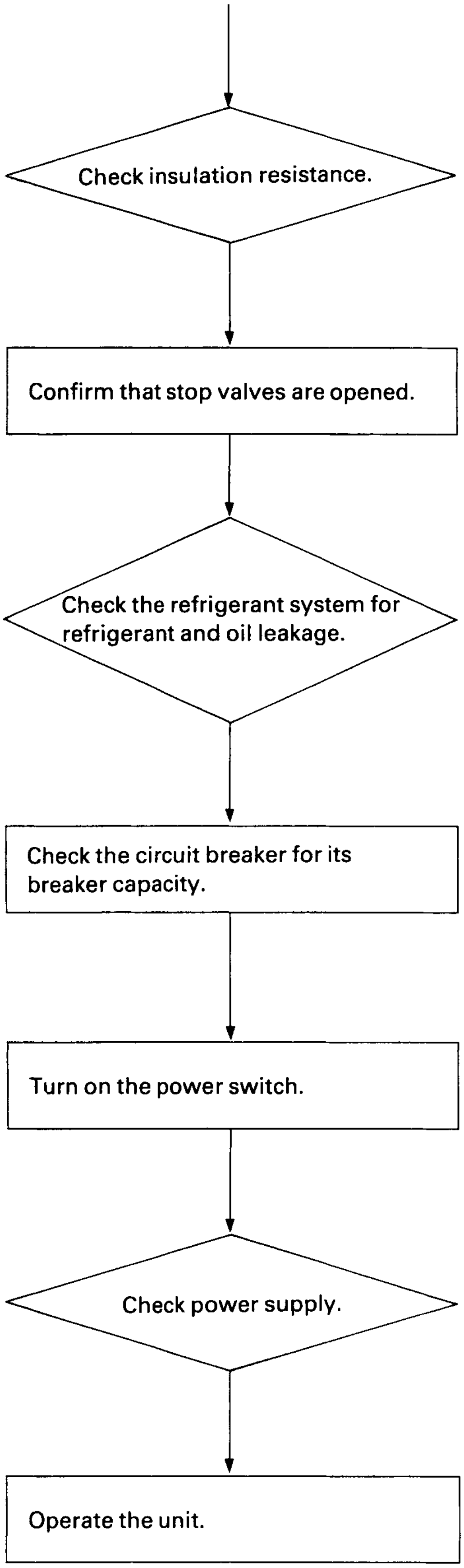
After finishing all installation work and before operating the air conditioner, check the following items again.

Note:

◇ : Checking items by using instruments.

▭ : Checking items by observing or others.

Check item	Remarks
Check the unit for internal damage. ↓	• Inspect the unit for the internal damage which may occur sometimes during transportation.
Check the internal wiring. ↓	• The internal wiring should not be in contact with the high temperature parts or the drain pan.
Check the fan. ↓	• Turn the fan several times by hand and inspect that there is no trouble caused by foreign objects in the fan housing.
Remove shipping plates. ↓	• Before operating the unit, remove shipping plates (yellow colour plates) and be sure to tighten the bolts again.
Check the ground connection. ↓	
Check the wiring connections. ↓	• All field wiring must be provided according to the wiring diagram which is stuck on the switch box cover of the unit.
Check the screws are not loosened. ↓	• Confirm that screws on the terminal strip are tightened up. Particularly tighten up screws on the main circuit connections additionally.



- Inspect insulation resistance between the charged parts and the ground.
  Insulation resistance is over 1MΩ (1000kΩ).

- In case of the split type and large units, the refrigerant is normally pumped down into the condenser or the liquid receiver to prevent the refrigerant from leaking due to the vibration during transportation.

- Although the refrigerant system is carefully inspected for the refrigerant and oil leakage before delivery, once again check it for caution's sake.
  Particularlly check the flare joint and brazing joint for leakage.
  Inspect oil leakage as well, because oil leakage is normally accompanied with refrigerant leakage.

- The circuit breaker capacity for the source switch is shown in the technical sheet.

- Suppling voltage must be within±10% fluctuation of the rated voltage.
  If power supply is excessively low, the over-current relay functions to stop the unit. The motor coil of the compressor may be sometimes burnt out.

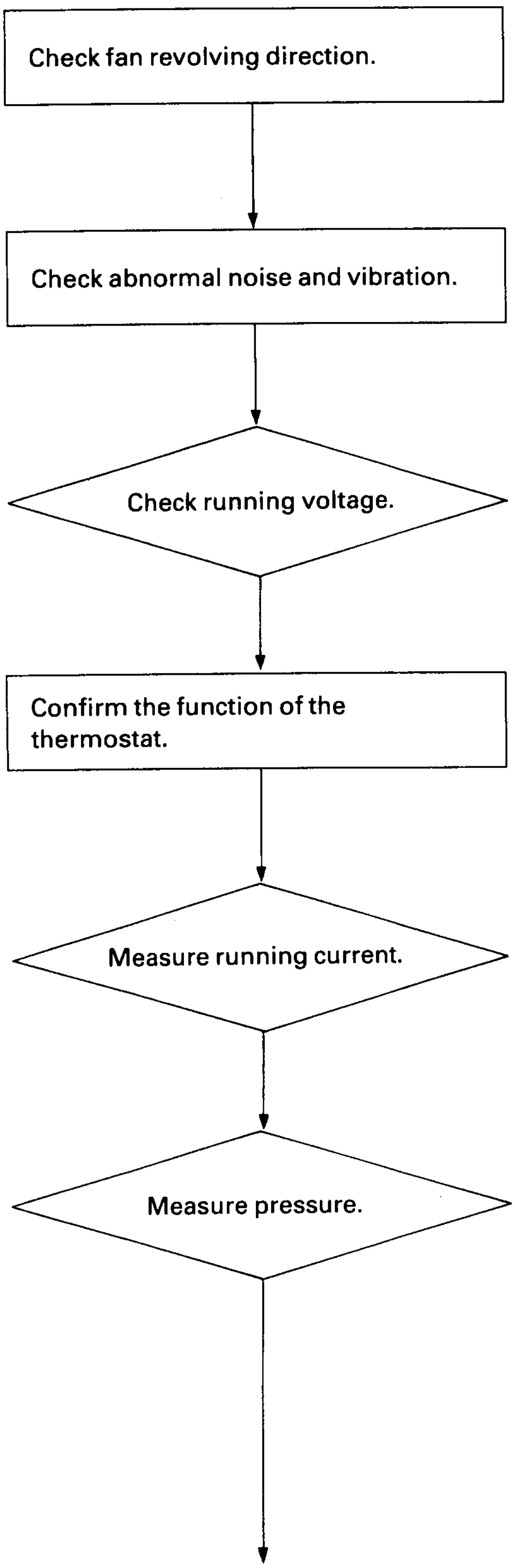
8.2 Test run

The air conditioner is inspected in the following order. If anything wrong is found with it, stop it at once and repair or replace it according to Chapter 9 "Troubleshooting".

Note:

◇ : Checking items by using instruments.

▭ : Checking items by observing or others.



- Fan revolving direction is pointed by the arrow mark.
- In case of the multi-blade fan, even if it is revolved reversely, small air volume comes out.
- If the fan motor and rotor revolve reversely, change the two wire connections out of three in the power source.

- Running voltage fluctuation must be within ± 10% of the rated voltage.

- Adjust the volume control.
  Check whether the unit stops. In case room temp. is very low, the thermostat is activated. So, confirm it by warming with fingers or warm water.

- Running current is less than 110% of the rated current. (in the normal operation)
  If running current is excessive, the over-current relay may functions.

- Operating pressure characteristic. (Reference data)

	Air cooled type	Water cooled type
H.P.	1.2~2.6 MPa (12~26 kgf/cm^2) (170~370 psi)	1.0~1.8 MPa (10~18 kgf/cm^2) (142~256 psi)
L.P.	0.35~0.75 MPa (3.5~7.5 kgf/cm^2) (50~107 psi)	0.3~0.6 MPa (3~6 kgf/cm^2) (42~86 psi)

H.P.……Discharge pressure
L.P.……Suction pressure

*R-22 is used.

Measure temperature at various points.

- If the temperature difference between the leaving and the entering air is over 8°C (46.4°F), cooling capacity is satisfactory.

Confirm that safety devices (such as high pressure switch) function.

- Check high pressure switch during operation by stopping the outdoor fan or condenser water flow.

Record operation data.

Explain how to operate and maintain the air conditioner to the customer.

- When finishing all test run, explain to your customer how to operate and maintain the air conditioner correctly according to the operation manual supplied with the unit.

8.3 Measuring items

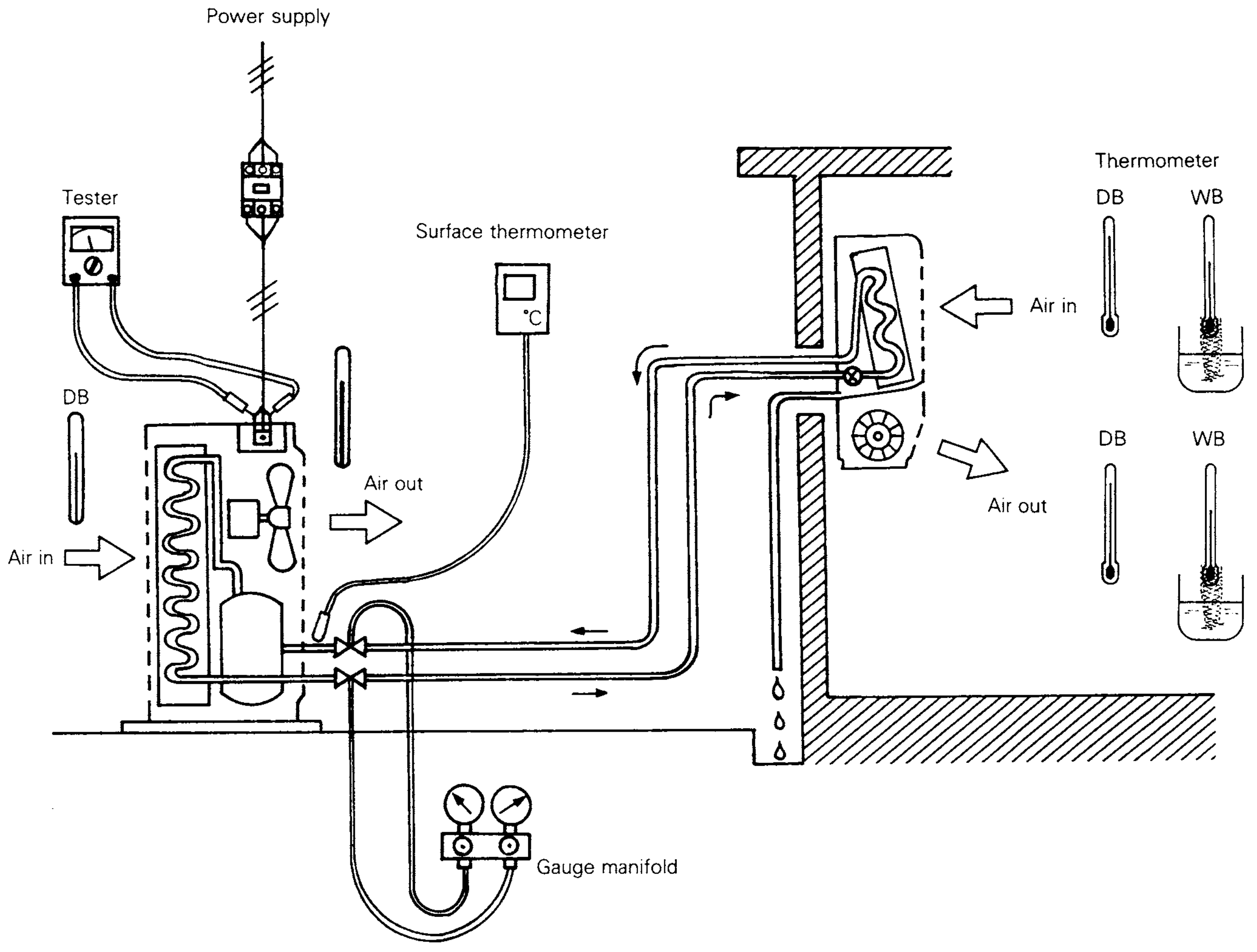
Measure at least the following points during test run.

(1) Voltage and running current

(2) Pressure
- Discharge pressure
- Suction pressure

(3) Temperature
- Leaving air (or water) temperature of condenser and evaporator.
- Entering air (or water) temperature of condenser and evaporator.
- Discharge gas temperature.
- Suction gas temperature.
- Liquid temperature before expansion valve.

Fig.8-1 Measuring items



Data sheet

Model name		Date	
Serial No.		Name	

1. Measuring items before operation

No.	Item	Standard	Data
1	Insulation resistance	More than 1 MΩ	MΩ
2	Power supply voltage	Within ±10% fluctuation of the rated voltage	V

2. Measuring items during operation

No.	Item		Standard	Data
①	Voltage		Within ±10% fluctuation of the rated voltage	V
②	Running current		Under 115% of the rated current	A
③	Discharge pressure (Condensing pressure)			MPa (kgf/cm²)
④	Suction pressure (Evaporating pressure)			MPa (kgf/cm²)
⑤	Condensing medium temperature	Inlet		°C DB
		Outlet		°C DB
		△t		degree
⑥	Evaporating medium temperature	Inlet		°C DB °C WB
		Outlet		°C DB °C WB
		△t	Over 8 deg.	degree
⑦	Suction gas temperature			°C
⑧	Discharge gas temperature			°C
⑨	Liquid temperature before capillary tube (Expansion valve)			°C
⑩	Saturated temperature of discharge pressure (③)			°C
⑪	Saturated temperature of suction pressure (④)			°C
⑫	Amount of superheat (⑦−⑪)			degree
⑬	Amount of subcool (⑩−⑨)			degree

8.4 Standard operation data

Operation data of air conditioners, water chillers and small size refrigerant units under their standard operation states are given in this article.
Be sure to use these data during after sales service and remember the standard operation states of the air conditioners and water chillers. Furthermore, each model has its own operation limits such as low temperature, overload, etc., so see the technical sheet (ES sheet) as well.

8.4.1 Air cooled packaged air conditioners

Fig.8-2 Normal state (R-22 is used)

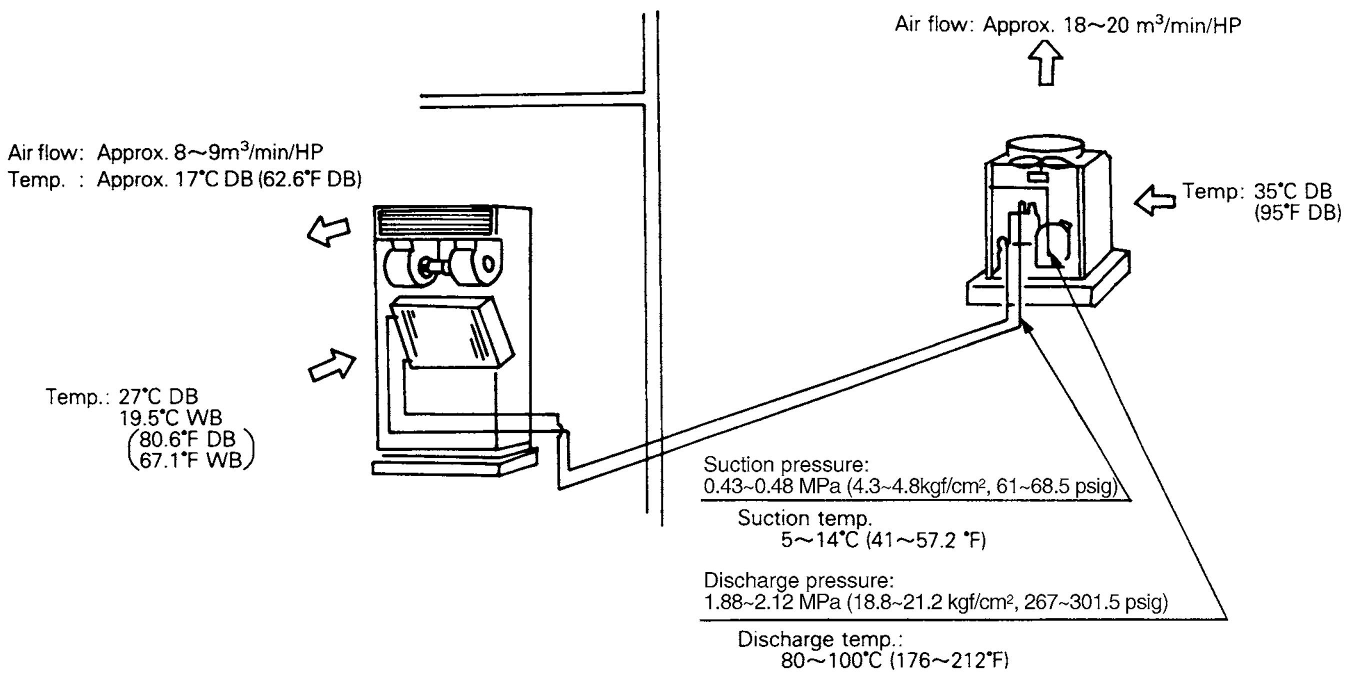


Table 8-1 Standard values (R-22 is used)

Item		Air cooled packaged air conditioners
		Cooling
Refrigerant pressure	Discharge pressure	Saturated pressure corresponding to {outdoor air temp. +approx. 15 deg.C (27 deg.F)}
	Suction pressure	Saturated pressure corresponding to {discharge air temp. -approx. 12 deg.C (22 deg.F)}
Condensing unit (outdoor)	Air flow	Approx. 18~20m³/min./HP
	Range	9~11 deg.C (16.2~19.8 deg.F)
Fan coil unit (indoor)	Air flow	Approx.8~9m³/min./HP
	Range	9~13 deg.C (16.2~23.4 deg.F)
Amount of superheat		3~10 deg.
Amount of subcool		3~8 deg.

Notes:
1. Standard design values.
   Corresponding piping length and level difference between fan coil (indoor) and condensing (outdoor) units are based on 5m (16.4ft) and 0m (0ft).
   (Piping length differs with such level difference of piping.)
2. Outdoor air temp. 35˚C DB (95˚FDB)
   Indoor air temp. 27˚CDB (80.6˚FDB)
   19.5˚C WB (67.1˚FDB)

8.4.2 Water cooled packaged air conditioners in combination with cooling towers

Fig.8-3 Normal state (R-22 is used)

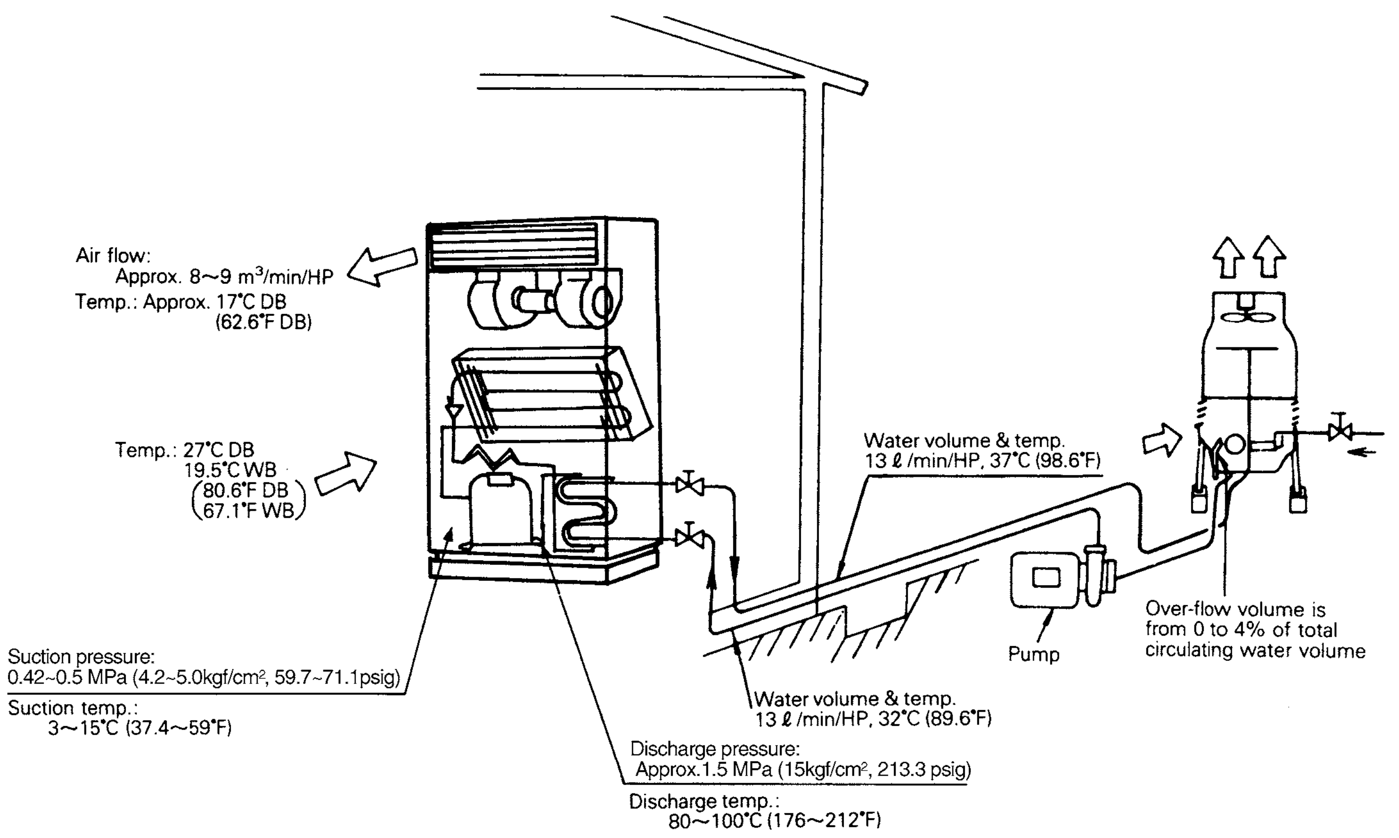


Table 8-2 Standard values (R-22 is used)

Item		Water cooled packaged air conditioner (Cooling)	Cooling tower	
Refrigerant pressure	Discharge pressure	Saturated pressure corresponding to {leaving condenser water temp. +approx. 5 deg.C (9 deg.F)}		
	Suction pressure	Saturated pressure corresponding to {air discharge temp.-approx. 11 deg.C (19.8 deg.F)}		
Condenser water	Water volume	Cooling tower 32˚C(89.6˚F)13 L/min/HP	Water volume	13 L/min/ton
	Range	Approx. 5 deg.	Range	Inlet 32˚C(89.6˚F) Outlet 37˚C(98.6˚F) ΔT=5 deg.
Air	Air flow	Approx. 8~9 m³/min/HP	Temp.	27˚C WB (80.6˚F WB)
	Range	10~14 deg.C (18~25.2 deg.F)		
Amount of superheat		3~10 deg.		
Amount of subcool		3~8 deg.		

Note:Standard design values.
a.Indoor temp. 27˚C DB, 19.5˚C WB. (80.6˚FDB, 67.1˚F WB)
b.Leaving tower water temperature 32˚C(89.6˚F) and entering tower water temperature 37˚C(98.6˚F).

8.4.3 Air cooled packaged water chillers

Fig.8-4 Normal state

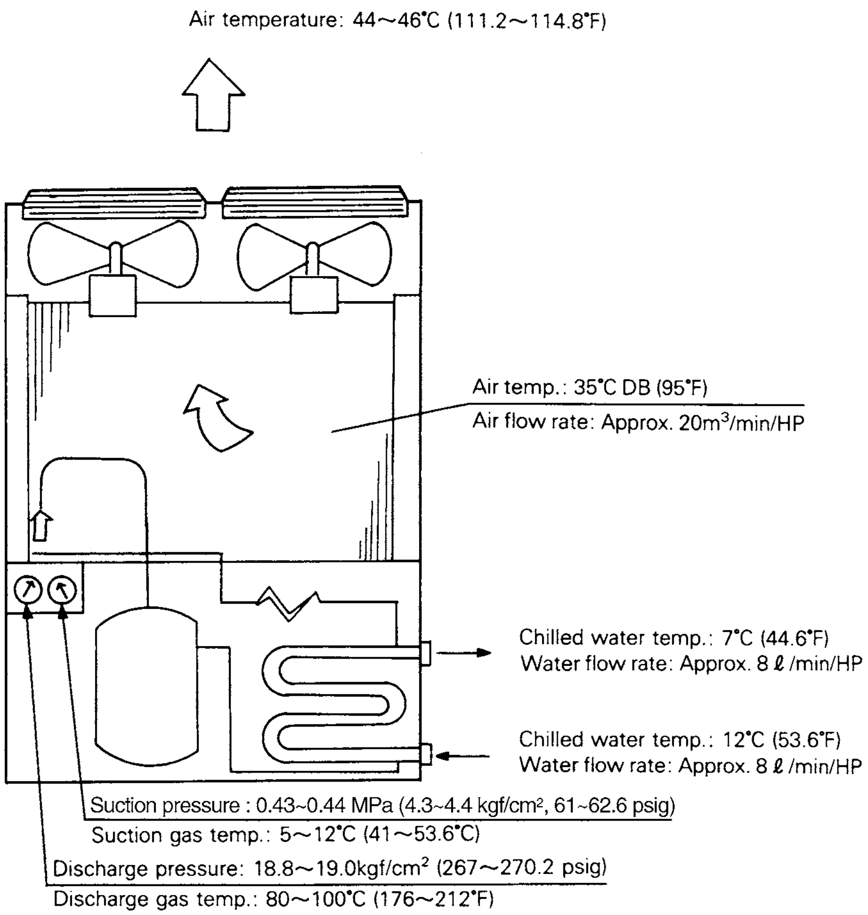


Table 8-3 Standard values

Item		Air cooled packaged water chiller
		Cooling
Refrigerant pressure	Discharge pressure	Saturated pressure corresponding to {outdoor temp.+approx.15 deg.C (27 deg.F)}
	Suction pressure	Saturated pressure corresponding to {leaving chilled water temp.-approx.7 deg.C (12.6 deg.F)}
Air	Air flow	Approx. $20m^3$/min/HP
	Range	9~11 deg.C (16.2~19.8 deg.F)
Chilled water	Water flow	Apporx. 8 L/min/HP
	Range	5 deg.C (9deg.F)
Amount of superheat		4~6 deg.
Amount of subcool		3~8 deg.

Note:
Outdoor air : 35˚CDB (95˚F)
Entering chilled water temp. : 12˚C(53.6˚F)
Leaving chilled water temp. : 7˚C(44.6˚F)

8.4.4 Water cooled packaged water chillers

Fig.8-5 Normal state (R-22 is used)

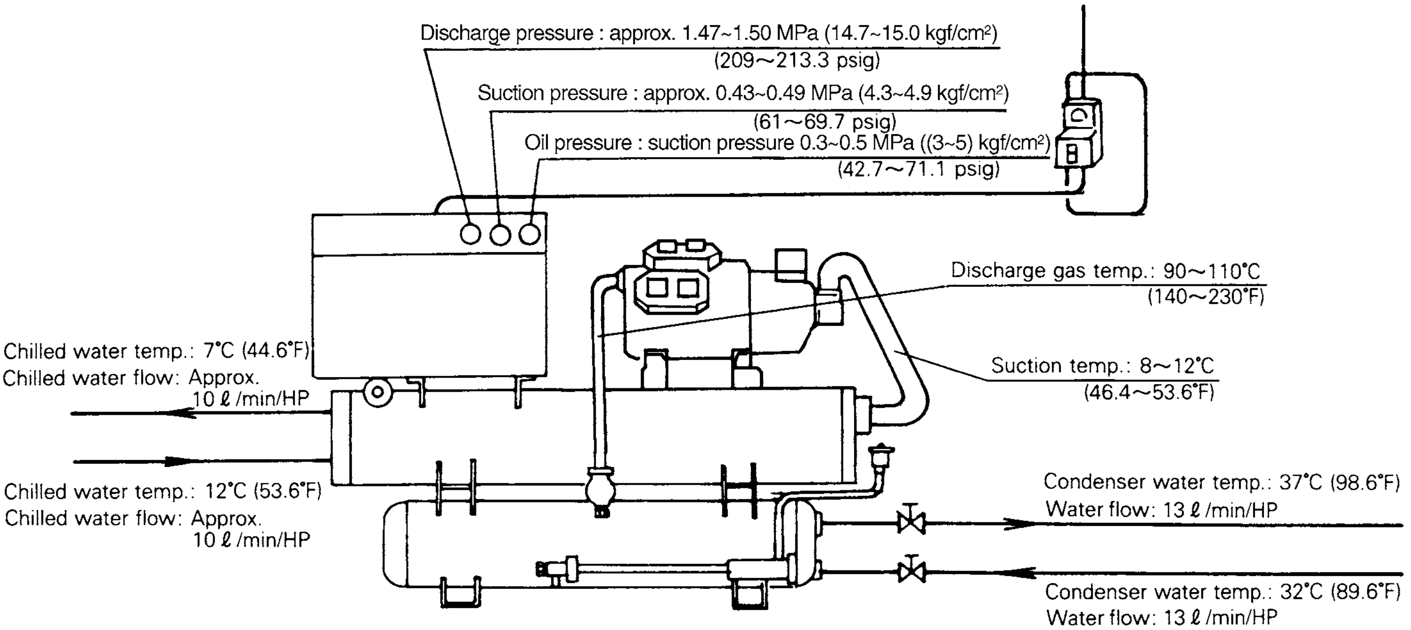


Table 8-4 Standard values (R-22 is used)

Item		Water cooled packaged water chiller
		Cooling
Refrigerant pressure	Discharge pressure	Saturated pressure corresponding to {leaving condenser water temp. +approx.5 deg.C (27 deg.F)}
	Suction pressure	Saturated pressure corresponding to {leaving chilled water temp. -5 deg.C (9 deg.F)}
Condenser water	Water flow	Approx.13 L/min/HP
	Range	5 deg.
Chilled water	Water flow	Approx. 10 L/min/HP
	Range	5 deg.C (9deg.F)
Amount of superheat		5~8 deg.
Amount of subcool		3~8 deg.

Note:Entering chilled water temp.12˚C (53.6˚F)
Leaving chilled water temp. 7˚C (44.6˚F)
Entering condenser water temp.32˚C (89.6˚C)
Leaving condenser water temp.37˚C (98.6˚F)

8.4.5 Small size refrigeration units

Fig.8-6 Normal state (R-22 is used)

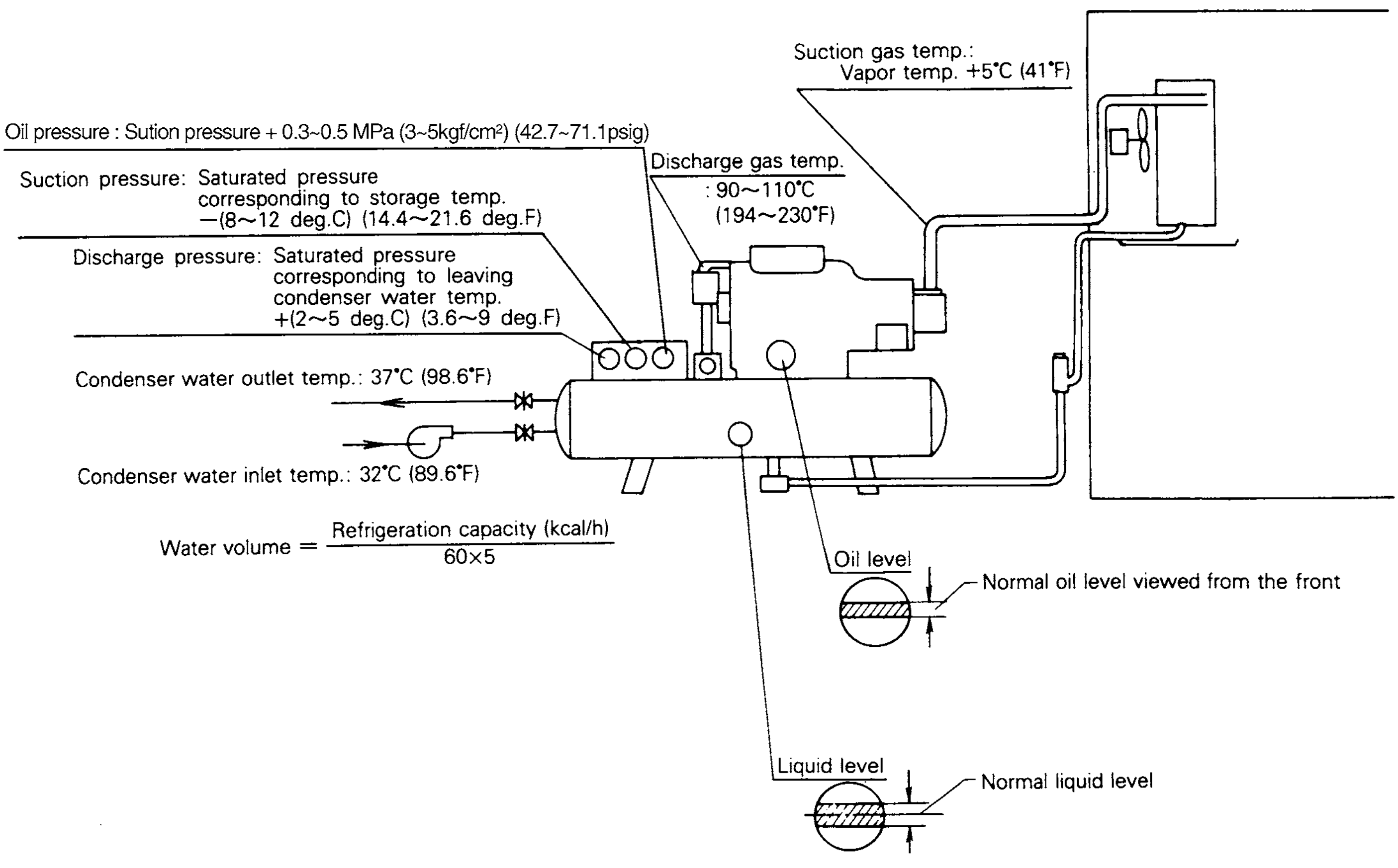


Table 8-5 Standard values (R-22 is used)

Item		Water cooled refrigerant unit
Refrigerant pressure	High pressure	Saturated pressure corresponding to {leaving condenser water temp. +(2~5 deg.C) (3.6~9 deg.F)}
	Low pressure	Saturated pressure corresponding to {storage temp.-(8~12 deg.C) (14.4~21.6 deg.F)}
Oil pressure		Suction pressure +0.3~0.5MPa, (3~5kgf/cm^2) (42.7~71.1psi)
Condenser water range		3~5 deg.C (5.4~9 deg.F)
Suction gas temp.		Evaporating temp. + (7~10 deg.C) (12.6~18 deg.F)

8.5 General tendency of each performance due to change in condensing and evaporating medium temperature.

In general, capacity, pressure and running current differs greatly with outdoor and indoor temperatures as shown in Figs. 8.7~8.9. Since outdoor temperature cannot be controlled, it is very important to judge whether operation state is normal, compared pressure and running current actually measured with the standard values described on 8.4 "Standard operation data", referring to the following charts.

Fig.8-7 Change of capacity

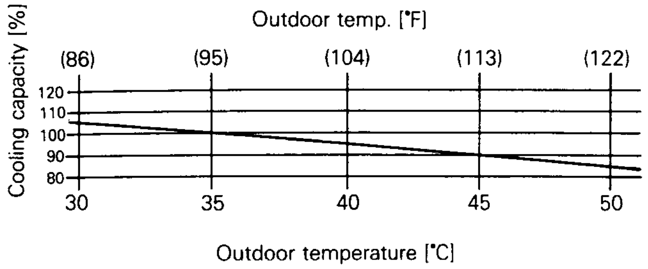
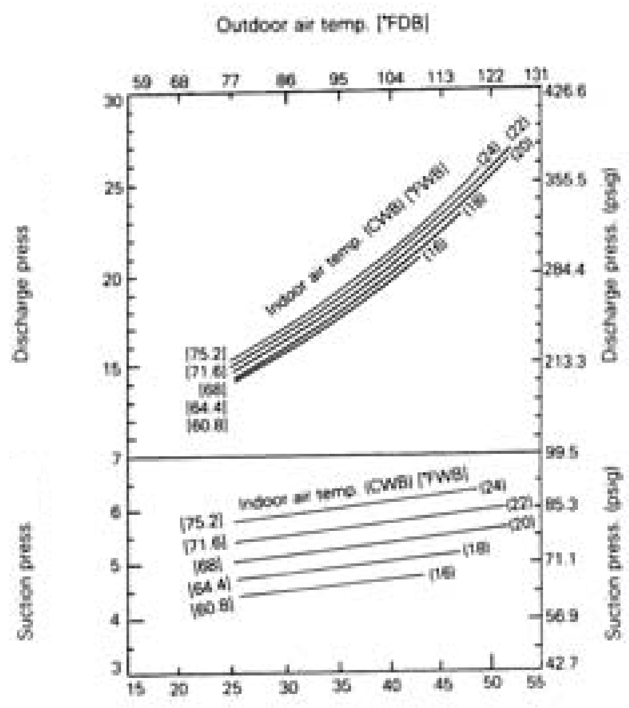
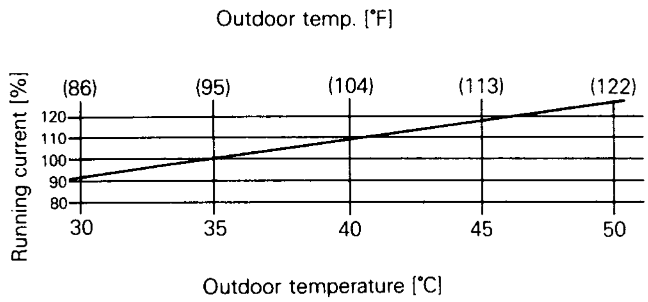


Fig.8-8 Change of pressure



Since pressure and running current differ greatly with outdoor and indoor temperatures, do not judge the refrigerant amount by pressure or running current when it is charged or charged additionally, but charge the predesigned amount correctly by use of a charging cylinder.

Fig.8-9 Change of running current



8.6 Data measurements in the field

- When trial running, check at least the following items.
- When the temperature or the pressure at each part is measured, it must be carried out after continual operation of 20 to 30 minutes.
- When an air conditioner is operated under a certain condition (surrounding temperature, for instance), it means that the air conditioner is operated under the refrigerant pressure and the electric current corresponding to it (surrounding temperature).

1. Measurement of temperatures and pressures of outdoor unit

■ Measurement of the temperature of outdoor unit

Dry bulb temperature ˚C (DB)
Wet bulb temperature ˚C (WB)

■ Measurement of running current (A)

■ Measurement of running pressure

Care should be paid that as shown in Fig. 8-10, there are two types of machines of which both high pressure and low pressure can be taken out from the stop valve and that of only low pressure can be taken out from the check joint.
High-side pressure MPa (kgf/cm^{2}G)
Low-side pressure MPa (kgf/cm^{2}G)

For instance , when the case of operating under the surrounding temperature 35˚C is compared with the case of surrounding temperature 30˚C, the former operating pressure is higher and the electric current much more flows.
Like this, it is important to know how the operation characteristics of the air conditioner change according to the change of surrounding temperature (dry bulb and wet bulb temperature).
Therefore, it is necessary to measure the temperature or the pressure of the each part.

Fig.8-10

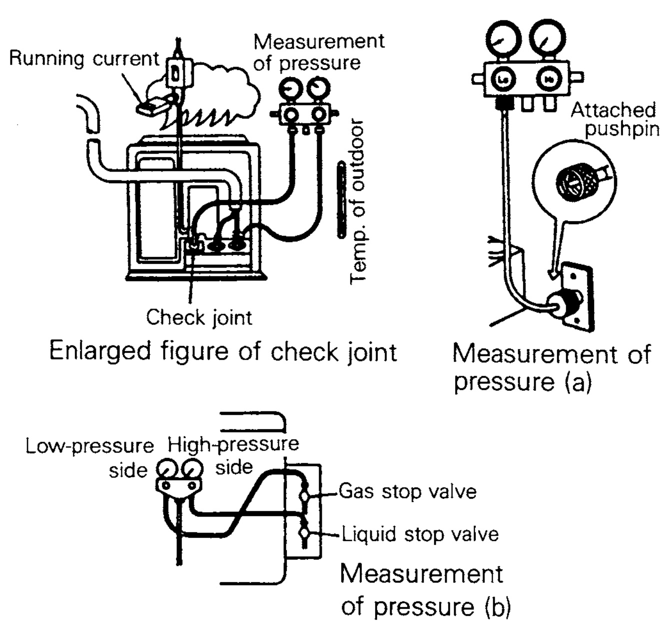
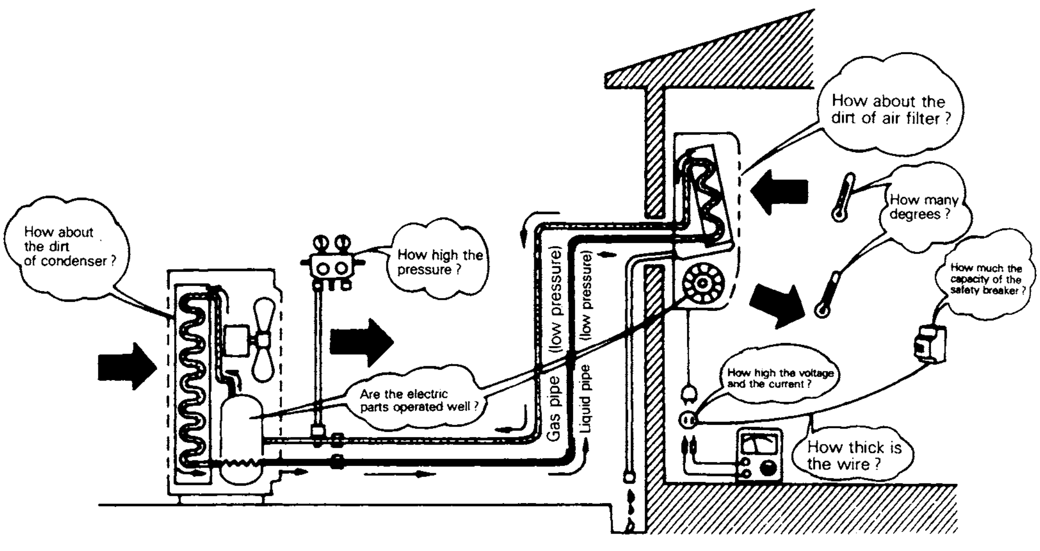


Fig.8-11



2. Measurement of temperatures at the air outlet and inlet

Temperature at the air inlet is measured at the central part of the inlet, likewise the temperature at the air outlet is measured at the central part of the outlet by inserting a thermometer.
Temperature difference between them is used as a guide.
More, when heat load calculating, this is used as a standard of finding enthalpy.

■ Indoor inlet-temperature (DB)

Measure the dry-bulb temperature of the air sucking in the air conditioner.
(Dry-bulb thermometer)

■ Indoor inlet-temperature (WB)

Measure the wet-bulb temperature of the air sucking in the air conditioner.
(Wet-bulb thermometer)

[Comment on a term]
Check joint······With the types of machines, there are some types having no outlet (service valve) on the low pressure side. Therefore, as shown in the figures, the check joint is used for the outlet for measurement of the low pressure or for the additional charging of refrigerant.

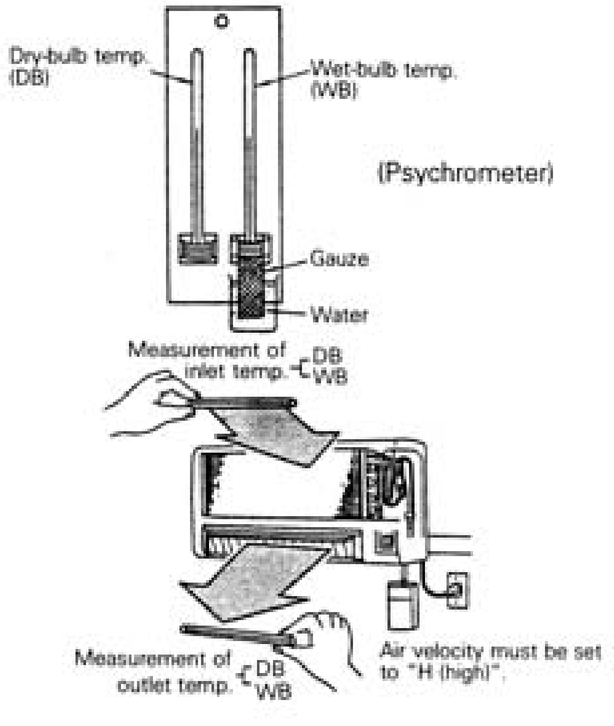
■ **Indoor outlet-temperature (DB)**

Measure the dry-bulb temperature of the air blowing off out of air conditioner into the room. (Dry-bulb thermometer)

■ **Indoor outlet-temperature (WB)**

Measure the wet-bulb temperature of the air blowing off out of air conditioner into the room. (Wet-bulb thermometer)

Fig.8-12



Temp. measurement of indoor unit

3. Measurement of temperatures of refrigerant circuit (Refrigerating cycle)

■ **Temperature measurement of refrigerant in suction pipe**

Refrigerant temperature in the suction pipe is measured.

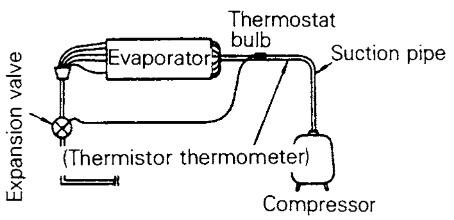
(a) How to find super heat

Super heat=T_1-T_2 (Temp. of compressor suction pipe- Saturated temp. corresponding to low pressure)

(b) For what is the super heat necessary?

By ensuring the super heat (5˚C to 10˚C as usual), we can prevent the liquid compression operation.

Fig.8-13



Temperature measurement of suction pipe

(Note) Measuring part must be insulated by using putty, and taken a lot of time till the reading becomes stable.

■ **Temperature measurement of refrigerant at inlet of expansion valve**

As shown in Fig. 8-14, the refrigerant temperature at the inlet of expansion valve is measured.

(a) How to find subcooling

Subcooling=T_1–T_2(Saturated temp. corresponding to high pressure – Temp. at inlet of expansion valve)

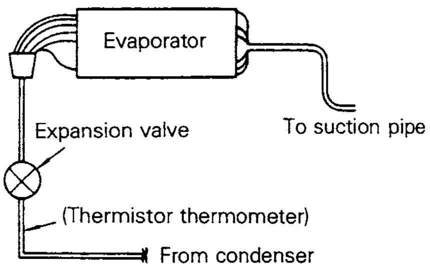
(b) For what is the subcooling necessary?

It is necessary to prevent the generation of flush gas on this side of expansion valve, and to enlarge the cooling capacity. (Normally about 5˚C)

[Comment on a term]

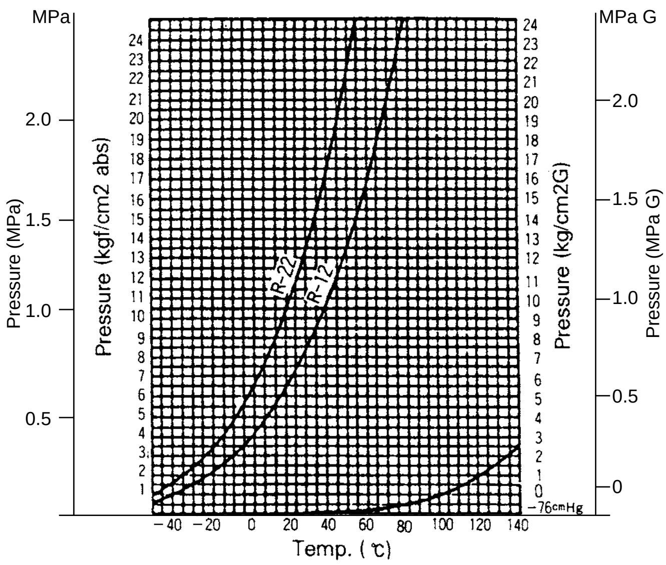
Flush gas······Some of the liquefied refrigerant is gasified to become to the liquid and gas mixture.

Fig.8-14



Temp. measurement at inlet of expansion valve

Fig.8-15



Saturation curve of refrigerant

4. How to calculate capacity

Under the temperatures measurement of the air at the inlet and the outlet of the indoor unit mentioned above, the capacity is calculated by the use of psychrometric chart.
For reference, the example will be shown as follows.

■ How to calculate the capacity of air conditioner

Cooling capacity (kcal/h)
= {(Enthalpy of inlet air) (kcal/kg)}
– (Enthalpy of outlet air) (kcal/kg)
× 1/Specific volume of outlet air (kg/m³)
× Air volume (m³/h)

Example for cooling
Conditions Inlet air: BD temp. 30˚C WB temp. 24˚C
Outlet air: BD temp. 20˚C WB temp. 18.5˚C
Air volume:800m³/h

From psychrometric chart,
Enthalpy of inlet air: 73kJ/kg (17.2kcal/kg)
Enthalpy of outlet air: 53kJ/kg (12.5kcal/kg)
Specific volume of outlet air: 0.85m³/kg,
are found. When these are substituted for the formula mentioned above,

Cooling capacity in kcal = (17.2 - 12.5) × 1/0.85 × 800
≒ 4423(kcal/h)
Cooling capacity in kJ = (73 - 53) × 1/0.85 × 800
≒ 18.823(kJ/h)

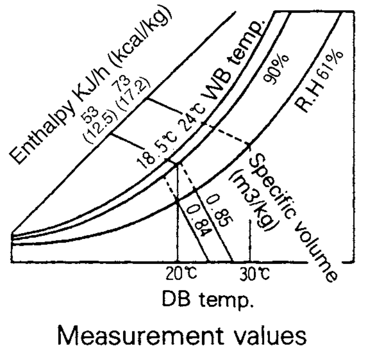
Heating capacity KJ / h (kcak/h)
= 1.005 kJ/kg·k(0.24 kcal/kg˚C)× (Temp. of outlet air (˚C)
– Temp. of inlet air (˚C) × Air volume (m³/h)
× 1/Specific volume (kg/m³)

Conditions Inlet air temp.: 15˚C
Outlet air temp.: 45˚C
Air volume: 800m³/h
Specific volume:0.91m³/kg

When these are substituted for the formula,

Heating capacity = 1.005(0.24) × (45 - 15) × 800 × 1/0.91
≒ 26,506 kJ/h (6330kcal/h)

Fig.8-16



Chapter 9 Troubleshooting

Chapter 9 Troubleshooting

9.1 Troubleshooting decision aid

Although the air conditioner is installed correctly, troubles may likely occur. It is impossible to discuss all possible troubles with the air conditioner, so the most common troubles only are discussed in this chart.
Troubles may often occur due to not only a single cause of trouble, but also combined causes. In such cases, solve all these combined troubles one by one. The common troubles and troubleshooting are tabulated in Table 9-1.

Table 9-1 Troubleshooting decision aid

		Possible causes of troubles	Unit will not start	Compressor will not start — Fans run	Compressor and condenser (outdoor) fan will not start	Evaporator (indoor) fan will not start	Condenser (outdoor) fan will not start	Unit runs, but shortly stops	*Compressor short-cycles due to overload	High discharge pressure	Low discharge pressure	High suction pressure	Low suction pressure	Unit runs continuously — insufficient cooling	Too cool	Compressor is noisy	Test method/remedy
Electrical circuit	①	Power failure	☆														Test voltage
	②	Blown fuse or varistor	☆														Inspect fuse type & size
	③	Loose connections	☆														Inspect connections —tighten
	④	Shorted or broken wires	☆	☆	☆	☆	☆										Test circuits with tester
	⑤	Safety device opens	☆														Test continuity of safety device
	⑥	Faulty thermostat		☆	☆		☆								☆		Test continuity of thermostat & wiring
	⑦	Faulty transformer	☆														Check control circuit with tester
	⑧	Shorted or open capacitor		☆		☆	☆										Check capacitor with tester
	⑨	Faulty magnetic contactor for compressor		☆	☆			☆	☆								Test continuity of coil & contacts
	⑩	Faulty magnetic contactor for fan				☆	☆										Test continuity of coil & contacts
	⑪	Low voltage						☆	☆								Test voltage
	⑫	Shorted or grounded compressor		☆													Check resistance with meger tester
	⑬	Shorted or grounded fan motor				☆	☆										Check resistance with meger tester
Refrigerant circuit	⑭	Compressor stuck		☆													
	⑮	Shortage of refrigerant						☆	☆		☆		☆	☆			Leak test
	⑯	Restricted liquid line						☆					☆	☆			Replace restricted part
	⑰	Dirty air filter											☆	☆			Clean or replace
	⑱	Dirty evaporator coil											☆	☆			Clean coil
	⑲	Insufficient air through evaporator coil											☆	☆			Check fan
	⑳	Overcharge of refrigerant						☆	☆	☆		☆				☆	Change charged refrigerant volume
	㉑	Dirty or partially blocked condenser						☆	☆	☆				☆			Clean condenser or remove obstacle
	㉒	Air or noncondensable gas in refrigarant cycle								☆				☆			Purge, evacuate and recharge
	㉓	Short cycling of condensing air								☆				☆			Remove obstruction to air flow
	㉔	High temperature condensing medium								☆							
	㉕	Insufficient condensing medium								☆							Remove obstruction in air or water flow
	㉖	Broken compressor internal parts														☆	Replace compressor
	㉗	Inefficient compressor									☆	☆		☆			Test compressor efficiency
	㉘	Expansion valve obstructed											☆				Replace valve
	㉙	Expansion valve or capillary tube closed completely						☆					☆				Replace valve
	㉚	Leaking power element on expansion valve						☆					☆				Replace valve
	㉛	Poor installation of feeler bulb										☆					Fix feeler bulb
Others	㉜	Heavy load condition										☆		☆			Check heat load
	㉝	Loosen hold down bolts and/or screws														☆	Tighten bolts or screws
	㉞	Shipping plates remain attached														☆	Remove them
	㉟	Contact of piping with other piping or external plate														☆	Rectify piping so as not to contact each other or with external plate

*In the case of R/A

9.2 Diagnoses by use of pressure gauges

The major troubles occured in the refrigeration cycle of small air conditioners are as follows:

(a) The air conditioner runs but shortly stops.
(b) The air conditioner short cycles with insufficient cooling.
(c) The air conditioner runs continuously with insufficient cooling.

Of course, many other troubles may occur in the electrical circuit, but those are described in the service handbook or technical guide of each model series.
In this chapter, therefore, the causes of troubles related with the refrigeration cycle are described in detail.
Three main conditions in the air conditioners that are operating but not cooling satisfactorily are:

(a) High discharge pressure
(b) Low suction pressure
(c) High suction pressure

Some of such trouble can be diagnosed by use of pressure gauges, as stated below.

(1) High discharge pressure
1) Dirty or partially blocked condenser ㉑*
2) Air or other non-condensable gases in refrigeration cycle ㉒*
3) Overcharge of Refrigerant ⑳*
4) Insufficient condensing medium(air or water) ㉕*
5) High temperature condensing medium ㉔*
6) Short cycling of condensing air ㉓*

(2) Low suction pressure
1) Insufficient air or heat load on evaporator coil ⑰* ⑱* ⑲*
2) Resistance against refrigerant flow ⑯*
3) Shortage of refrigerant ⑮*
4) Faulty capillary tube or expansion valve ㉙* ㉚*

(3) High suction pressure
1) Heavy load conditions ㉜*
2) Unit undersized for application
3) Low superheat adjustment
4) Improper expansion valve adjustment
5) Poor installation of feeler bulb ㉛*
6) Inefficient compressor ㉗*

Note:
Number within circle marked with * shows the number of table 9-1" Trouble shooting decision aid".

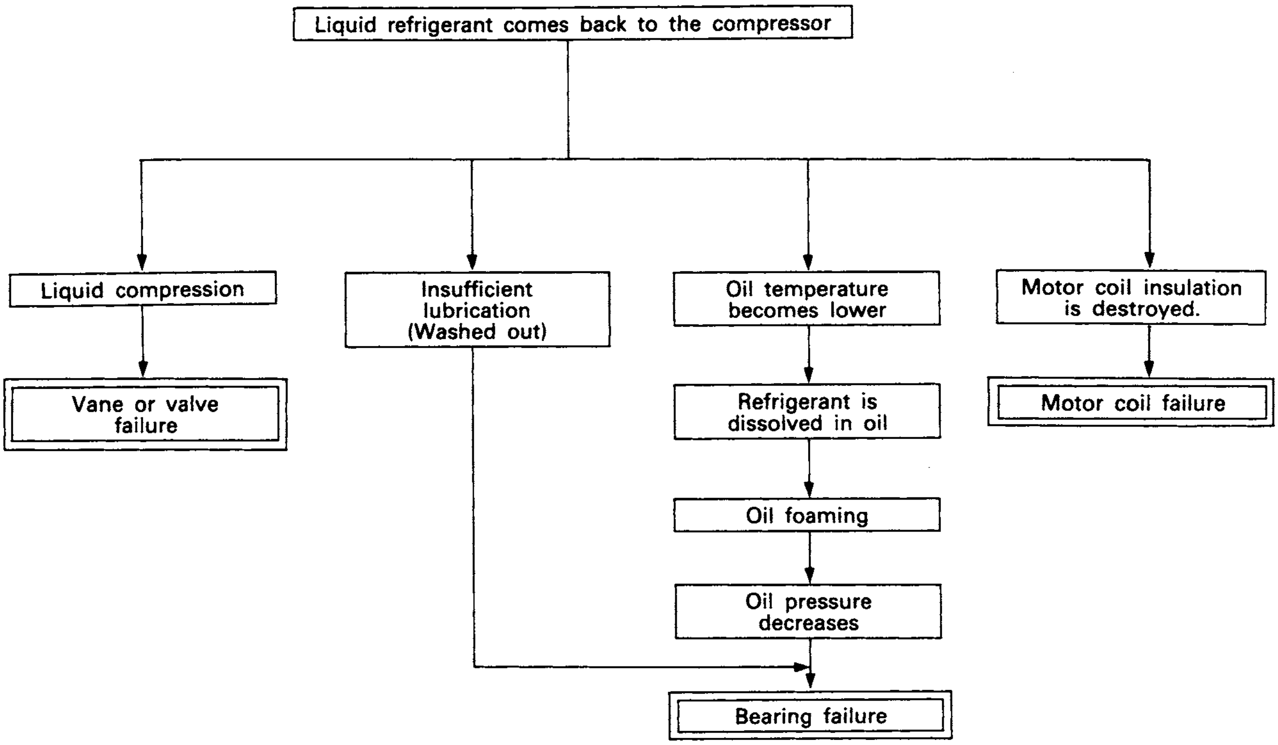
Table 9-2 Diagnoses by use pressure gauge

*1. H.P ... Discharge pressure L.P ... Suction pressure AMP ... Running current

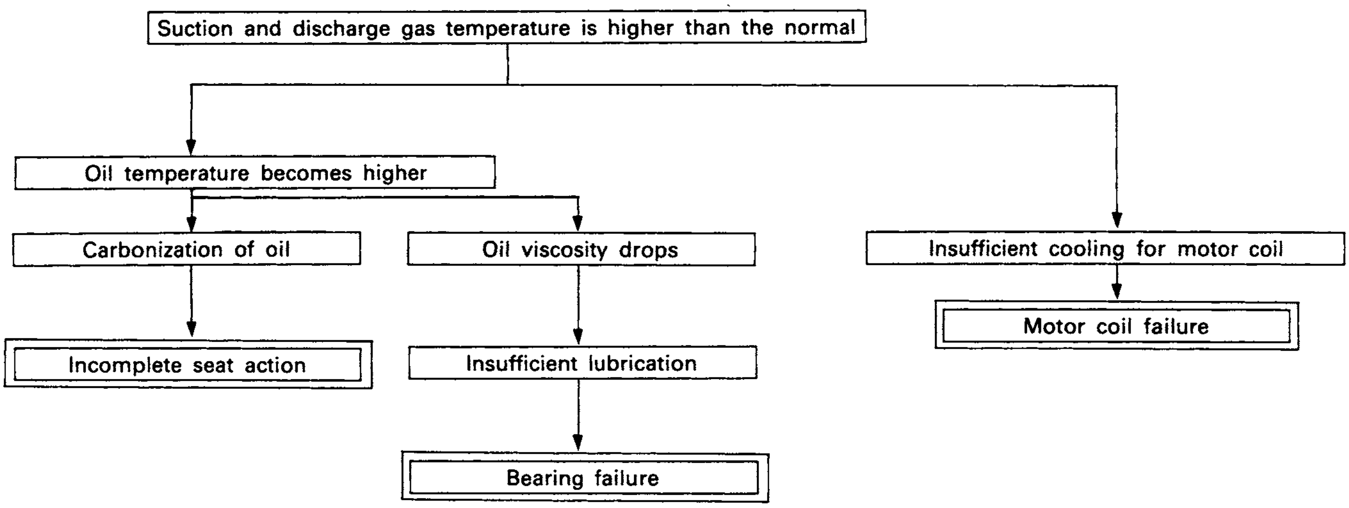
*1		Pressure and running current	Main causes of troubles
H.P L.P AMP	↗ ↗ ↗	• Both high and low pressures are very high • Running current increases extremely	• Refrigerant overcharged ⇨ Wet operation*2 (accompanied with liquid back) * In case refrigerant is overcharged excessively, high pressure switch or overcurrent relay functions.
H.P L.P AMP	↗ ↗ (slight) ↗ (slight)	• Discharge pressure is very high • Suction pressure is a litte higher than normal. • Running current increases	• Insufficient condensing medium Air cooled type: • Dirty condenser • Partially blocked condenser • Malfunction of condenser fan or fan motor • Reverse revolution of condenser fan • Short cycling of condensing air • High temperature condensing air Water cooled type: • Poor condenser water flow rate ⇨ Temp. difference is large • Water pipe obstructed • Air in water pipe • Dirty water pipe ⇨ Temp. difference is small. • Water piping smudged with water scale • High temperature condening water • Malfunction of a cooling tower • Air in water system of condenser • Air or other non-condensable gases in refrigeration system.
H.P L.P AMP	↗ (slight) ↗ ↗ (slight)	• Discharge pressure is a little higher than normal. • Suction pressure is very high • Running current increases	• Unit undersized for application. • Heavy load condition • High suction air temperature. • Excessive air flow rate. (above three) ⇨ Super heated operation*3 • Excessively opened expansion valve ⇨ Wet operation*2 • Poor installation of feeler bulb • Low superheat adjustment
H.P L.P AMP	↘ (slight) ↘ ↘ (slight)	• Discharge pressure is a little lower than normal • Suction pressure is very low. • Running current decreases ☆Frost grows on evaporator coil	• Shortage of refrigerant • Restricted refrigerant flow (above two) ⇨ Super heated operation*3 • Expansion valve or capillary tube obstructed • Dryer or filter clogged with dirt • Valve in liquid line partially closed • Obstruction in liquid line • Leaking power element on expansion valve • Insufficient heating medium ⇨ Wet operation • Poor evaporating air flow rate • Dirty air filter • Slippage of fan belt • Reverse revolution of evaporator fan • Short cycling of cooling air • Light load condition • Low suction air temperature * In case of water cooled type • Excessively low condenser water temp. • Great condenser water flow rate (above two) ⇨ Wet operation*2
H.P L.P AMP	↘ ↗ ↘	• Discharge pressure is a little lower than normal • Suction pressure is very high • Running current decreases	• Malfunction of compressor ⇨ Super heated operation*3
H.P L.P AMP	↘ ↘ ↘	Both high and low pressures are very low Running current decreses extremely	• Extreme refrigerant shortage ⇨ Super heated operation*3

*2, *3 ; Refer to the next page.

*2 Wet operation



*3 Super heated operation

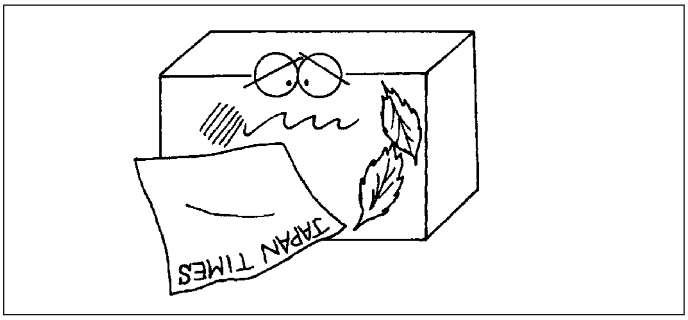


9.3 Explanation of major troubles with the refrigeration cycle

(1) High discharge pressure

1) Dirty or partially blocked condensers ㉑*

Like an automobile engine, which may be overheated if the radiator is clogged with leaves or insects, the air cooled condensing unit is seriously affected by papers, leaves, dust, grease deposited on the condenser fins, because such dirt prevent the condensing unit from performing proper heat transfer.
However, such trouble can be visually found by a service technician.



2) Air or other non-condensable gases in the refrigeration circuit ㉒*

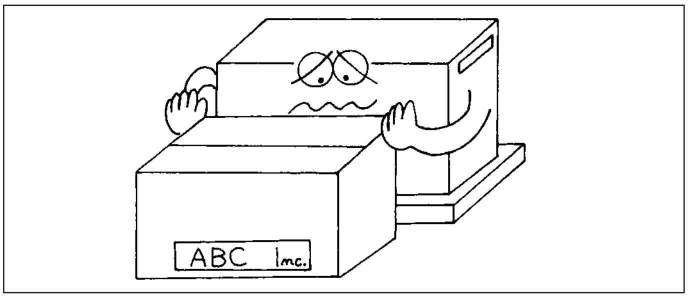
If air or other non-condensable gases are present in the condenser, discharge pressure may rise higher than the pressure which corresponds to the temperature at which the refrigerant vapor is condensed. In extreme cases, discharge pressure rises to the point at which either the high pressure switch or the over-current relay is activated to stop the air conditioner or the compressor.
One of the ways to determine whether non-condensable gas such as air exists in the refrigeration cycle is to cool down the refrigeration cycle to the surrounding air temperature while idling the compressor. Such process can be quickened by means of bypassing the expansion valve and operating the condenser fan alone. After the entire refrigeration cycle has cooled to the surrounding air temperature, if the reading of the discharge pressure gauge is more than about 0.7kgf/cm^2 G (10psi) above the pressure corresponding to the surrounding air temperature, non-condensable gas exists in the refrigeration cycle. So purge it from the refrigeration cycle.

3) Overcharge of refrigerant ⑳*

An overcharge of refrigerant in the refrigeration cycle may cause abnormally high discharge pressure. The liquid refrigerant backs up from the receiver into the condenser, and decreases the area of surface available for condensing purpose. As a result, discharge pressure rises abnormally. In extreme cases, it may rise to the point at which either the over-current relay or the high pressure switch is activated to stop the air conditioner or the compressor.
In such case, extract all refrigerant from the unit to the cylinder and charge right amount of refrigerant.

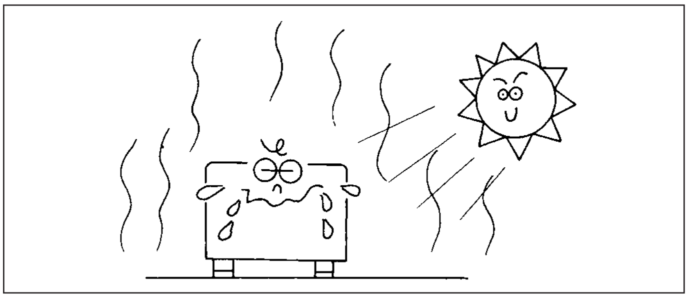
4) Insufficient condensing medium (air or water) ㉕*

As explained in "Dirty and partially blocked condensers", a partially blocked condenser may result in inadequate heat transfer between the refrigerant and the cooling medium (air or water). Although the condenser is not obstructed, there are other reasons to decrease cooling medium (air). For example, if the condenser is located close to the wall, partition, or other obstacle, sufficient air cannot be drawn by the condenser. Insufficient air supply to the condenser is also caused by loosening or slippage of the fan belt, a loose fan wheel on direct-drive equipment, or binding of the shaft of either the motor or fan because of bad shaft bearings or lack of lubrication.



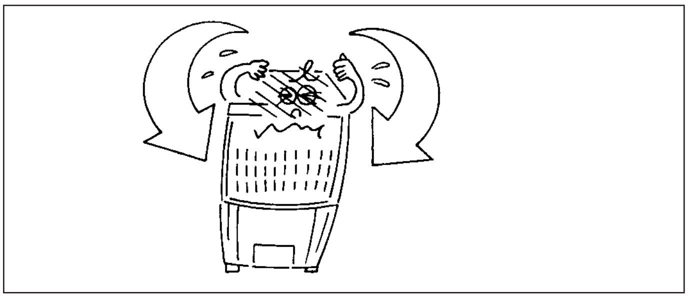
5) High temperature condensing medium ㉔*

If surrounding air temperature around the condensing unit becomes high, discharge pressure of the condensing unit increases accordingly.
It is advisable to protect the condensing (outdoor) unit from the direct sunlight by providing a shade over it. Do not install the condensing(outdoor)unit indoors, because surrounding air temperature around the condensing unit becomes very high due to high discharge air temperature from the condenser.



6) Short-cycling of condensing air ㉓*

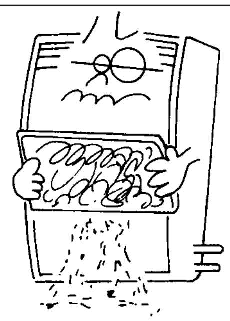
If the condensing (outdoor) unit is located close to the wall or other obstacles, once discharged air from the condenser is drawn by the condenser again. This raises the high pressure of the refrigerant, which activate the high pressure switch to stop the compressor.



(2) Low suction pressure

1) Insufficient air flow across the evaporator coil (Dirty air filter, clogged evaporator coil, etc.) ⑰∗ ⑱∗ ⑲∗

Insufficient air flow across the evaporator coil is the most common cause of abnormally low suction pressure. If air flow rate across the evaporator coil reduces, normal heat transfer between the refrigerant and air reduces accordingly; i.e. when the refrigerant picks up less heat from the air for evaporation, temperature of the refrigerant is lowered in accordance with decrement of suction pressure.
Insufficient air flow through the evaporator may be caused by dirty air filter with dust and dirt, excessively small return ducts, improper speed of the fan, clogged cooling coil or combination of these causes of troubles. So service technicians should check if the air filters are provided in the air distribution system, or they are dirty. If so, clean and replace them.
In addition, if the fan motor and/or fan shaft bearings are not lubricated regularly and are not running freely, air flow rate through the cooling coil may be reduced less than the normal, and improperly adjusted fan belt also reduces fan speed, which in turn reduces air flow rate across the coil.

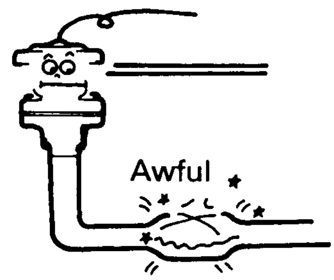


2) Restricted refrigerant flow ⑯∗

In order to vaporize the refrigerant sufficiently through the cooling coil suited for the capacity of the compressor and to remove a proper amount of heat from the air (cooling load), adequate amount of the liquid refrigerant is required for the evaporator. Any resistance against the refrigerant flow means a reduction in capacity of the cooling coil to remove heat from the air (cooling load). Since there is no resistance for the liquid refrigerant flow from the outlet of the condensing unit to the inlet of the cooling coil, where a liquid receiver, dryer, filter, valve and refrigerant control such as expansion valve and capillary tube are installed, such restrictions must be partially smashed tubing, valves in the liquid line which are partially opened, dryer containing full of moisture, or obstructions in the expansion valve or capillary tube. In any case, a resistance to the liquid refrigerant flow may cause lowering of the evaporation pressure of the liquid refrigerant. Such a resistance in the refrigerant passage may be easily found depending on its location as there is obvious temperature drop across the point of a resistance.

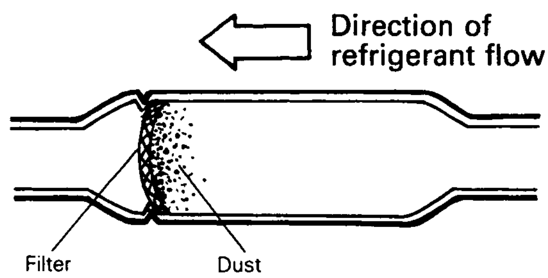
(1) Obstructions in expansion valve ㉘∗
The expansion valve may sometimes stick in a nearly closed position with frozen moisture, dirt or foreign object, and allows to only small amount of refrigerant to pass it. In such a case, the low pressure switch functions if it is provided.
If the low pressure switch is not provided, the outlet of the expansion valve is sweating or frozen, and cooling coil and the suction pipe become warm.

(2) Clogged dryer or filter with dust
The dryer or filter in the liquid line may sometimes be clogged with dust and dirt. If such trouble takes place, leaving refrigerant temperature from the dryer or filter is cooler than entering refrigerant temperature.
If it is badly clogged, its outlet may be sweating or frosted.
The other symptoms remain the same as explained in ①.



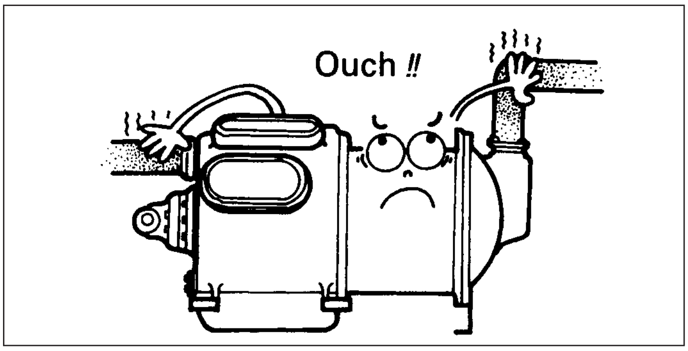
(3) Partially clogged valves in the liquid line
If the valves in the liquid line are not completely opened, liquid temperature in the liquid line after the valves is felt cooler than that in the condenser. The other symptoms remain the same as described in ①, except that sweat or frost appears only if the valves are nearly closed.

(4) Obstructions in the liquid line
If an obstruction exists in the liquid line, the liquid line after the obstruction is felt cooler than that before it. In extreme cases, the piping after the obstruction is sweating or frozen, and the cooling coil and suction line are felt warm.



3) Shortage of refrigerant

A shortage of refrigerant in the refrigeration cycle is normally found by warm suction line with a low suction pressure. In case the refrigerant is excessively short, the refrigerant vapor cannot be condensed sufficiently through the condenser and cannot pick up sufficient heat from the air (cooling load) through the evaporator, as stated previously. If the refrigerant vapor enters the liquid line, hissing sound is given out from the refrigerant controller. In case a liquid indicator or a sight glass is installed in the liquid line, a shortage of refrigerant can be easily found by bubbles in the sight glass.



4) Faulty expansion valve

The expansion valve has mechanical problems; i.e. it sometimes stick in a nearly closed position or a fully closed position with dirt or frozen moisture, reducing the refrigerant flow to the evaporator. If the expansion valve is completely stopped up, low refrigerant pressure drops to the degree at which the low pressure switch is activated to stop the compressor.

If no low pressure switch is equipped, the compressor operates cotinuously. As a result, the compressor motor is no longer cooled by the refrigerant vapor, which rises coil temperature abnormally. Therefore, the thermal protector functions to stop the compressor.

(1) Completely closed expansion valve or capillary tube ㉙*

The expansion valve or the capillary tube may sometimes be completely stopped up with dirt or frozen moisture, which prevents the refrigerant from flowing to the evaporator completely.

(2) Leaking power element of expansion valve ㉚*

The power element of the expansion valve consists of the feeler bulb, connecting tube and bellows or diaphragm which opens or closes the valve. If the power element leaks, the valve may be completely closed or nearly closed.

In order to check the power element for leaking, remove the feeler bulb and warm it by hand. At this time, when the valve is opened, the power element is not defective.

(3) Improperly adjusted expansion valve

If the expansion valve is adjusted to allow only little amount of the refrigerant to pass it, the symptoms stated previously are observed.

(3) High suction pressure

1) Heavy load conditions ㉜*

Load conditions may increase depending on ambient conditions. In this case, however, discharge pressure and suction pressure increase, but there is no trouble with the air conditioner.

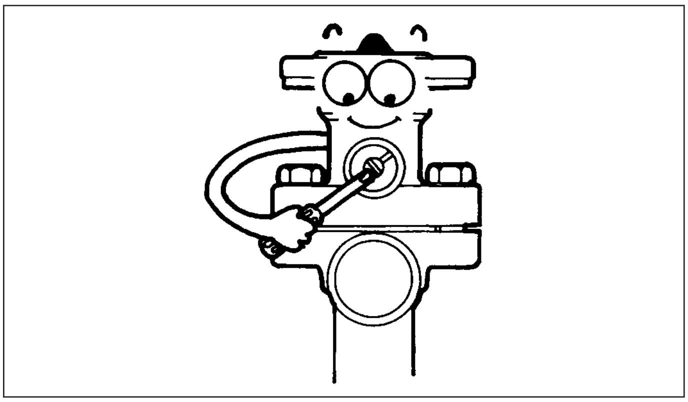
2) Low superheat adjustment

Operation with extreme low superheat setting may cause abnormally high suction pressure. If the liquid refrigerant overflows and enters the compressor, the compressor may be damaged.

In this case, correct superheat setting of the expansion valve. In addition, if the expansion valve is adjusted wrongly or the location of the feeler bulb is wrong, the same trouble as stated previously may occur.

3) Improper expansion valve adjustment

If the expansion valve is adjusted to open fully, it allows large amount of the refrigerant to pass to the evaporator, which may cause excessive amount of dew and frost formation around the suction piping. In case the expansion valve is incorrectly adjusted slightly, no serious symptoms will appear. If the valve is adjusted to allow a little more than the normal amount of the refrigerant to pass to the evaporator, the suction line is sweating a little.



4) Poor installation of feeler bulb ㉛*

If the feeler bulb is not in good contact with the suction pipe, the expansion valve may sometimes open widely. Such poor contact may be caused by lack of insulation around the bulb especially when ambient temperature around it is extremely high. Attach the feeler bulb in closed contact with the suction pipe.

5) Faulty compressor (Broken suction valves in compressor) ㉗*

If high suction pressure exists in the system, although super heat in the cooling coil is normal and all other possible troubles are eliminated, the compressor may be found faulty caused by damaged valves.

9.4 Troubles and countermeasures for air conditioners-cooling

9.4.1 Air conditioner does not start cooling (Mainly caused by trouble with electric devices)

Phenomena of trouble	Trouble points	Causes of troubles	Diagnoses	Countermeasures
A. Both fan and compressor do not operate	• No trouble with air conditioner	• Interruption of electric service • Wrong power source wiring • Power source fuse (in transformer or in source switch) is blown off. • Power source is open phased.	• Measure and inspect electric power with a tester (In case other electric device is used with the same power source, check if it works)	• Repair devices in switchboard. • Replace fuse • Regarding trouble with electric wiring before switchboard, ask a power company for repairing.
		• High pressure switch has functioned and is not reset yet. (In case of manual reset type high press. switch.)	• Press down reset button for high press. switch.	
		• Air conditioner is under pump down and low pressure switch has functioned		• Open stop valves for refrigerant.
		• Oil pressure switch has functioned and is not reset yet.	• Press down reset button for oil pressure switch	
	• Reverse phase protector (only for three phase power source)	• Reverse phase protector has functioned		• Change the two wire connections out of three on the terminal strip or on the secondary side of circuit breaker
	• Electric circuit	• Fuse in the unit is blown off or bad contact. • Varistor on the printed circuit board.	• Inspect circuit visually or with a tester.	• Replace fuse or varistor. • Repair the contact of fuse.
		• Wrong wiring in control circuit	• Inspect control circuit visually or with a tester.	• Correct wiring.
	• Safety devices (High press. switch Low press. switch Oil press. switch Overcurrent relay Compressor thermal protector Freeze-up protection thermostat)	• Contact is cut out due to trouble.	• Short-circuit each contact.	• Repair or replace faulty devices.
	• Magnetic switch or magnetic relay	• Trouble with solenoid coil • Contact is damaged.	• Inspect solenoid coil visually or with a tester.	• Repair or replace it.
	• Rotary switch or button switch	• Contact is damaged.	• Inspect switch with a tester.	• Repair or replace it.
	• Refrigerant	• Low pressure switch has functioned due to shortage of charged refrigerant or gas leakage.	• Inspect refrigeration cycle for leakage with a leak detector.	• Repair leaking places. • Extract remaining refrigerant and then charge pre-designed amount of refrigerant.
B. Fan operates, but compressor does not operate.	• No trouble with air conditioner	• Indoor air temperature is very low, so thermostat is activated.	• Change thermostat setting. • Warm thermistor or feeler bulb of thermostat with fingers.	• Compressor starts when thermistor or feeler bulb is warmed.
	• Magnetic switch for compressor	• Contact is damaged. • Trouble with solenoid coil	• Inspect magnetic switch visually or with a tester.	• Repair or replace it.
	• Compressor	• Short-circuit or grounded compressor	• Check insulation resistance with a meger tester.	• Repair or replace it.
		• Compressor is locked.	• Compressor hums.	• Repair or replace it.
	• Thermostat	• Contact is not cut in due to trouble with thermostat switch.	• Compressor does not start when thermistor or feeler bulb is warmed, but compressor starts when thermostat is short circuited.	• Replace it.
	• Rotary switch or button switch	• Contact is damaged.	• Inspect with a tester.	• Repair or replace it.
	• Electric circuit	• Disconnection, bad contact or single phasing of compressor main circuit.	• Inspect with a tester.	• Repair wiring.
C. In case two compressors are mounted, 2nd compressor is not operative.	• See 9.4.1 A	• See 9.4.1 A		• See 9.4.1 A
	• Timer	• Trouble with a timer	• Short-circuit contact for a timer.	• Repair or replace it.

9.4.2 Air conditioner starts but shortly stops (Both fan and compressor are operative, but shortly stop.)

Phenomena of trouble	Trouble points	Causes of troubles	Diagnoses	Countermeasures
A. High pressure switch will function.	• No trouble with air conditioner	• Condensing medium (air or water) is not circulated. • Condensing medium is insufficient. • Temperature of condensing medium is very high.	• Check if air flow in and out of condenser is interrupted. • Check condenser water valves, pumps and cooling tower.	• Remove objects. • If condenser water valve is closed, open it. • When pump or cooling tower is not operated, operate them.
	• Condenser	• Condenser fins are dirty.	• Inspect condenser visually.	• Clean condenser fins.
		• Condenser water tubes are clogged with scale.	• Temperature difference between condenser leaving water temp and condensing temp. is large.	• Clean cooling tubes.
	• Refrigerant	• Overcharge	• Both discharge and suction pressure are high. • Power consumption increases and compressor is noisy.	• Extract refrigerant and then charge standard volume of refrigerant.
	• Non-condensable gas.	• Air exists in refrigeration cycle.	• Discharge pressure is high. • Pump down refrigerant. Check relationship of outdoor temperature or water temperature with pressure.	• Extract refrigerant and then perform vacuum drying. • Charge standard volume of refrigerant.
	• High pressure switch	• Bad adjustment	• Inspect it with pressure gauge.	• Replace it or readjust it to designed pressure. However, do not change designed pressure as it may cause a serious trouble.
B. Low pressure will function.	• No trouble with air conditioner	• Evaporation medium is not circulated. • Evaporating medium is insufficient.	• Check if air flow in and out of evaporator is interrupted.	• Remove objects.
		• Opening of stop valves in refrigeration cycle is insufficient.	• Inspect them.	• Open them fully.
	• Dryer or filter in liquid line	• Clogging	• Check if there is temperature difference between inlet and outlet of dryer or filter. When clogging, temp. difference is excessive.	• Pump down refrigerant and clean dryer or replace them.
	• Capillary tube	• Clogging		• Replace it.
	• Expansion valve	• Clogging		• Pump down refrigerant and clean it.
		• Gas leaks from feeler bulb.		• Replace expansion valve.
	• Refrigerant	• Shortage of refrigerant		• Extract remaining refrigerant after leak test. • Repair leaking parts if any is founded. • Charge standard volume of refrigerant.
	• Low pressure switch	• Bad adjustment		• Adjust it to pre-designed pressure.
C. Over-current relay will function	• Over-current relay	• Bad adjustment	• Measure current	• Adjust it to pre-designed current.
	• Compressor	• Excessive pressure difference between discharge and suction pressure • Current is excessive (Trouble with compressor internal parts and bearings)	• Measure current	• Trace a cause of trouble and take necessary measures.
	• Fan motor	• Current is excessive. (Trouble with fan motor internal parts and bearings)	• Measure current	• Trace a cause of trouble and take necessary measures.
D. Oil pressure switch will function.	• Oil pressure switch	• Bad adjustment	• Inspect oil press. switch.	• Adjust it to pre-designed pressure.
	• Oil pump	• Dirty oil filter • Oil pump is faulty	• Dismantle oil pump or oil filter for inspection.	• Repair or replace it.
	• Oil Level	• Oil does not come back compressor.	• Oil level drops	• Check field piping for its length and height.

9.4.3 Air conditioner runs continuously or short cycles with insufficient cooling (Fan and compressor are operative.)

Phenomena of trouble	Trouble points	Causes of troubles	Diagnoses	Countermeasures
A. Condensing and evaporating medium are sufficient.	• No trouble with air conditioner	• Cooling load increases extremely.	• Check if numbers of occupants increase or opening of window or door is excessive.	• Take necessary measures for each case.
		• Air distribution direction is wrong or location of duct is wrong.	• Check it.	• Correct it if necessary.
		• Distributed air is interrupted by obstacles and cannot be distributed evenly throughout the room.	• Check it.	• Correct it if necessary.
	• Compressor	• Compressor failure	• Check it with pressure gauges and clamp meter.	• Replace or repair it.
	• Dryer or filter	• Clogging (to such a degree as low pressure switch does not function)	• Check the temperature difference between inlet and outlet of dryer or filter.	• Clean or replace it.
	• Expansion valve	• Bad adjustment	• Check it with pressure gauges and surface thermometer.	• Readjust it. (However, do not change its setting more than necessary.)
		• Gas leak from feeler bulb.	• Evaporator inlet pipe is frosted.	• Replace it.
		• Contact between feeler bulb and suction pipe is poor. • Feeler bulb is not insulated.	• Check it with pressure gauge and surface thermometer. • Noise is given out from compressor due to liquid hammer.	• Rectify it.
	• Refrigerant	• Shortage (to such a degree as low pressure switch does not function)	• Evaporator inlet pipe is frosted.	• Extract remaining refrigerant after leak test. • Repair leaking parts if any is founded. • Charge standard volume of refrigerant volume.
B. Condensing and evaporating media are insufficient.	• No trouble with air conditioner	• Opening of air discharge grille is insufficient.	• Check visually.	• Rectify it.
	• Air passage	• Defect of air duct or foreign object.	• Check it.	• Rectify it or remove foreign object.
	• Fan	• Evaporator and/or condenser fan rotates reversely.	• Check it visually.	• Change the two wire connections out of three.
		• Fan belt slips due to its loosening.	• Check it.	• Adjust its tension.
	• Air filter	• Clogging	• Check it visually.	• Clean it.

9.4.4 Noise, abnormal sound and vibration

Phenomena of trouble	Trouble points	Causes of troubles	Diagnoses	Countermeasures
A. Cooling efficiency is good, but nasty noise and vibration take place.	• Fan	• Damaged bearing • Damaged fan rotor		• Repair or replace faulty parts.
		• Foreign object in fan housing	• Check it visually.	• Remove foreign object.
		• Loosening of fan rotor		• Tighten it.
	• Fan belt	• Vibration occurs or fan belt comes in contact with other thins due to wrong tension of fan belt.	• Check it by fingers.	• Adjust its tension.
	• Fan pulley • Fan motor pulley	• Fan pulley or fan motor pulley is wrongly installed and/or inclined. • Fan pulley is not in parallel with fan motor pulley.	• Check them.	• Rectify it.
	• Compressor	• Liquid hammer takes place due to liquid back.	• Check it with ear.	• Charge standard volume of refrigerant.
		• Excessively charged oil	• Check it with ear.	• Extract surplus oil.
	• Magnetic switch	• Chattering takes place due to poor contact of each part, loosened screw, bad contact and/or rust, dust or foreign object in contacting part of steel core.		• Cleaning or replace it.
	• Piping	• Piping comes in contact with casing or other devices.		• Repair it.
	• Screws	• Screws such as those on external plate are loosened or fallen off.		• Tighten them if any.
	• No trouble with air conditioner	• Bad installation		• Repair.
		• Shipping plates remain attached.		• Remove them.

9.4.5 others

A. Water leaks	• Drain piping	• Bad internal drain piping • Clogging of internal drain piping • Damaged internal piping • Insufficiently inclined drain piping.		• Repair or clean it.
	• Condenser water piping	• Pipe connections are loosened or damaged.	• Check them visually.	• Additionally tighten them.
	• Water cooled condenser	• Water jackets for inlet and outlet are loosened.		• Additionally tighten them.
		• Damaged packings		• Replace damaged packings.

9.5 Maintenance inspections in SkyAir series

9.5.1 Optimal operation condition

Guide lines for optimal operation condition

The operation value guide lines when operating under standard conditions by pushing the test run button on the remote controller are as given in the table below. RY71~160LU are used as example outdoor units in the table.

Table 9-3
Indoor unit fan: "H" operation

	Cooling		Heating	
	50Hz	60Hz	50Hz	60Hz
High Pressure MPa (kg/cm^2)	1.62~1.91 (16.5~19.5)	1.72~2.1 (17.5~20.5)	1.42~1.86 (14.5~19.0)	1.62~2.01 (16.5~20.5)
Low Pressure MPa (kg/cm^2)	0.39~0.59 (4.0~6.0)	0.34~0.54 (3.5~5.5)	0.29~0.44 (3.0~4.5)	0.29~0.44 (3.0~4.5)
Discharge Pipe Temperature (˚C)	60~95	70~115	55~95	60~115
Suction Temperature (˚C)	0~14	-2~10	-4~4	-6~2
Indoor Unit Side: Differential Between Suction Temperature and Discharge Temperature (˚C)	8~18		14~30	
Outdoor Unit Side: Differential Between Suction Temperature and Discharge Temperature (˚C)	7~12		2~6	

Note: Figures given inside parentheses are in unit of kg/cm∑

Standard conditions

	Indoor Unit Conditions	Outdoor Unit Conditions
Cooling Operation	27˚C DB/19˚C WB	35˚C DB
Heating Operation	20˚C DB	7˚C DB/6˚C WB

■ During or after maintenance, when the power supply is turned back on, operation restarts automatically by the "auto restart function." Please exercise the proper caution.

Fig.9-1

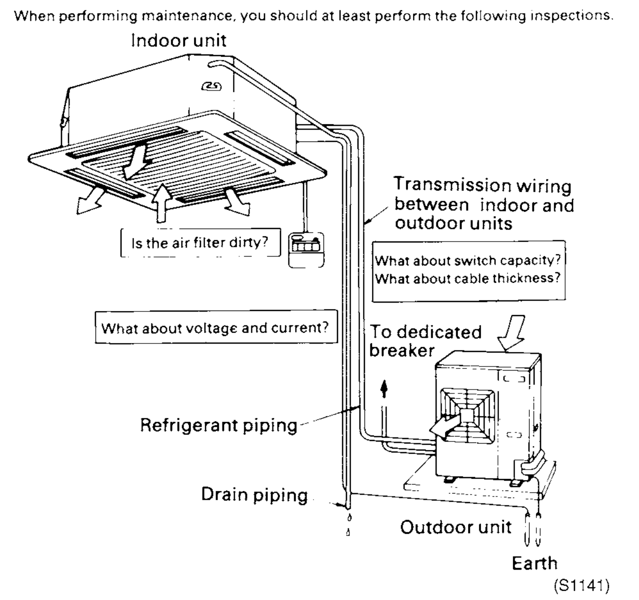
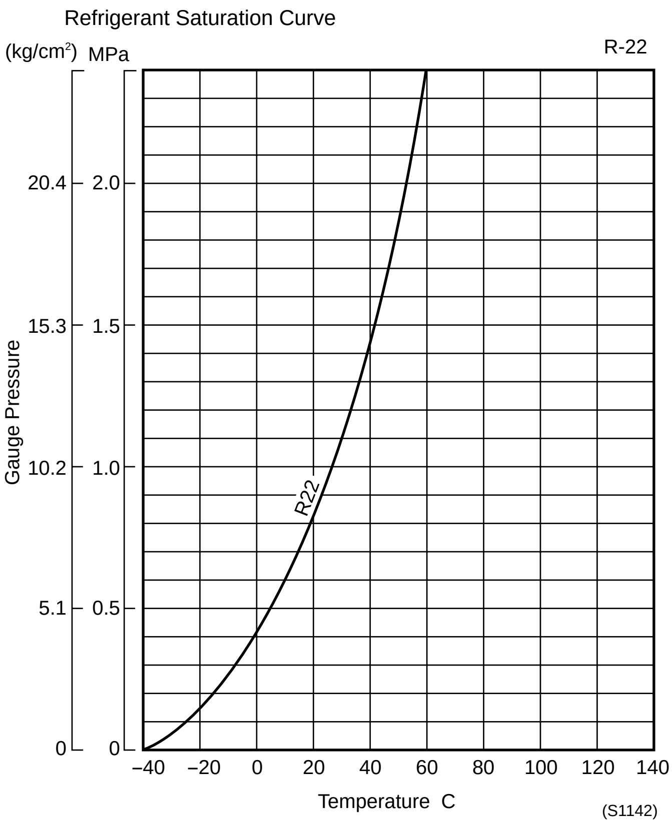


Fig.9-2



Correlation of air-conditioner's operation status and pressure / running current

What happens in comparison to normal values is summarized in the table below.
(Measured from 15 ~ 20 minutes or more after operation starts.)

Table 9-4
When cooling

Air-Conditioner Status	Low Pressure	High Pressure	Running Current
Air Filter Fouling	Lower	Lower	Lower
Short Circuit of Indoor Unit Inlet/Outlet Air	Lower	Lower	Lower
Outdoor Unit Fin Fouling	Higher	Higher	Higher
Short Circuit of Outdoor Unit Inlet/ Outlet Air	Higher	Higher	Higher
Air Mixed in Refrigerant	Higher	Higher	Higher
Water Mixed in Refrigerant	*1 Lower	Lower	Lower
Dirt Mixed in Refrigerant	*2 Lower	Lower	Lower
Lack of Refrigerant (Gas)	Lower	Lower	Lower
Unsatisfactory Compression	*3 Higher	Lower	Lower

When heating

Air-Conditioner Status	Low Pressure	High Pressure	Running Current
Air Filter Fouling	Higher	Higher	Higher
Short Circuit of Indoor Unit Inlet/Outlet Air	Higher	Higher	Higher
Outdoor Unit Fin Fouling	Lower	Lower	Lower
Short Circuit of Outdoor Unit Inlet/ Outlet Air	Lower	Lower	Lower
Air Mixed in Refrigerant	Higher	Higher	Higher
Water Mixed in Refrigerant	*1 Lower	Lower	Lower
Dirt Mixed in Refrigerant	*2 Lower	Lower	Lower
Lack of Refrigerant (Gas)	Lower	Lower	Lower
Unsatisfactory Compression	*3 Higher	Lower	Lower

Note:
1. *1. Water in the refrigerant freezes inside the capillary tube or expansion valve, and is basically the same phenomenon as pump down.
2. *2. Dirt in the refrigerant clogs filters inside the piping, and is basically the same phenomenon as pump down.
3. *3.Pressure differential between high and low pressure becomes slight.

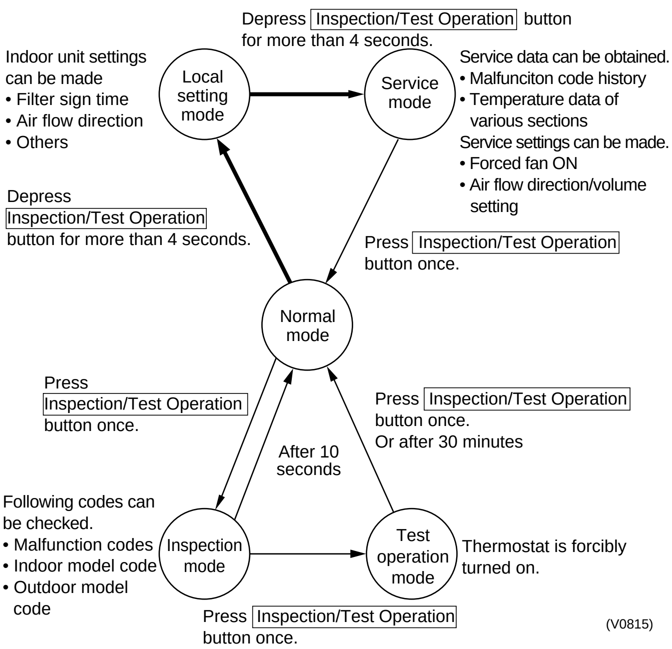
9.6 Procedure of self-diagnosis by remote controller

9.6.1 The INSPECTION/TEST button

Explanation

By turning the remote controller's inspection /test button ON, you can change the mode as shown in the figure below.

Fig.9-3



- When in the inspection mode, malfunction contents can be cleared by continuing to press the ON/OFF button for 5 seconds.
  (Let you know completion timing by blinking.)
- To carry out a test run, follow the procedure below.

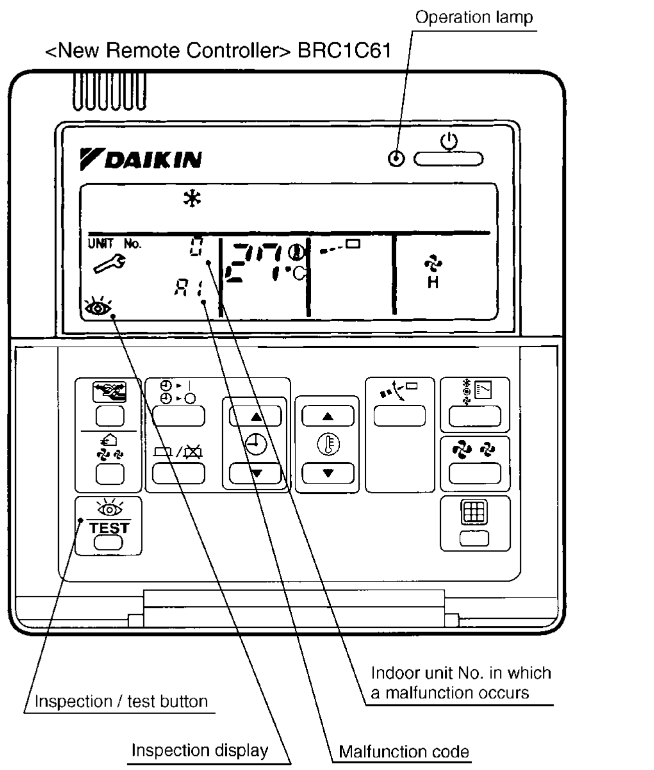
1. Open the gas side stop valve all the way.
2. Open the liquid side stop valve all the way.
3. Energize the crank case heater for 6 hours.
4. Enter the test run mode.
5. Continue to operate by the operation switch for 3 minutes.
6. Enter the normal mode.
7. Check the functions according to the operation manual.

9.6.2 Self-Diagnosis by wired remote controller

Explanation

If operation stops due to malfunction, the remote controller's operation LED blinks, and malfunction code is displayed. (Even if stop operation is carried out, malfunction contents are displayed when the inspection mode is entered.) The malfunction code enables you to tell what kind of malfunction caused operation to stop. See page 268 for malfunction code and malfunction contents.

Fig.9-4



(S1155)

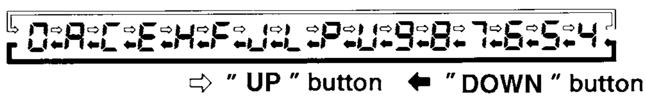
9.6.3 Diagnosis for faults by wireless remote controller

If equipment stops due to a malfunction, the operation indicating LED on the light reception section flashes.
The malfunction code can be determined by following the procedure described below. (The malfunction code is displayed when an operation error has occurred. In normal condition, the malfunction code of the last problem is displayed.)

Procedure

1. Press the INSPECTION/TEST button to select "Inspection."
   The equipment enters the inspection mode. The "Unit" indication lights and the Unit No. display shows flashing "0" indication.
2. Set the Unit No.
   Press the UP or DOWN button and change the Unit No. display until the buzzer (*1) is generated from the indoor unit.
   ∗1 Number of beeps
   3 short beeps : Conduct all of the following operations.
   1 short beep : Conduct steps 3 and 4.
   Continue the operation in step 4 until a buzzer remains ON. The continuous buzzer indicates that the malfunction code is confirmed.
   Continuous beep : No abnormality.
3. Press the MODE selector button.
   The left "0" (upper digit) indication of the malfunction code flashes.
4. Malfunction code upper digit diagnosis
   Press the UP or DOWN button and change the malfunction code upper digit until the malfunction code matching buzzer (*2) is generated.

■ The upper digit of the code changes as shown below when the UP and DOWN buttons are pressed.

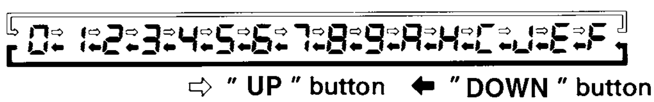


(S1156)

∗2 Number of beeps
Continuous beep : Both upper and lower digits matched.(Malfunction code confirmed)
2 short beeps: Upper digit matched.
1 short beep : Lower digit matched.

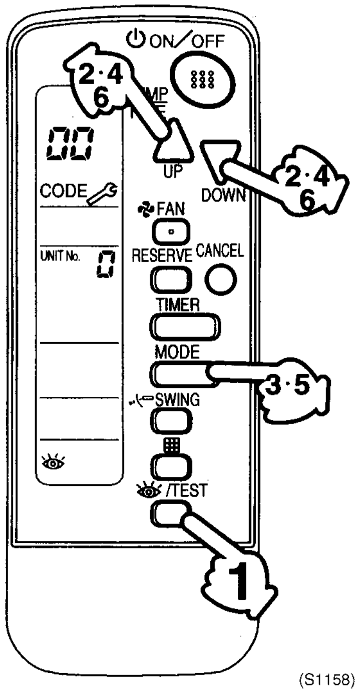
5. Press the MODE selector button.
   The right "0" (lower digit) indication of the malfunction code flashes.
6. Malfunction code lower digit diagnosis
   Press the UP or DOWN button and change the malfunction code lower digit until the continuous malfunction code matching buzzer (*2) is generated.

■ The lower digit of the code changes as shown below when the UP and DOWN buttons are pressed.



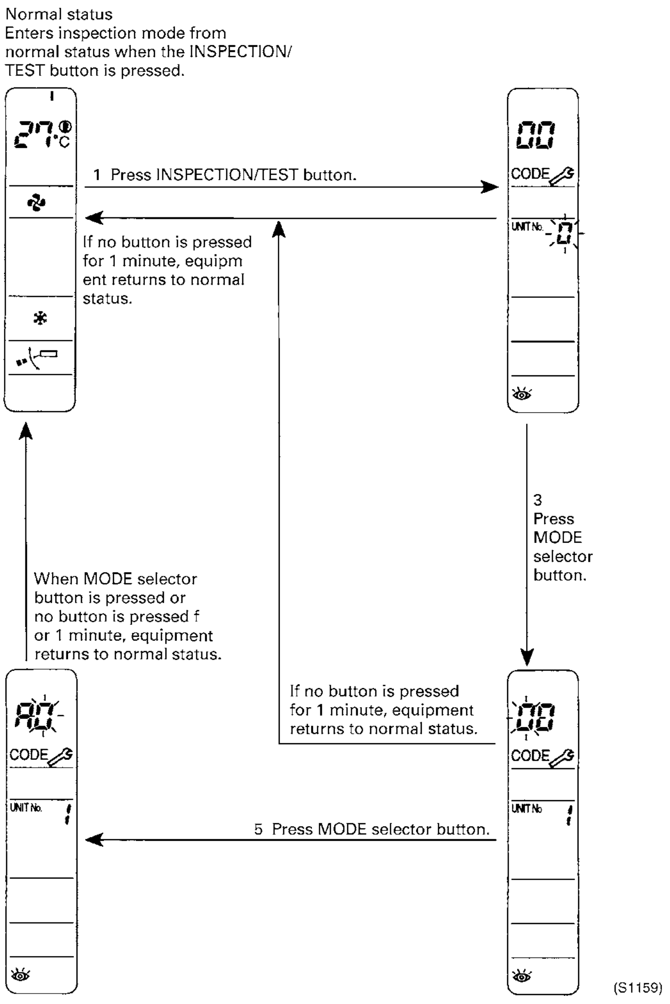
(S1157)

Fig.9-5



ON/OFF
2·4
6
UP
DOWN
2·4
6
CODE
UNIT No.
FAN
RESERVE
CANCEL
TIMER
MODE
3·5
SWING
/TEST
1
(S1158)

Fig.9-6



Normal status
Enters inspection mode from normal status when the INSPECTION/ TEST button is pressed.
1 Press INSPECTION/TEST button.
If no button is pressed for 1 minute, equipm ent returns to normal status.
CODE
UNIT No.
3 Press MODE selector button.
When MODE selector button is pressed or no button is pressed f or 1 minute, equipment returns to normal status.
If no button is pressed for 1 minute, equipment returns to normal status.
5 Press MODE selector button.
(S1159)

9.6.4 Remote controller display malfunction code and contents

Table 9-5

Malfunction Code	Contents/Processing	Remarks
A1	Failure of PC board ass'y for indoor unit	
A3	Malfunction of water level system	
A6	Indoor unit fan motor overload / overcurrent / lock	
A7	Swing flap motor lock	Only Air flow direction adjustment cannot be set.
AF	Malfunction of water level system	Float switch is OFF during indoor unit stops.
AJ	Failure of capacity setting	Either capacity data is set incorrectly, or capacity has not been set for the data IC
C4	Malfunction of heat exchanger temperature sensor system	
C9	Malfunction of suction air temperature sensor system	
CJ	Malfunction of remote control temperature sensor system	The remote controller thermistor does not function, but the system thermostat operation is possible.
E0	Actuation of safety device (outdoor unit)	
E1	Outdoor P.C. board malfunction	
E3	High pressure malfunction (outdoor unit)	
E4	Low pressure malfunction (outdoor unit)	
E6	Compressor overcurrent	
E9	Malfunction of electronic expansion valve (outdoor unit)	
F3	Discharge pipe temperature malfunction (outdoor unit)	
F6	Heat exchanger temperature abnormal	
H3	Failure of high pressure switch (outdoor unit)	
H9	Malfunction of outdoor air temperature sensor system (outdoor unit)	(Note 1)
J2	Malfunction of current sensor system	
J3	Malfunction of discharge pipe temperature sensor system (outdoor unit)	
J6	Malfunction of heat exchanger temperature sensor system (outdoor unit)	(Note 1)
PJ	Failure of capacity setting (outdoor unit)	Either capacity data is set incorrectly, or capacity has not been set for the data IC
U0	Malfunction of suction pipe temperature	
U1	Reverse phase	Switch R.S.T. of the 3-phase power supply.
U4 or UF	Failure of transmission (between indoor and outdoor unit)	Wrong wiring between indoor and outdoor units or malfunction of the PC board mounted on the indoor and the outdoor units. If UF is shown, the wiring between the indoor and outdoor units is not properly wired. Therefore, immediately disconnect the power supply and correct the wiring. (The compressor and the fan mounted on the outdoor unit may start operation independent of the remote controller operation.)
U5	Failure of transmission (between indoor unit and remote controller)	Transmission between indoor and remote controller is not being correctly carried out.
U8	Failure of transmission (between "main" and "sub" remote controller	Transmission between "main" and "sub" remote controller is not being correctly carried out.
UA	Failure of field setting	System setting mistake for Twin system.
UC	Address duplication of central remote controller	

■ In the case of the shaded error codes, "inspection" is not displayed. The system operates, but be sure to inspect and repair it.

Note 1: Operation when a malfunction occurs may differ according to the model.

9.7 Procedure of self-diagnosis by LED

9.7.1 Troubleshooting by LED on the indoor unit’s

Table 9-6

Troubleshooting can be carried out by service monitor LED (green). (Blinks when normal)

☼ : LED on

● : LED off

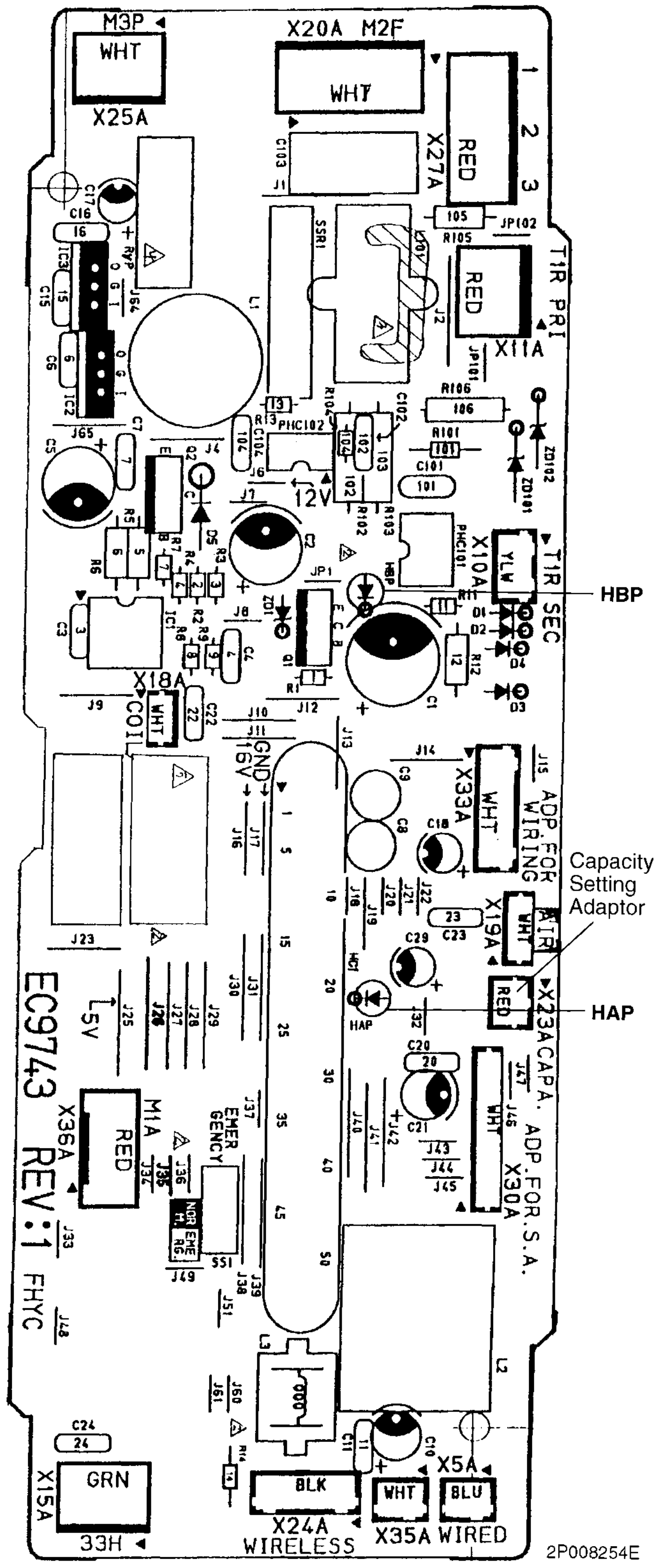
◐ : LED blinks — : No connection with troubleshooting

Microcomputer Normal Monitor	Transmission Normal Monitor	Details
HAP (H1P)	HBP (H2P)	
◐	◐	Indoor unit is normal → Diagnose the outdoor unit
◐	☼	Malfunction of indoor unit PC board assembly or faulty wiring between indoor and outdoor unit
	●	If the outdoor unit LED-A does not light, diagnose the outdoor unit. If it flashes, it is due to either faulty wiring or malfunction of the indoor unit PC board assembly. (Note 1)
☼	—	Malfunction of the indoor unit PC board (Note 2)
●		Abnormal power supply, malfunction of PC board assembly or disconnection between the indoor and outdoor units (Note 2)

Note: 1. If LED-B is off, the transmission wiring between indoor and outdoor unit may be incorrect or disconnected. Before performing the previously described troubleshooting, check the transmission wiring.

2. Troubleshoot by turning off the power supply for a minimum of 5 seconds, turning it back on, and then rechecking the LED display.

Fig.9-7 FHYC35~FHYC160KVE



9.7.2 Troubleshooting by LED on the outdoor unit's PC board

With the power on, following trouble shooting is possible with the LEDs for service monitor of the outdoor unit.

☼ : LED on

● : LED off

◐ : LED flashing — : Not related with the trouble shooting

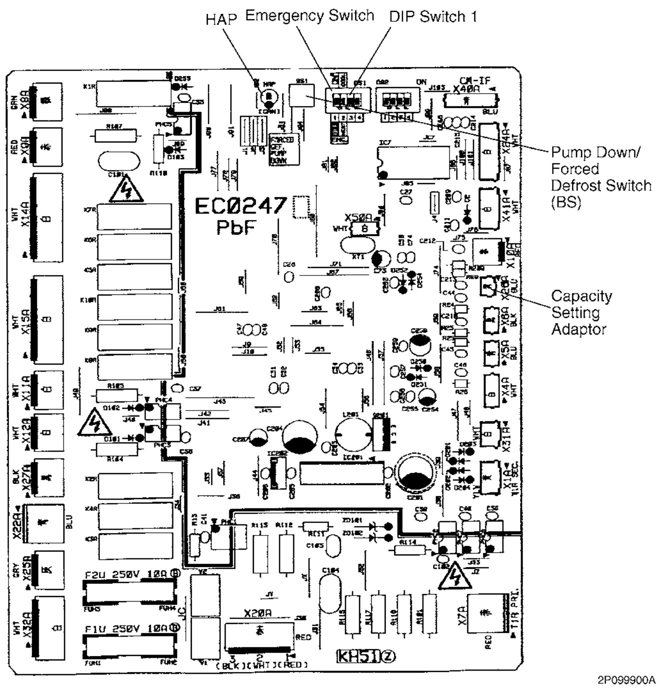
Microcomputer monitor HAP (green)	Flashing pattern	Descriptions
◐	☼0.4s⟵⟶●0.4s	Outdoor unit normal (Also check the indoor unit HAP.)
◐	☼0.4s⟵⟶●0.8s	Outdoor unit trouble
☼	—	Outdoor A1P (PCB) defective (Note 1)
●	—	Trouble in power, or outdoor A1P (PCB) defective (Notes 1 and 2)

Note:
1. Cut off the power, turn it on again in five seconds or more, see if the HAP light up, and check for the trouble.
2. If the outdoor unit's HAP starts flashing when the power is turned on after the field wire (2) is removed with the power off for 5 seconds or more, the indoor unit's A1P (PCB) or T1R is defective.
3. The service monitor keeps displaying trouble history as long as the power is on. Turn off the power after inspection.

General precautions when performing maintenance

1. When disconnecting the fasten terminal from the PC board, hold down the PC board with your finger and do not apply excessive force. Also, do not hold the neck of the fasten terminal and pull the lead wire.
2. Do not use a mega tester on the secondary side (transformer secondary side) of the electronic circuitry.
3. Even when not energized, beware of static electricity when touching parts or pattern. (If handling PC board when dry [winter], be sure to discharge the electrostatic charge by grounding. Do not touch any other grounded metal parts with your fingers.)

Fig.9-8 R(Y)71~160LU



Chapter 10 Water cooled type air conditioners

10

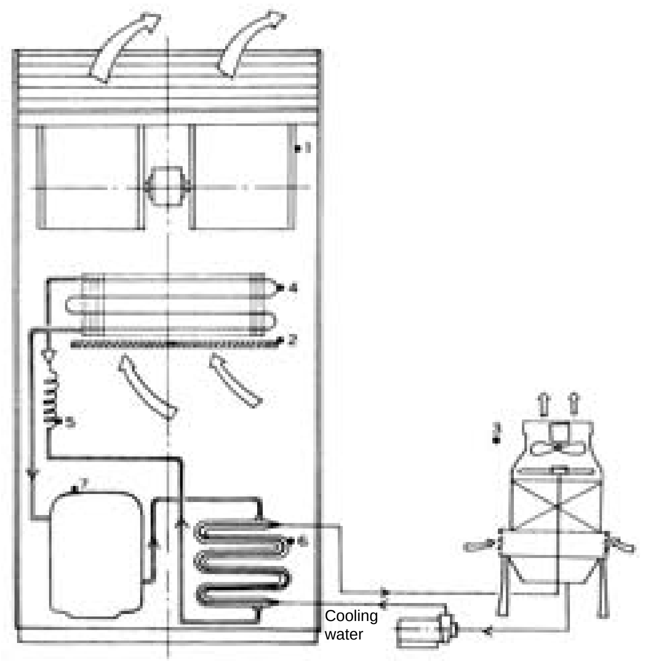
Chapter 10 Water cooled type air conditioners

10.1 Outline of water cooled type air conditioners

Basic works are common in water cooled type air conditioners and air cooled air conditioners. This chapter describes items unique to the water cooled type air conditioners and special notes.

10.1.1 Main components of water cooled type air conditioners

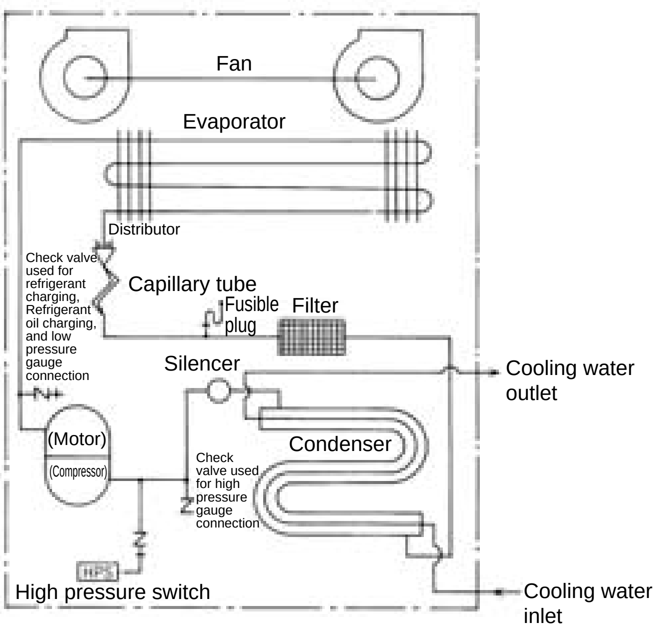
Fig.10-1



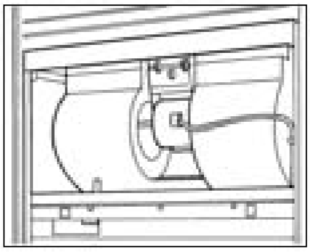
Refrigerant piping circuit diagram on water cooled type air conditioner

■ **UCJ160P (Example)**

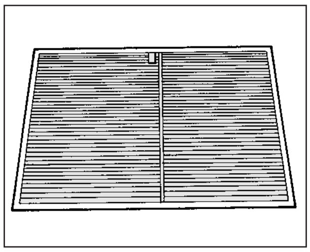
Fig.10-2



(1) Fan
Used to circulate indoor air.

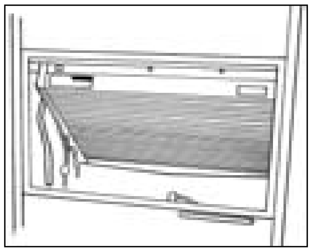


(2) Air filter
Used to remove dirt and dust contained in air.
Air filter clogged with dirt and dust reduces the airflow rate, thus resulting in degraded performance.
It is required to clean the air filter once in 2 weeks during operation.

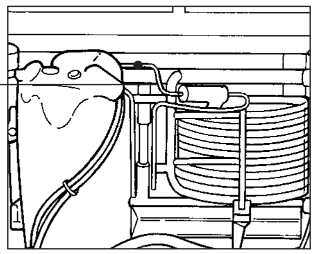


(3) Cooling tower
Used to re-cool the cooling water that has become high in temperature by absorbing the heat of condensation taken from the inside of room.

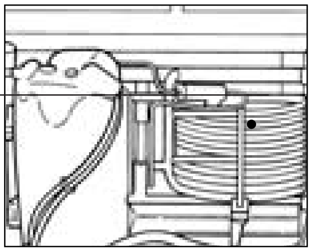
(4) Evaporator
Used to cool indoor air by means of low-temperature, low-pressure, and to dehumidify the indoor air as well.



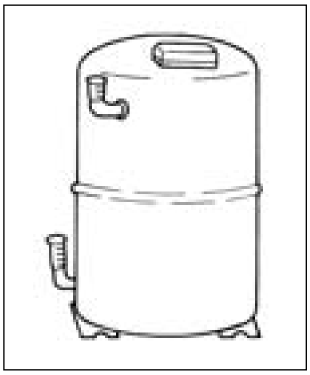
(5) Expansion valve or capillary tube
Used to turn the refrigerant into the state of low temperature and low pressure.



(6) Condenser
Used to cool and liquefy the high-temperature, high-pressure refrigerant gas.

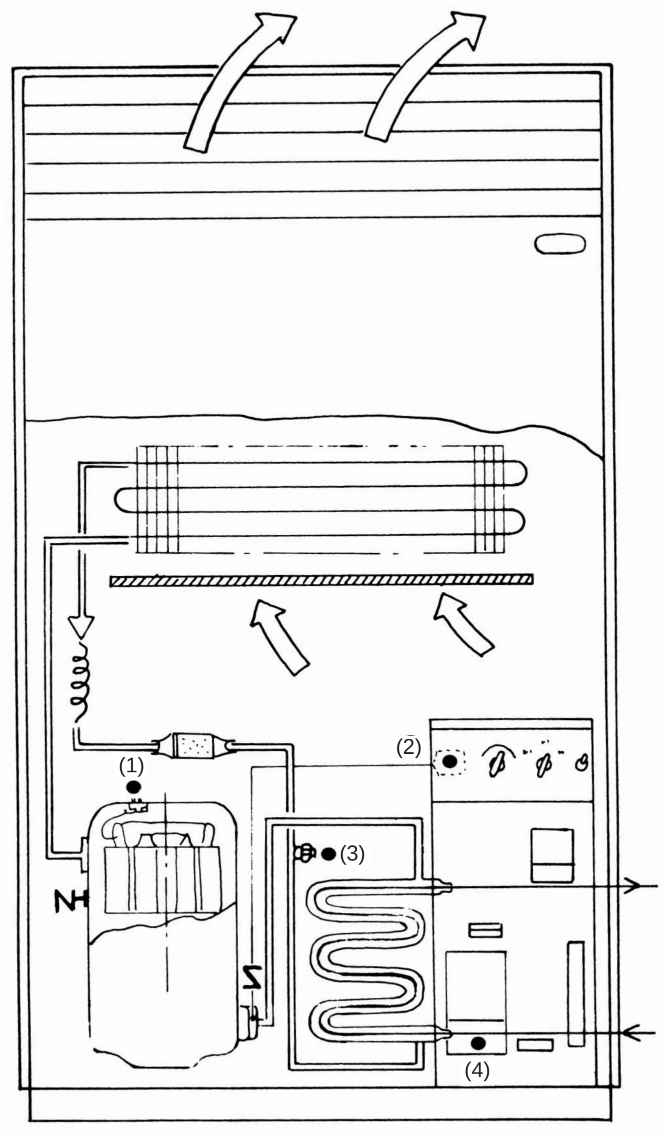


(7) Compressor
Used as a pump to circulate the refrigerant. The compressor compresses the low-temperature, low-pressure refrigerant gas evaporated through the evaporator up to a pressure by which the gas can be easily liquefied through the condenser.



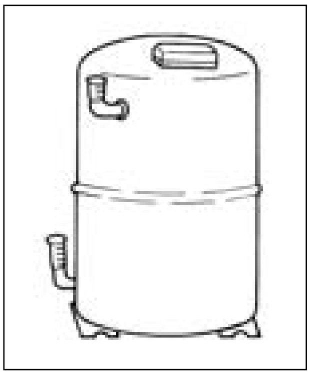
10.1.2 Safety devices of water cooled type air conditioners

Fig.10-3

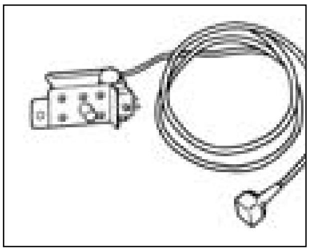


Safety device on water cooled type air conditioner (UC5JA)

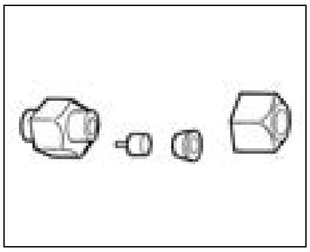
(1) Compressor protection thermostat
Used to automatically stop the compressor when the temperature of coil in the motor becomes abnormally high due to overloaded operation of the compressor, thus preventing the compressor motor from burning out. This thermostat is mounted directly in the motor coil.



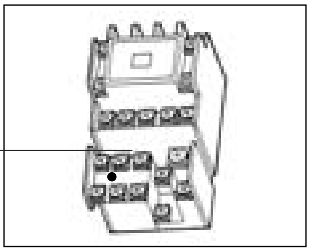
(2) High pressure switch
Used to automatically stop the compressor when the refrigerant becomes abnormally high in the pressure, thus preventing an accident due to malfunction.



(3) Fusible plug
In case of fire or if the high pressure switch is not activated, the plug head fuses to automatically relieve the refrigerant, thus preventing the occurrence of an accident.



(4) Overcurrent relay for compressor
Used to prevent the compressor motor from burning out due to the overloaded operation.

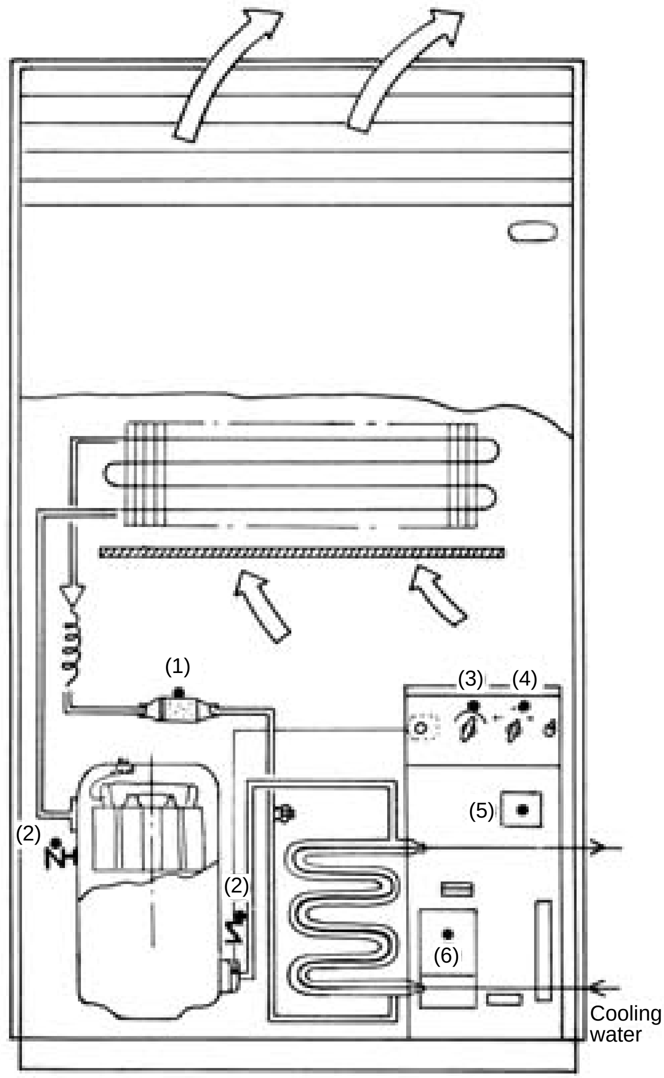


(5) Temperature switch
Used to automatically stop the compressor when the discharge pipe temperature becomes abnormally high in the temperature, thus preventing the compressor from burning out.

10.1.3 Functional parts of water cooled type air conditioners

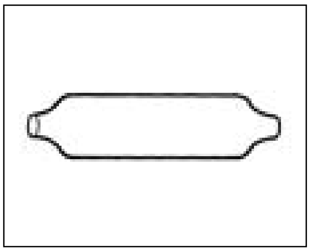
The structure and parts of the main unit are shown by "Example" together with the refrigerant piping circuit diagram of water cooled type air conditioners.

Fig.10-4

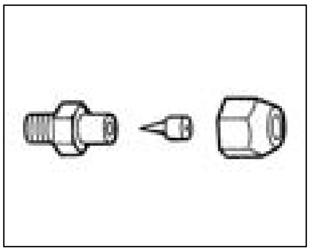


Functional parts on water cooled type air conditioner (UCJ160P)

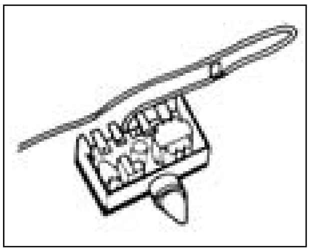
(1) Filter
Used to remove foreign particles contained in the refrigerant, thus preventing the clogging of the expansion valve and capillary tube.



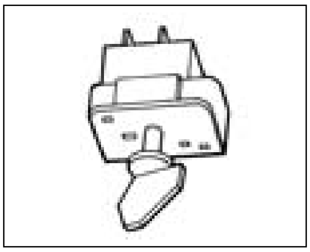
(2) Gauge joint with check valve
Used for piping connection for servicing use such as the charging of refrigerant, the removal of pressure, and vacuum drying.



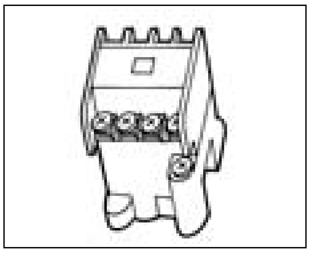
(3) Thermostat
Used to automatically control indoor air temperature.



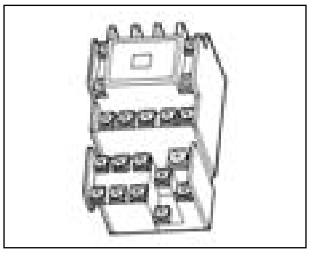
(4) Rotary switch (Operation switch)
Used to run or stop operation.



(5) Magnetic contactor for fan motor use



(6) Magnetic switch for compressor motor use
The magnetic switch consists of magnet contactor and overcurrent relay, which has contact closing the circuit through energized magnet and opening the circuit with de-energized magnet, thus switching a large amount of current.



10.2 Cooling tower

10.2.1 Outline

Cooling water from air conditioner (chiller) absorbs the heat of condensation and becomes high in temperature. Therefore, this water cannot be used as the cooling water as it is. However, it is very wasteful for you to dispose the water.
The cooling tower is a device that cools cooling water having an increased temperature down to a temperature at which this cooling water can be used as cooling water by means of air.
Thus, the cooling water can be circulated to use, achieving the economical operation. Using the cooling tower solves the following problems.

(1) Insufficient quantity of well water, or extremely low city water pressure.
(2) Poor water quality, much impurities contained especially in underground water.
(3) Substantially high cost of water (especially city water).
(4) It is hard to bore a well due to adverse influences given to foundation or building.
(5) Drawing underground water is abated by law.
(6) A large quantity of industrial water cannot be obtained.

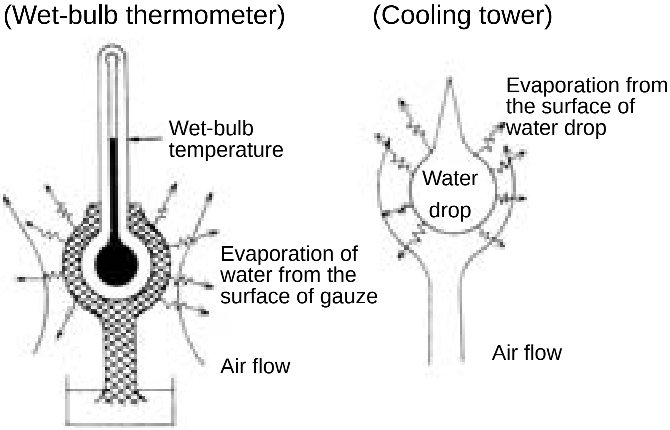
10.2.2 How to cool

When liquid turns the state into gas, it must absorb the heat of evaporation. Since water has the same state change as that of the liquid, **the heat of evaporation per 1-kg water is approximately 2400 kJ (600 kcal). In other words, when evaporating only 1% of the 1-kg water, 24-kJ (6-kcal) heat becomes absorbed. By absorbing this heat of evaporation with the residual water (0.99 kg), the temperature of the residual water becomes lower by approximately 6˚C.**
Namely, the evaporation of water makes it possible to reduce the temperature of the residual water. That is the principle of the cooling tower.

*Heat of evaporation of water 100˚C - 2260 kJ/kg (539 kcal/kg)
30˚C - 2430 kJ/kg (580 kcal/kg)

However, there is a limit on the evaporation of water, and the temperature cannot decrease below the limit. When water keeps contacted with air for an extended period of time, the temperature of water reaches wet-bulb temperature of air at the limit to counterpoise. In other words, water cannot be cooled below the wet-bulb temperature of air even at the limit.
Furthermore, in terms of acceleration of the evaporation of water, 3 points, that is, **contact area and contact time between water and air, and relative velocity of air and water,** are the main precautions on the cooling device.

Fig.10-5 Principle of cooling tower and wet-bulb temperature



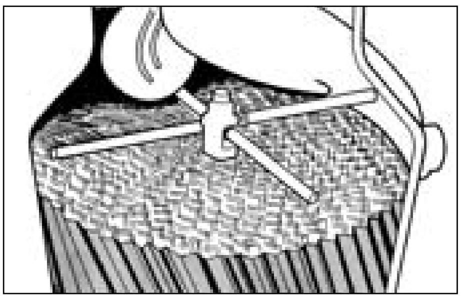
10.2.3 Types of Cooling Tower

Natural draft type
- Cooling pond
- Spray pond
- Atmosphere-system natural draft type
- Chimney-system natural draft type

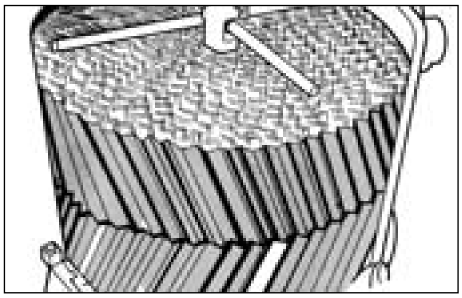
Forced draft type
- Forced draft type
- Suction draft type

* Daikin's cooling tower is of the suction draft type. Considerations are given to the following 3 points in order to upgrade the evaporation effect.

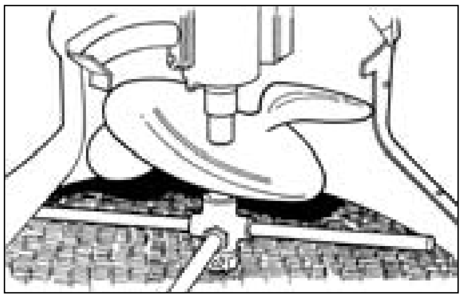
(1) Ideal water spray mechanism providing a large contact area between water and air.
The water spray mechanism is a critical part as its quality can determine the performance of the cooling tower. The Daikin's cooling tower employs the rotary water spray mechanism on all models, thus achieving the ideal water spray distribution.



(2) Incorporating high-performance filling with extended period of contact time between water and air.
This filling serves to cool "hot cooling water" by means of suction air. The Daikin's filling is compact in size and of unique shape to demonstrate a high performance.



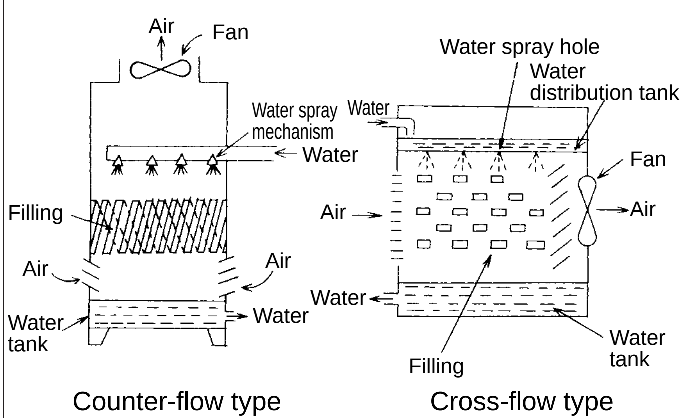
(3) Super-quiet laminar flow fan providing fast relative speed between water and air.
This fan, which is produced through the Daikin's unique design, quietly sends air used to take heat from the cooling water. The fan is running in quiet sound that is negligible even during nighttime operation.



10.2.4 Forced draft type

At present, the forced draft type is used most commonly. By using a fan, upward draft is produced in the tower, and heat exchange is performed between the upward draft and water falling in the tower. Two types of flow of air and water are available, counter-flow type and cross-flow type.

Fig.10-6



- On the counter-flow type cooling tower, cooling water is sprayed from the top of the tower, cooling air is sucked from the bottom of the tower by means of the fan, and high-temperature water from the condenser of the chiller passes along the surface of the filling in the tower against air. Through these processes, the water temperature itself is decreased by the evaporation of water.
- On the cross-flow type cooling tower, cooling water is distributed by free-fall water spray mechanism from the top of the tower, and forced draft passes in a direction at right angles to the cooling water.
  This pimp is returned by means of the pump to the heat exchanger (condenser) for circulation and reuse. The water consumption rate is a sum of the amount of evaporation, the amount flying together with air in the state of water drop and the amount of forced replacement from forced blow pipe. The make-up water quantity is approximately 1.5% of the total circulation water quantity. The make-up water is automatically fed, thus achieving substantially economical operation.
- Forced blow pipe: A header is provided at the bottom to receive falling water that replaces water for the water receiving area, thus minimizing the concentration of water contamination.

Fig.10-7

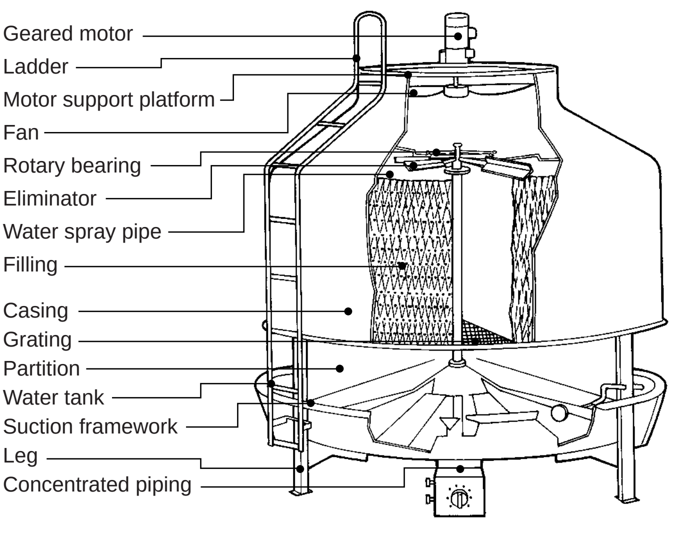
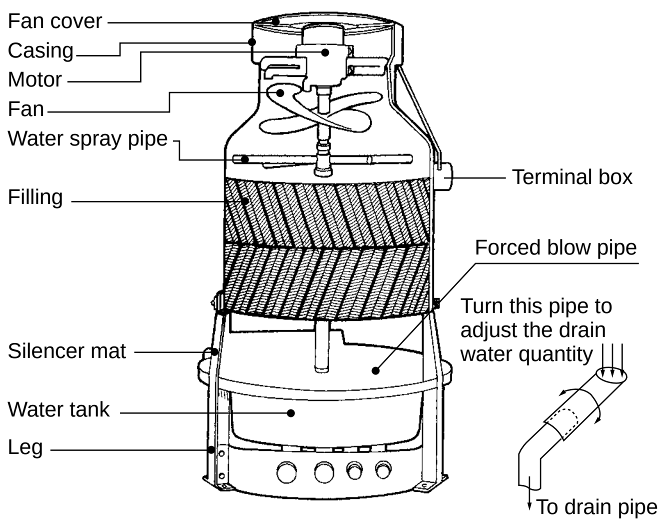


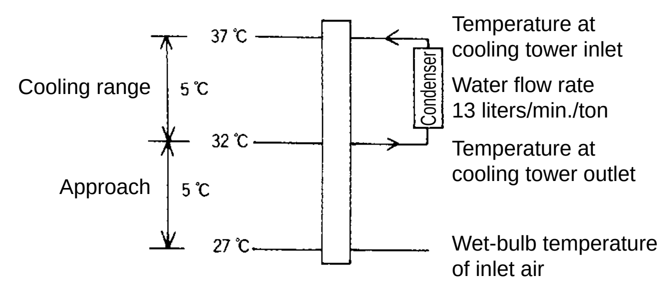
Fig.10-8



10.2.5 Address term of cooling tower

According to Japan Cooling-tower Institute, the nominal tonnage of cooling tower is 1 ton = 4.5 kW (3900 kcal/h), provided that the following conditions are met.

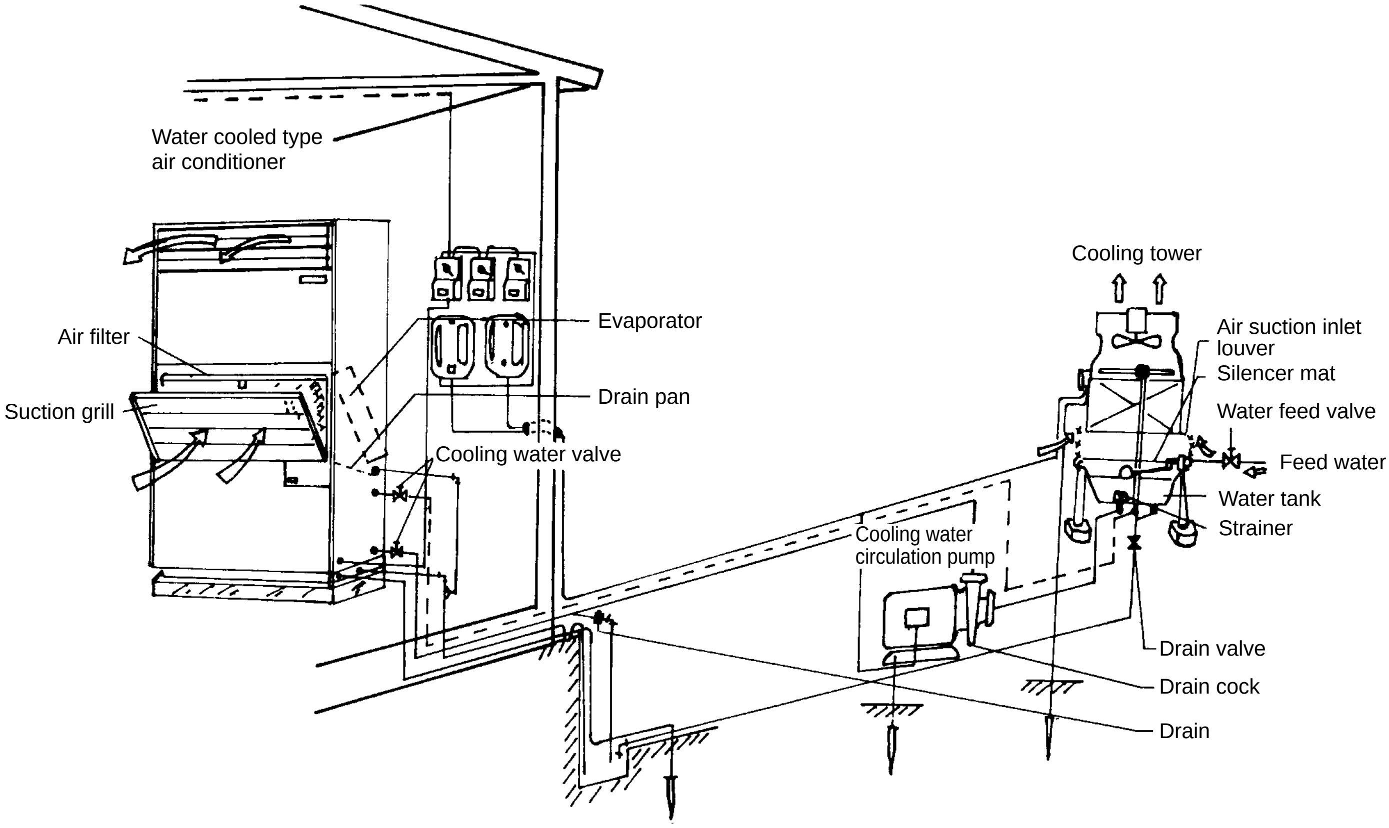
Wet-bulb temperature at air inlet	27˚C
Inlet water temperature	37˚C
Outlet water temperature	32˚C
Circulated water quantity	13 L/min./ton



10.3 Inspection and maintenance

In order to perform inspection and maintenance, be sure to turn off the power supply for fail-safe.

Fig.10-9 Water cooled type air conditioner



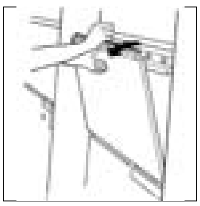
10.3.1 During season

Precautions during season, off-season, and on season are shown respectively.

(1) Cleaning of air filter: Be sure to clean the air filter once every 2 weeks.
The air filter is provided to remove dust in air and feed clean cool air at all times.
If the air filter is left without cleaning for an extended period of time, it will become clogged, thus resulting in poor airflow, degraded cooling performance, and higher operating sound of fan.

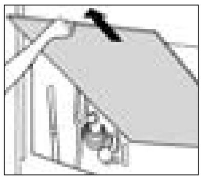
- How to clean the air filter

a. Hold the grip of the suction grill and pull the suction grill toward you to open.

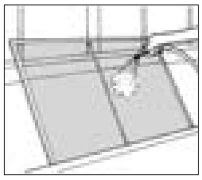


b. Opening the suction grill, you will see the air filter inside.

c. Hold the grip of the air filter to pull out the air filter.



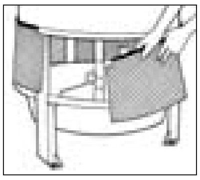
d. Dust the air filter and clean it with fresh water or lukewarm water.

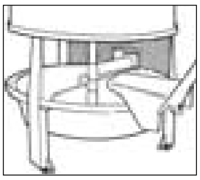


e. After completely drying the air filter, put it back to the original position. Operation without air filter installed will impair the dusting effect, thus resulting in dirty machine or causing machine failure.
(Note) 1. Do not clean the air filter with hot water.
2. Do not expose the air filter to direct sunlight, otherwise it may be deformed.
3. Do not use organic solvent such as gasoline and thinner.

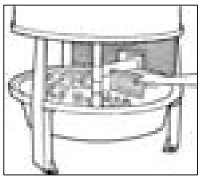
(2) Cleaning of tower water tank and strainer: Clean the water tank monthly and the strainer once every 2 weeks.
Mud and dirt easily mix in the water tank. Letting them sit in the tank will result in clogged water circulation pump. Therefore, the strainer is installed.
Letting the strainer sit there without cleaning will cause clogged strainer to reduce the cooling water quantity and degrade the cooling efficiency. Then, the high pressure switch is activated to disable the operation.

- How to clean the strainer (TIF53)
  a. Remove the louver and the silencer mat at the air suction inlet.





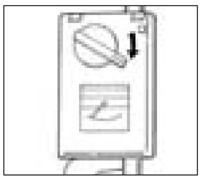
  b. Remove the strainer to clean.



  c. In order to clean the water tank, open the drain valve at the lowest part of the tank, flush out with water while brushing the inside of tank.
  d. When the cleaning is complete, put the strainer back to the original position.

10.3.2 During off-season

(1) Half-day blast
Perform blasting operation for half a day to completely dry the inside, where water is accumulated.
(2) Clean the air filter.
(3) Be sure to turn off the power supply.



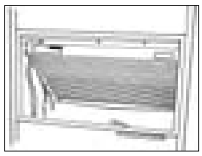
(4) Cleaning of drain pan
Since the drain pipe may get clogged with dust and dirt, it is recommended to clean the drain pan periodically.
Furthermore, remove dirt clogging the drain pipe inlet.
(5) Cleaning of evaporator: Clean the evaporator once every 2 to 3 years.
Dust, dirt accumulated while stopping operation, or superfine dust passing through the air filter may adhere to the evaporator fin and solidifies there, thus significantly degrade the performance. The more dust adheres, the faster this phenomenon is developed. In order to run the system with efficiency at all times, be sure to clean the evaporator once every 2 to 3 years.
As for the cleaning of the evaporator, consult with your representative.
(6) Drain from water piping, pump, or tower water tank
Open the drain cock to completely drain water. Incomplete drain may cause damage to them due to freeze-up of water in winter.
(Note) 1. Be sure to close the water feed valve.
2. Keep the drain cock of the tower water tank open, otherwise rainwater is accumulated.

10.3.3 When season begins

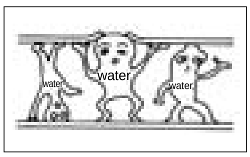
At the beginning of cooling season, perform the following items before starting the operation of air conditioner. After that, perform blasting operation to dry the inside of air conditioner and follow with running the air conditioner according to the procedure of operation preparation and operation.
(1) Cleaning of air filter
(2) Cleaning of water tank and strainer
(3) Inspection of internal damage
(4) Inspection of oil leak
(5) Checking of fan for rotating direction
Check whether the fan rotates in the direction shown on the motor by the arrow.
(6) When restarting the operation after stopping the air conditioner for an extended period of time, dust on the fan may blow off. Pay attention to this matter.

10.3.4 Case study through trouble examples

(1) Degradation in performance due to clogged air filter
Neglecting to clean the air filter, the following troubles will be cause.
  a. The cooling capacity will degrade.
  b. The air filter will get clogged, thus resulting in increased air resistance and operating sound.
  c. Keeping the operation for an extended period of time with the air filter clogged will extremely decrease the evaporating temperature and activate wet operation, thus resulting in damage to the compressor.
  Be sure to clean the air filter once every 2 weeks.



(2) Burst through freeze-up due to neglecting to drain in winter
In winter, it is often heard news of burst of city water pipe because water freezes up in winter to expand its volume. Therefore, during off-season (winter), be sure to drain from the pumps in the piping and the water tank of the cooling tower.



10.4 Troubleshooting

10.4.1 Contents and detecting method of common troubles

Fig.10-10 Water cooled type air conditioner

No operation

↓ Operated

Reset the red button of the high pressure switch. ⇨ Check the following points.
1. Is the cooling water valve located adjacent to air conditioner fully open?
2. Is the cooling tower in operation?
3. Is the cooling water pump in operation?
4. Is the filter of the cooling tower not dirty?
5. Is there adequate amount of water in the water tank?

↓ To Flow Chart (6)

↓ No operation

Is there a power failure?

↓ No power failure

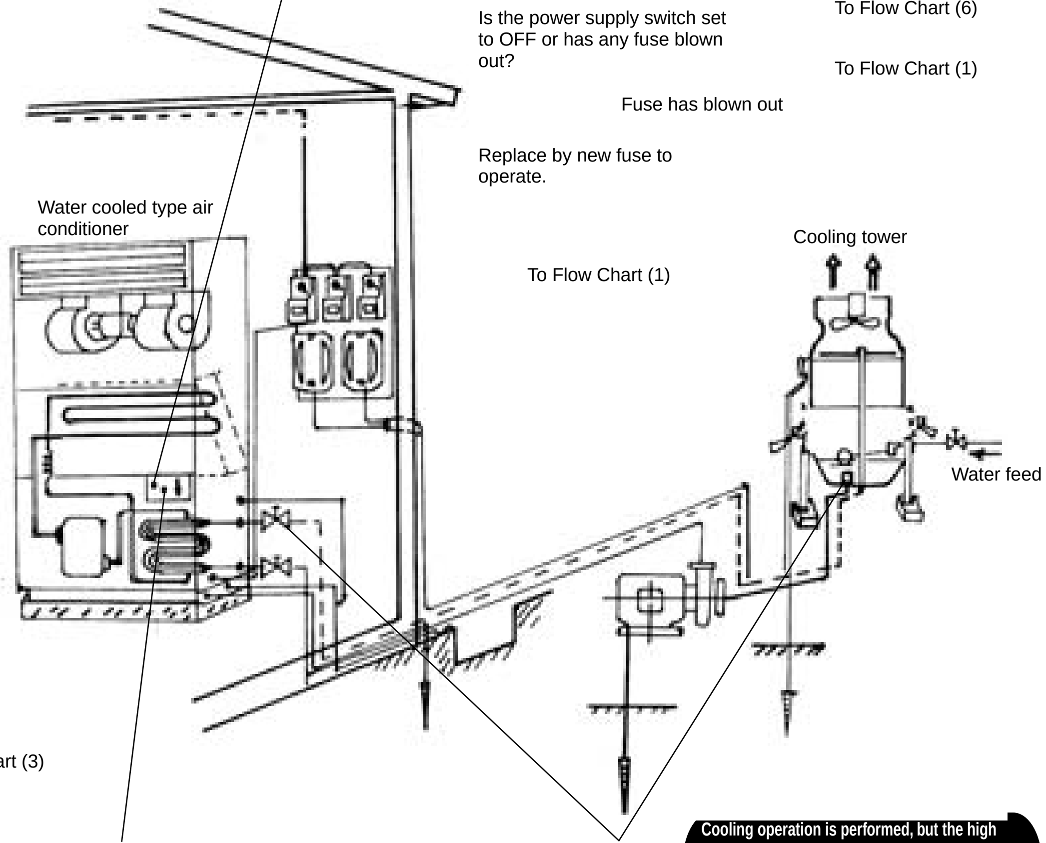
Is the power supply switch set to OFF or has any fuse blown out?

To Flow Chart (1)

Fuse has blown out

Replace by new fuse to operate.

To Flow Chart (1)



Cooling operation is performed, but does not cool down.

↓

Measure the suction and discharge temperatures to find the temperature difference.

Temperature difference
1. Temperature difference: 10 C–2 C
   - Normal operation
   - Is there much heat loads inside the room? (Is any window or door open?)
2. Temperature difference: 12 C or more
   - Is the air filter dirty?
   - Is any obstacle put at the suction inlet of indoor unit?
3. No temperature differences are provided. (7 C or less)

→ To Flow Chart (3)

Fan operates by cooling operation is not performed. (2)

↓

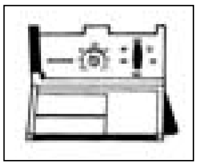
Turn clockwise the temperature control thumbwheel.

↓ No operation

Are the cooling tower and cooling water pump in operation? ⇨ Not in operation: To Flow Chart (2)

↓ In operation

To Flow Chart (2)



Cooling operation is performed, but the high pressure switch is immediately activated to stop the operation. (Pressing the RESET pushbutton starts the operation but stop again.)

↓

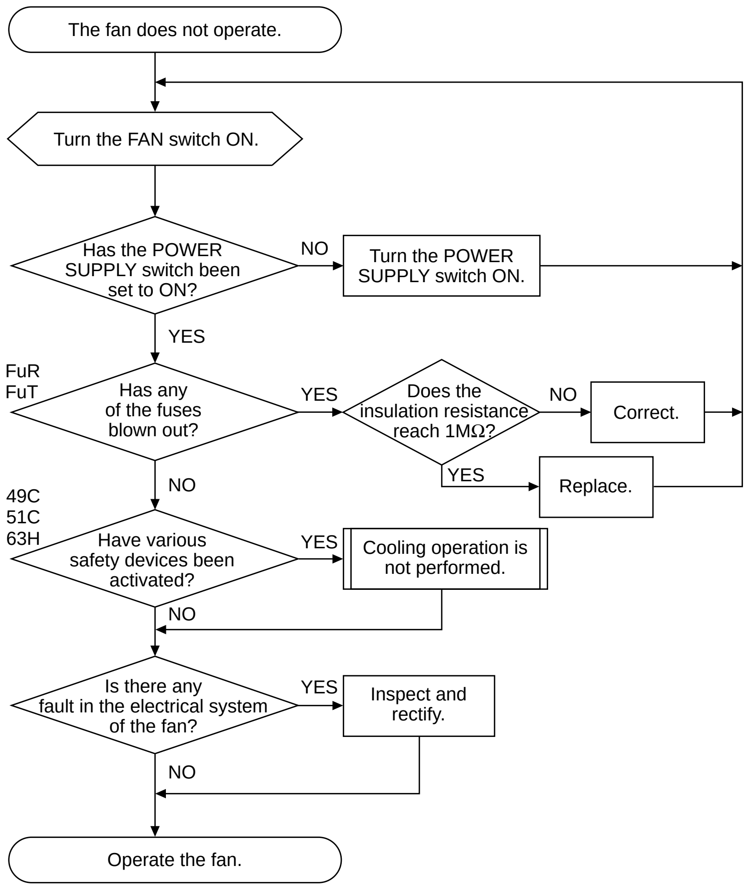
Check the following points.
1. Is the cooling water valve located adjacent to air conditioner open?
2. Are the cooling tower and the cooling water pump in operation?
3. Is there adequate amount of water in the water tank of the cooling tower?
4. Is the strainer of the cooling tower not dirty?

↓ No abnormality

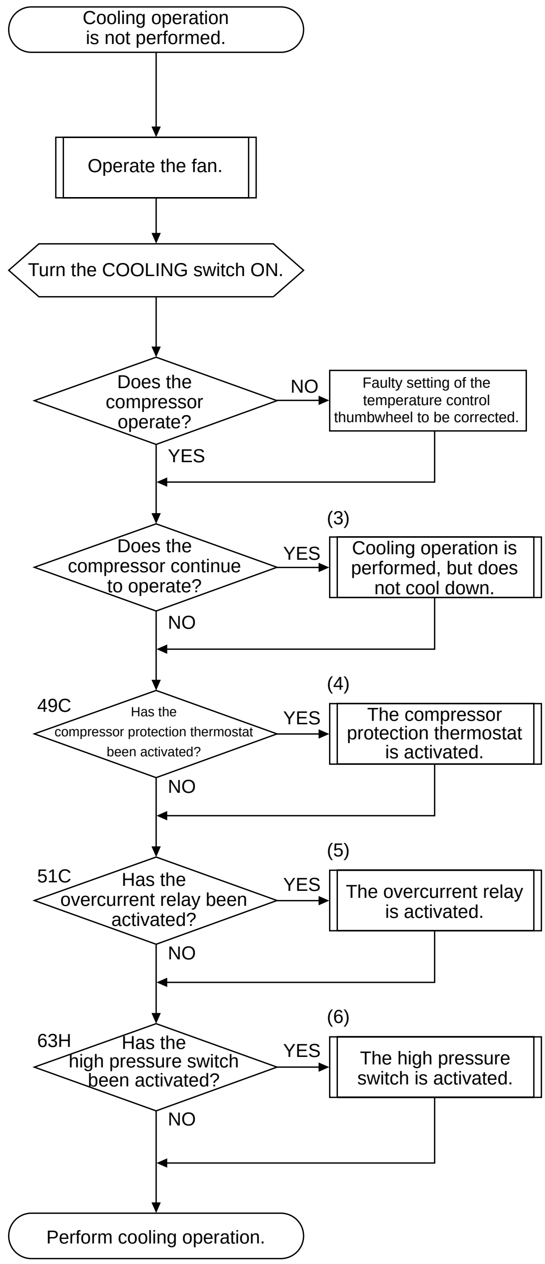
To Flow Chart (6)

10.4.2 Flow chart of troubleshooting

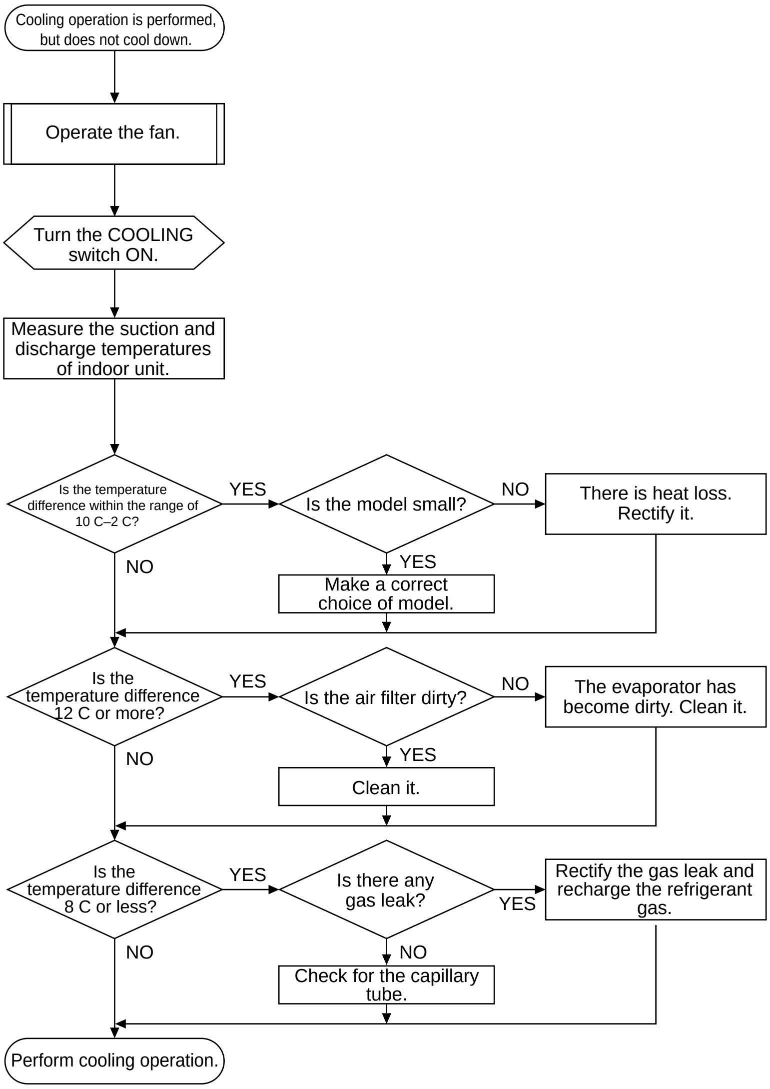
(1)



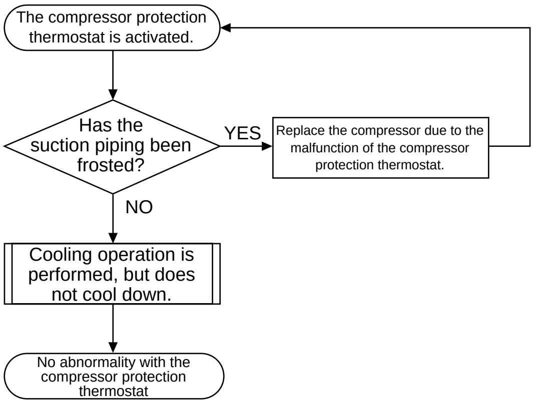
(2)



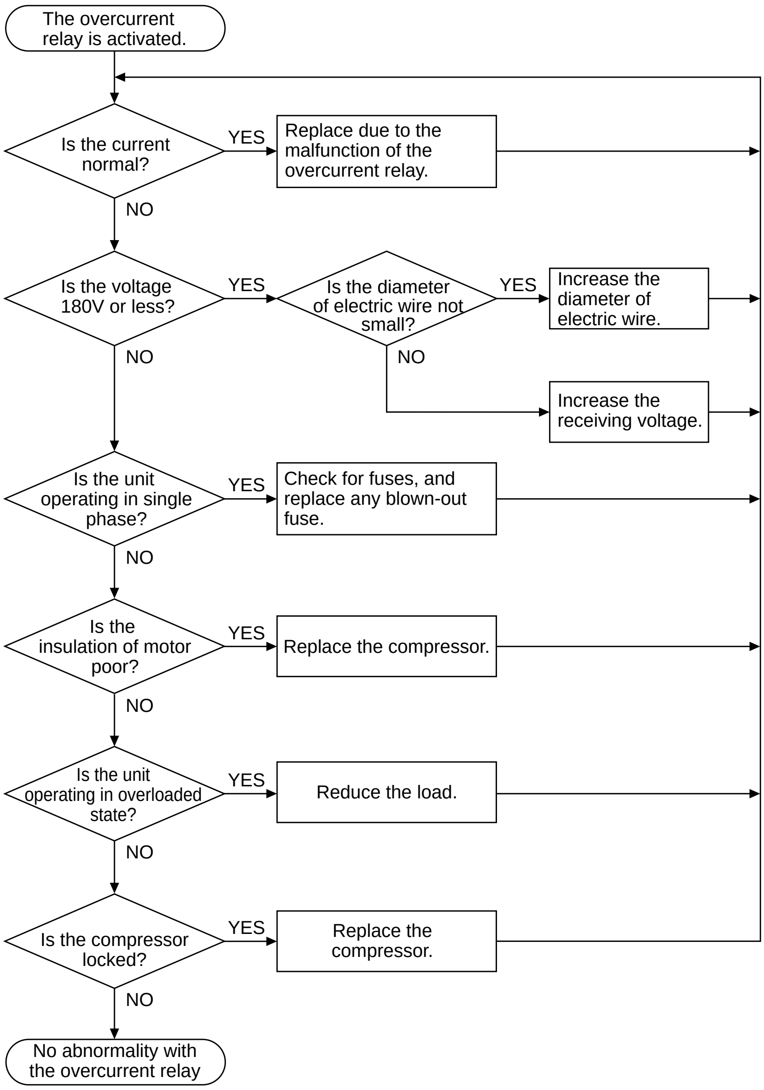
(3)


Cooling operation is performed, but does not cool down.
Operate the fan.
Turn the COOLING switch ON.
Measure the suction and discharge temperatures of indoor unit.
Is the temperature difference within the range of 10 C–2 C?
YES
Is the model small?
NO
There is heat loss. Rectify it.
YES
Make a correct choice of model.
NO
Is the temperature difference 12 C or more?
YES
Is the air filter dirty?
NO
The evaporator has become dirty. Clean it.
YES
Clean it.
NO
Is the temperature difference 8 C or less?
YES
Is there any gas leak?
YES
Rectify the gas leak and recharge the refrigerant gas.
NO
Check for the capillary tube.
NO
Perform cooling operation.

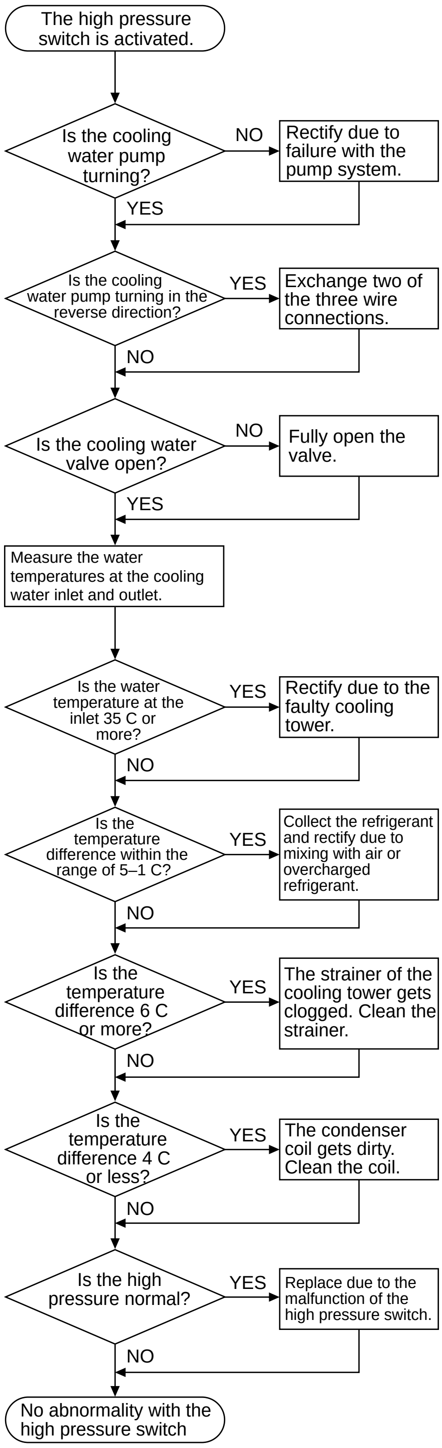
(4)


The compressor protection thermostat is activated.
Has the suction piping been frosted?
YES
Replace the compressor due to the malfunction of the compressor protection thermostat.
NO
Cooling operation is performed, but does not cool down.
No abnormality with the compressor protection thermostat

(5)


The overcurrent relay is activated.
Is the current normal?
YES
Replace due to the malfunction of the overcurrent relay.
NO
Is the voltage 180V or less?
YES
Is the diameter of electric wire not small?
YES
Increase the diameter of electric wire.
NO
Increase the receiving voltage.
NO
Is the unit operating in single phase?
YES
Check for fuses, and replace any blown-out fuse.
NO
Is the insulation of motor poor?
YES
Replace the compressor.
NO
Is the unit operating in overloaded state?
YES
Reduce the load.
NO
Is the compressor locked?
YES
Replace the compressor.
NO
No abnormality with the overcurrent relay

(6)


The high pressure switch is activated.
Is the cooling water pump turning?
NO
Rectify due to failure with the pump system.
YES
Is the cooling water pump turning in the reverse direction?
YES
Exchange two of the three wire connections.
NO
Is the cooling water valve open?
NO
Fully open the valve.
YES
Measure the water temperatures at the cooling water inlet and outlet.
Is the water temperature at the inlet 35 C or more?
YES
Rectify due to the faulty cooling tower.
NO
Is the temperature difference within the range of 5–1 C?
YES
Collect the refrigerant and rectify due to mixing with air or overcharged refrigerant.
NO
Is the temperature difference 6 C or more?
YES
The strainer of the cooling tower gets clogged. Clean the strainer.
NO
Is the temperature difference 4 C or less?
YES
The condenser coil gets dirty. Clean the coil.
NO
Is the high pressure normal?
YES
Replace due to the malfunction of the high pressure switch.
NO
No abnormality with the high pressure switch

Chapter 11 Psychrometric chart

11

Chapter 11 Psychrometric chart

11.1 Air

Atmospheric air is referred to as "air", which means the moist air in terms of air conditioning.

11.1.1 Properties of moist air

Moist air is a mixture of dry air and 1 to 3% mass of water vapor.

1. **Properties of dry air**
   The composition of dry air in the standard state (temperature: 0˚C, pressure: 760mmHg {101.325kPa}, acceleration of gravity g = 9.80655 m/S[2]) is as follows.

Table 11-1

Composition	Nitrogen (N_2)	Oxygen (O_2)	Argon (Ar)	Carbon dioxide (CO_2)
Volumetric (%)	78.09	20.95	0.93	0.03
Gravimetric (%)	75.53	23.14	1.28	0.05

*1 Constant pressure specific heat of dry air Cpa
=0.240 [kcal/kg • deg] =1.005 {kJ/kg • K}

*2 Enthalpy of dry air ha
=0.240t [kcal/kg] =1.005t {kJ/kg}

(This means the enthalpy of dry air at arbitrary temperature and pressure based on the condition that the enthalpy of dry air is 0 at a temperature of 0˚C and standard atmospheric pressure.)

2. **Properties of water vapor**
   Constant pressure specific heat of water vapor Cpw
   =0.441 [kcal/kg • deg] =1.85 {kJ/kg • K}
   Evaporation latent heat of water vapor r
   =597.3 [kcal/kg] =2501 {kJ/kg}
   Enthalpy of water vapor hw
   =r+Cpwt=597.3+0.441t [kcal/kg] =2501+1.85t {kJ/kg}

(Water vapor enthalpy hw at arbitrary pressure and temperature is shown as a function of temperature t˚C alone, under the condition that the enthalpy of saturated water at 0˚C is 0, and the pressure and temperature are not so high.)

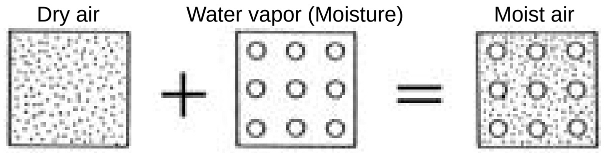
11.1.2 Moist air

It is convenient to assume that the moist air is an ideal gas that is mixture of dry air of 1kg in a certain composition and water vapor of X [kg] variable with state.

Thus, concerning moist air, a variety of numerical values are not handled for the unit weight of mixed gas of dry air and water vapor, while the mixed gas of 1 kg of dry air and X [kg] of water vapor, that is, (1+ X) kg of air is used as one unit weight.

Namely, the following figure represents the weight, pressure, and volume of the moist air by the expressions.

Fig.11-1



Weight	1 [kg]	+	X [kg]	=	1+X [kg]
Volume	V	+	V	=	V
Pressure	Pa [kg/cm[2]]	+	Pw [kg/cm[2]]	=	P [kg/cm[2]] =1.03323kg/cm[2]
	Pa{kPa} *(Partial pressure)*		*Pa{kPa}* *(Partial pressure)*	=	*P {kPa} =101.325kpa* *(Total pressure)*

11.1.3 How to represent water vapor (Humidity) in moist air

There are different kinds of method available to represent the humidity.

1. **Relative humidity** [ϕ=%]
   The relative humidity is the ratio of the moist-air specific weight to the saturated-air specific weight, or the ratio of the water vapor partial pressure Hw [mmHg] {kpa} in given moist air to the moisture partial pressure Hs [mmHg] {kPa} in saturated moist air at the same temperature.

(a) y = Specific weight [kg/m[3]] (Specific weight = 1/Specific volume)
This is the weight of water vapor [kg] contained in 1-m[3] moist air.

(b) Saturated moist air

○ When the temperature t of moist air is equal to the temperature t of saturated water vapor corresponding to the partial pressure Hw of the water vapor, the air is called "saturated moist air" or "saturated air" in short.

○ When pressure and temperature are determined, the limit of water vapor containable in the said air is also determined. This air containing water vapor up to the limit is called saturated air.

2. **Absolute humidity** [X = kg/kg]
   X in Fig. 1.1 represents the absolute humidity itself. The weight ratio of water vapor contained in the moist air becomes X/1 [kg/kg] to 1-[kg] dry air contained in the moist air. In other words, this is the ratio of the moisture weight to the dry air weight, both of which are contained in the moist air.

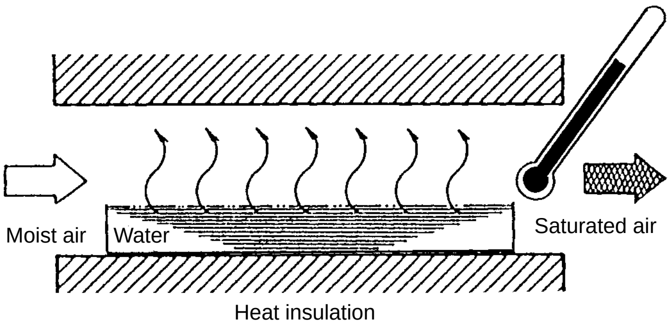
3. Wet-bulb temperature [t' = ˚C]

This is the moist air temperature shown on a wet-bulb thermometer.

The wet-bulb thermometer shows different values subject to the air velocity and the radiant heat, which strike the thermometer. When the air velocity exceeds 5 [m/s], the wet-bulb temperature becomes nearly equal to the adiabatic saturated temperature. (The wet-bulb temperature shown on the psychrometric chart means this adiabatic saturated temperature.)

(a) Adiabatic saturated temperature

Fig.11-2



When moist air in a certain state (t, h, or X) flows through a long and totally-insulated path while contacting a large quantity of water having a temperature t', moisture evaporates in the air from water and heat transfers from air to water. Then, after an extended flow, air turns into saturated state and keeps equilibrium with water. Suppose that the saturated air temperature is just equal to the water temperature t' and the water temperature remains unchanged all the way through the flow path. The temperature t' is a value determined by the state of air (t, h, or X) and called adiabatic saturated temperature of air (t, h, or X).

4. Dew-point temperature [t'' = ˚C]

- ○ This is the temperature of saturated moist air having a water-vapor partial pressure equal to that of the moist air.
- ○ The unsaturated moist air continues decreasing the temperature to finally reach the saturated state, where it starts condensing. The temperature at which the condensation starts is called dew-point temperature.

5. Others

- ○ Partial pressure of water vapor [Pw = mmHg], {Pw = kPa}
  This is the partial pressure of water vapor contained in the moist air.
- ○ Relative humidity [ϕs = %] or Saturation ratio
  This is the ratio of the absolute humidity X to the absolute humidity Xs of saturated air having the same humidity, which is represented by percentage.

$$\phi s = 100 \times \frac{X}{Xs}$$

11.1.4 Terms used on psychrometric chart

Besides terms described in Section 1-3, the following terms are used on the psychrometric chart.

1. Dry-bulb temperature [t = ˚C]

This is the temperature shown on ordinary thermometers.

2. Enthalpy [h = kcal/kg] {h = kJ/kg}

Any substance holds a given heat quantity in a certain state. This holding heat quantity is called enthalpy, which is measured with respect to a given reference point.

The enthalpy means the heat quantity held by moist air per 1-kg dry air contained in the moist air.

h = ha (i.e., enthalpy of 1-kg dry air) + Xhw (i.e., enthalpy of X-kg water vapor)

$= 0.240t + (597.3 + 0.441t) \times$ [kcal / kg]

$h = 1.005t + (2501 + 1.85t) \times$ {kJ/kg}

3. Specific volume [V = m^3/kg]

This is the volume of moist air per 1-kg dry air contained in the moist air, which is called specific volume as well.

4. Enthalpy-humidity difference ratio [u = kcal/kg] {u = kJ/kg}

This is the ratio of the change rate in enthalpy of air Δh (kcal/kg) {kJ/kg} to the change rate in absolute humidity ΔX (kg/kg) at the time when the air receives heat and moisture.

$u = \Delta h / \Delta x$[kcal/kg]{kJ/kg}

5. Sensible heat factor (SHF)

This represents the ratio of total heat to sensible heat. For details, refer to information in Section 5.1.

11.2 Psychrometric chart

Generally speaking, air chart means moist air chart (hereinafter simply referred to as the "psychrometric chart"), which represents the state of saturated air under the standard atmospheric pressure [760 mmHg]{101.325kPa}. Therefore, in order to put it more precisely, under any pressure other than the standard atmospheric pressure, psychrometric charts according to the said pressure are required.

11.2.1 Types of psychrometric charts

Psychrometric charts are one of the most useful tools in air conditioning engineering, and with these charts, one can easily understand the state of air and its state changes.
The types of psychrometric charts are as follows.

(1) h-X chart: Absolute humidity X and enthalpy h are drawn on the oblique coordinate. This chart is useful for theoretical analysis.
(2) t-X chart: Absolute humidity X and dry-bulb temperature t are drawn on the rectangular coordinate. This chart is useful for practical application.
(3) t-h chart: Dry-bulb temperature t and enthalpy h are drawn on the rectangular coordinate. This is particularly useful for expressing the state changes with air simultaneously.

This text explains the psychrometric chart using the h-X chart.

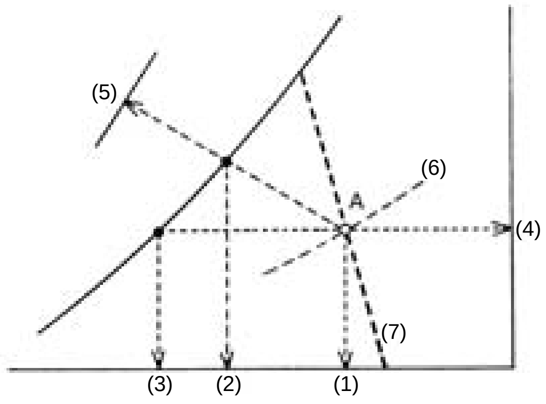
11.2.2 How to read psychrometric chart

The state of moist air is expressed at one point on the chart. The point is indicated by the dry-bulb temperature, wet-bulb temperature, dew-point temperature, absolute humidity, relative humidity, specific volume, and enthalpy. If the total pressure H is constant, once two conditions among them have been determined, a single point, that is, the state is determined as well.
In other words, if two conditions (i.e., item and its numerical value) are known, other five conditions (i.e., items and their numerical values) can be read easily on the psychrometric chart.

The following items express the state at Point A on the psychrometric chart.

(1)	Dry-bulb temperature	(D.B)	t	[˚C]
(2)	Wet-bulb temperature	(W.B)	t’	[˚C]
(3)	Dew-point temperature	(D.P)	t”	[˚C]
(4)	Absolute humidity		X	[kg / kg]
(5)	Enthalpy		h	[kcal / kg]*{kJ / kg}*
(6)	Relative humidity	(R.H)	ϕ	[%]
(7)	Specific volume		V	[m^3 / kg]

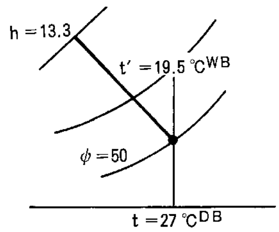
Fig.11-3



Example 1

Find the enthalpy when the dry-bulb temperature is 27˚C and the wet-bulb temperature is 19.5˚C.

Fig.11-4



[Solution] 1. Drawing two determinate values on the psychrometric chart locates the intersection, which becomes the state point.
2. Find the relative humidity and the enthalpy at this state point.

Answer: Relative humidity 50%, and enthalpy 13.3 kcal/kg [55.7 kJ/kg]

Exercise 1

Indicate air having a dry-bulb temperature of 20˚C and a relative humidity of 50% on the chart and find the values of the following items.

Enthalpy		kcal/kg		kJ / kg
Dew-point temperature		˚C		
Specific volume		m^3/kg		
Wet-bulb temperature		˚C		
Absolute humidity		kg /kg		

11.2.3 State changes on psychrometric chart

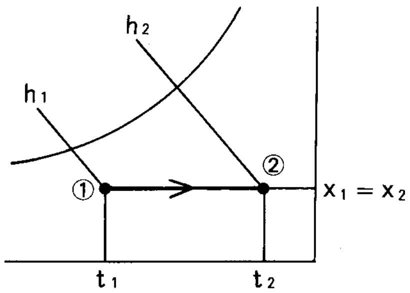
The following section shows how given air changes its state on the psychrometric chart while it cooled or heated.

1. Heating

Heating takes place when cool moist air is sucked in, heated through and discharged from heater (heat exchanger on indoor unit side in the case of heat pump type, or electric heater, hot-water heater, steam heater, or else in the case of cooling only type) incorporated in the air conditioner. In this case, since air is heated and the heater has a dry heat transfer surface, the passing air only increases in the temperature while the absolute humidity remains unchanged.

Fig.11-5 shows the above state changes on the psychrometric chart.

Fig.11-5



The dry-bulb temperature changes from t_1 to t_2. The enthalpy changes from h_1 to h_2. The absolute humidity x, however, remains unchanged.

2. Cooling and cooling & dehumidifying

When the cooler or the evaporator of air conditioner sucks and cools moist air, the moist air changes the state in the following manner.

2.1 Cooling only

If the surface temperature of the cooler or the evaporator is higher than the dew-point temperature of suction air, the suction air only decreases in the temperature.

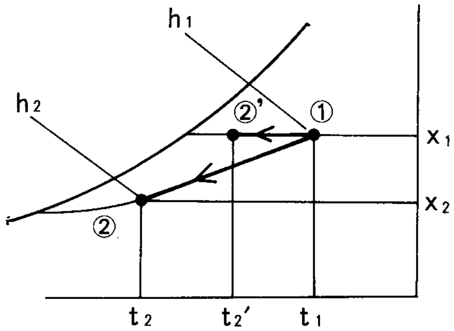
Fig. 2.4 shows the state change ① → ② ' on the psychrometric chart.

2.2 Cooling / Dehumidifying

If the surface temperature of the cooler or the evaporator is lower than the dew-point temperature of suction air, the suction air decreases in the temperature and the moisture is removed. In other words, it is dehumidified to turn into drain water.

Fig.11-6 shows the state change ① → ② on the psychrometric chart.

Fig.11-6



3. Humidifying

When humidity is low, moisture is added to air to increase the humidity. Namely, increasing absolute humidity is called "humidifying". Water, hot water, steam, or the like is used as the humidifying source, while a variety of humidifying methods are available. Changes on the psychrometric chart vary with the humidifying method applied.

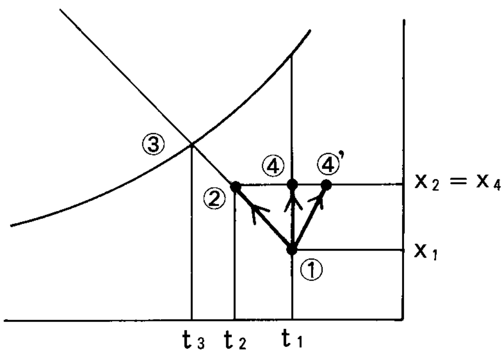
3.1 In the case of water spray humidifier

If water spray humidifier, pressure-type water spray humidifier, ultrasonic humidifier, or else is used, it is assumed that the state approximately changes as ① → ② on the wet-bulb temperature line on the psychrometric chart (Fig. 11-7).

3.2 In the case of steam spray humidifier

If steam spray humidifier, evaporate-plate-type humidifier, or else is used, it is assumed that the state approximately changes as ① → ④ on the dry-bulb temperature line on the psychrometric chart (Fig. 11-7). Actually, it changes in the direction of ④ ' on the line having a slope equal to the enthalpy-humidity difference ration.

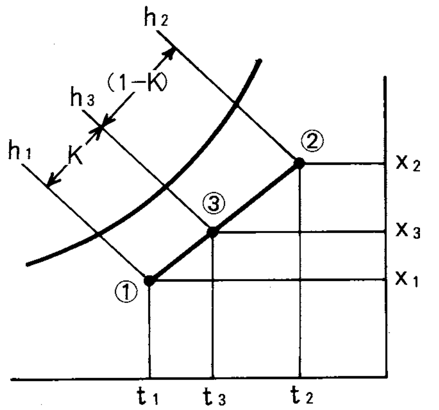
Fig.11-7



4. Mixing

For the calculation of the state of air produced when two types of air, such as indoor air and outdoor air, are mixed, the Equation (2.1) applies.

Fig.11-8



$t_3 = t_1 + (t_2 - t_1) \cdot K$

$= K \cdot t_2 + (1 - K) \cdot t_1$

$x_3 = K \cdot X_2 + (1 - K) \cdot X_1 \cdots (2.1)$

$h_3 = K \cdot h_2 + (1 - K) \cdot h_1$

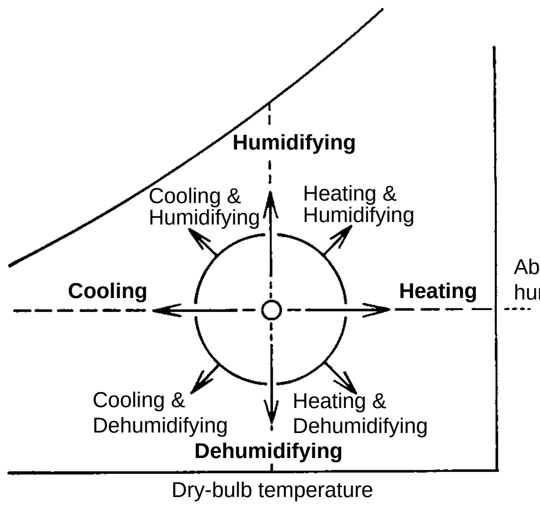
K: Outdoor air intake ratio (Outdoor air intake rate/Air flow rate)

The mixing point is found on the line connecting Points ① and ②.

5. Summary of changes on psychrometric chart

Fig. 11-9 shows the summary of moist air state changes on the psychrometric chart.

Fig.11-9



Exercise 2

Find the state of air in the case of mixing 30% of the quantity of outdoor air having a dry-bulb temperature of 33˚C and a relative humidity of 80% and 70% of the quantity of indoor return air having a dry-bulb temperature of 27˚C and a relative humidity of 50%.

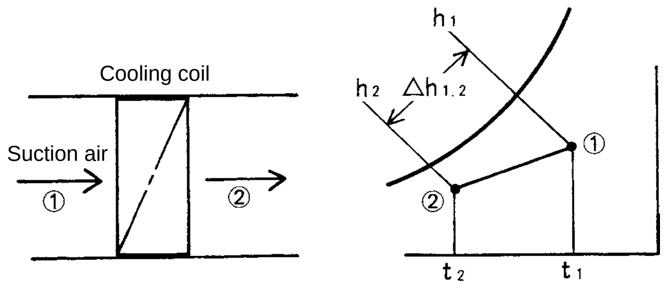
11.3 Various patterns of state changes

The following section describes how to draw some typical state changes used for air conditioning.

11.3.1 Cooling

(1) Indoor air circulates to cool down.

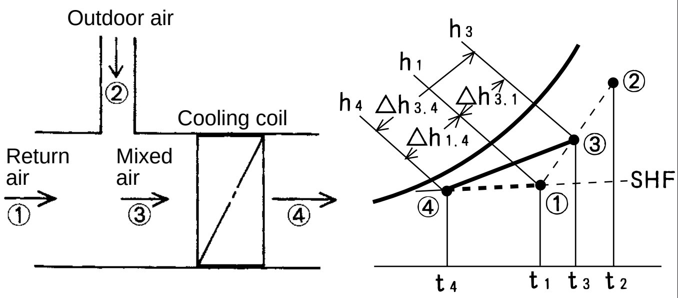
Fig.11-10



$\Delta h_{1,2}$: Cooling coil (evaporator) load or cooling heat load

(2) Fresh air (outdoor air) is taken in to cool down.

Fig.11-11



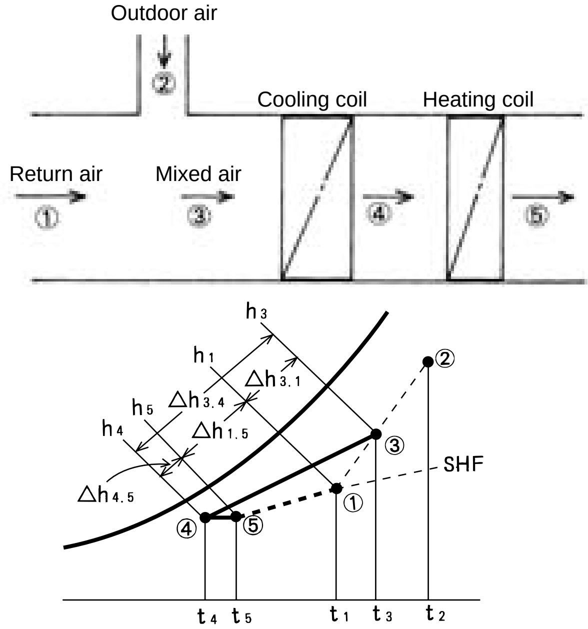
$\Delta h_{3,4}$: Cooling coil (evaporator) load

$\Delta h_{3,4}$: Fresh air (outdoor air) load

$\Delta h_{1,4}$: Cooling heat load

(3) Fresh air (outdoor air) is taken to cool down and reheat.

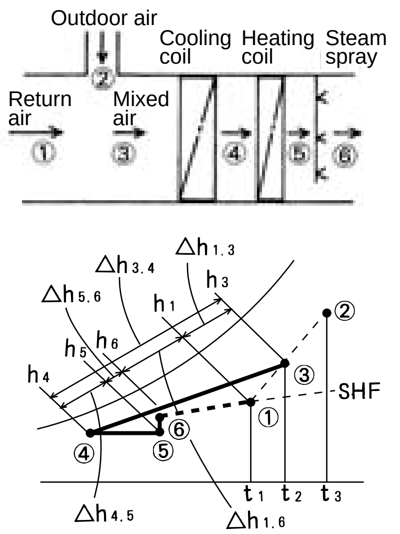
Fig.11-12



$\Delta h_{3,4}$: Cooling coil load
$\Delta h_{3,1}$: Fresh air (outdoor air) load
$\Delta h_{4,5}$: Heating (reheating) coil load
$\Delta h_{1,5}$: Cooling heat load

(4) Fresh air (outdoor air) is taken in to cool down, reheat, and humidify.

Fig.11-13

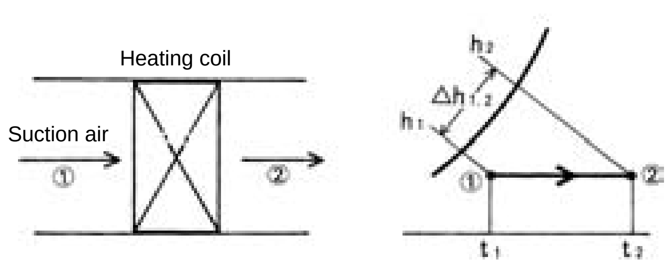


$\Delta h_{3,4}$: Cooling coil (evaporator) load
$\Delta h_{1,3}$: Fresh air (outdoor air) load
$\Delta h_{4,5}$: Heating (reheating) coil load
$\Delta h_{5,6}$: Humidifying load
$\Delta h_{1,6}$: Cooling heat load

11.3.2 Heating

(1) Indoor air circulates to heat up.

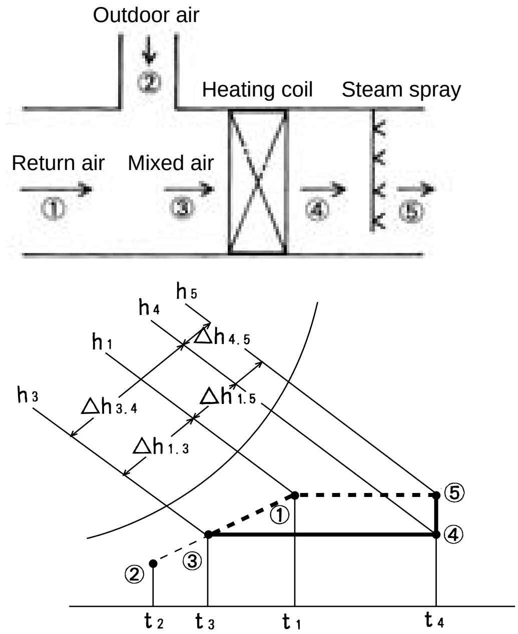
Fig.11-14



$\Delta h_{1,2}$: Heating coil load or heating heat load

(2) Fresh air (outdoor air) is taken to heat up and humidify.

Fig.11-15

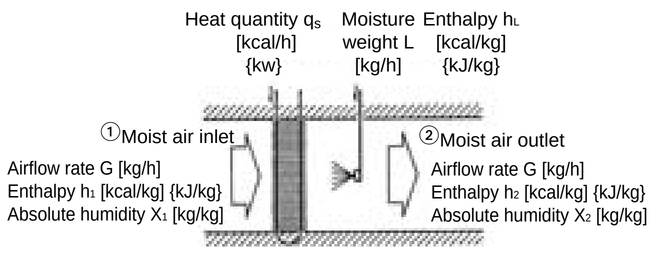


$\Delta h_{3,4}$: Heating coil load
$\Delta h_{3,1}$: Fresh air load
$\Delta h_{4,5}$: Humidifying load
$\Delta h_{1,5}$: Heating heat load

11.4 Heat quantity calculation through psychrometric chart

11.4.1 Heat balance

Fig.11-16



① Assume that bypassing moist air in the state of ① (airflow rate G [kg/h], enthalpy h_1 [kcal/kg] {kJ/kg}, and absolute humidity X_1 [kg/kg] through insulated path adding heat quantity q_s [kcal/h] {kw} enthalpy h_L [kcal/kg] {kJ/kg} of moisture L [kg/h] to the moist air, moist air in the state of ② (airflow rate G [kg/h], enthalpy h_2 [kcal/kg] {kJ/kg}, and absolute humidity X_2 [kg/kg] is obtained.
In this system, assume the heat balance (thermal equilibrium) between the above ① and ②.

(a) Heat quantity of inlet moist air $G \times h_1$[kg / h] × [kcal / kg]{(kJ/kg)/ 3600} = [kcal / h]{kw}
(b) Heat added q_s+($L \times h_L$) [kcal / h]{kw} +([kg / h] ×[kcal / kg] {(kJ/kg)/ 3600}) = [kcal / kg]{kw}
(c) Heat quantity of outlet moist air $G \times h_2$[kg / h] × [kcal / kg]{(kJ/kg)/ 3600} = [kcal / h]{kw}

Under the equilibrium condition,
(a)+(b) = (c)→$Gh_1+q_s+Lh_L = Gh_2$→ $\boxed{G(h_2\text{-}h_1) = q_s + Lh_L}$ ···(4.1)
In the same way, assume the moisture balance (mass balance).

(d) Moisture in intake air	$G \times X_1$	[kg / h]×[kg / kg] = [kg / h]
(e) Moisture added	L	[kg / h]
(f) Moisture in discharged air	$G \times X_2$	[kg / h]×[kg / kg] = [kg / h]

Under the equilibrium condition,
(d) + (e) = (f) → $GX_1 + L = GX_2$ → $\boxed{G(X_2\ \ X_1) = L}$ ············(4.2)
The above two equations (4.1) and (4.2) are the fundamental equations for the air conditioning process, which hold not only in air-conditioned rooms but also for the state changes of moist air in air conditioners.

11.4.2 Practical equations for heat quantity calculations

Lh_L in the fundamental equation (4.1) is the latent heat of evaporation of water. Substituting q for Lh_L and assuming that q (total heat) = q_s (sensible heat) + q_L (latent heat).
Equation (4.1) will be

$$\boxed{q = q_s+q_L = G(h_2\ h_1) = G\Delta h[\text{kcal/h}]} \quad \cdots\cdots\cdots\cdots(4.3)$$

$$q = q_s+q_L = \frac{1}{3600}G(h2-h1) = \frac{1}{3600}G\Delta h\{\text{kw}\}$$

q	: Heat quantity required for state changes	[kcal/h]{kw}
G	: Airflow rate (fan delivery), (weight unit)	[kg/h]
h_1	: Enthalpy of air at the beginning	[kcal/kg]{kJ/kg}
h_2	: Enthalpy after state change	[kcal/kg]{kJ/kg}
Δh	: Enthalpy change rate	[kcal/kg]{kJ/kg}

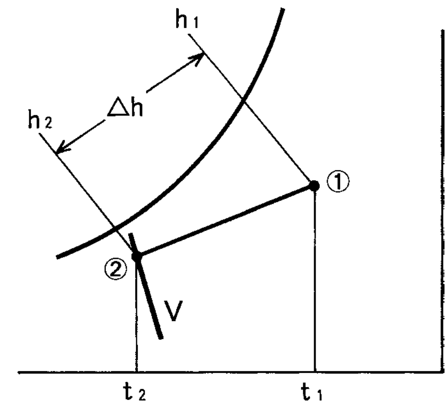
In theoretical calculations, air is handled in weight unit (Gkg/h), while in practical calculations for air conditioning, it is convenient to handle air in volume unit (Qm^3/h).

$$\boxed{q = Q \times \frac{1}{V} \times \Delta h} \quad \cdots\cdots\cdots\cdots(4.4)$$

Q: Airflow rate (fan delivery)	[m^3/h]	(volume unit)
V: Air specific volume	[m^3/kg]	(discharge air)

Equation to convert the airflow rate G [kg/h] into the air volume Q [m^3/h]
$Q[m^3 / h]=G[kg / h] \times V[m^3 / h]$ ·································(4.5)

Fig.11-17

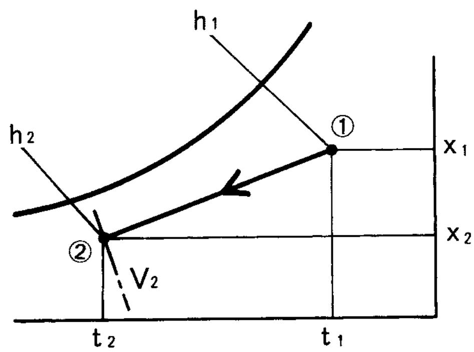


① Evaporator inlet air
② Evaporator outlet air

1. Equations for cooling and dehumidifying rate calculations

For changing the state of moist air from ① into ②:

Fig.11-18



Use the following equations to find heat quantity required for cooling qt [kcal/h] *{k/w}*.

$$q_T = G(h_1-h_2) = Q \times \frac{1}{V_2} \times (h_1-h_2)[\text{kcal/h}] \quad \cdots\cdots\cdots\cdots (4.6)$$

$$q_T = \frac{1}{3600}G(h_1-h_2) = \frac{1}{3600}Q \times \frac{1}{V_2}(h_1-h_2)\{\text{kw}\} \quad \cdots\cdots\cdots\cdots (4.6)$$

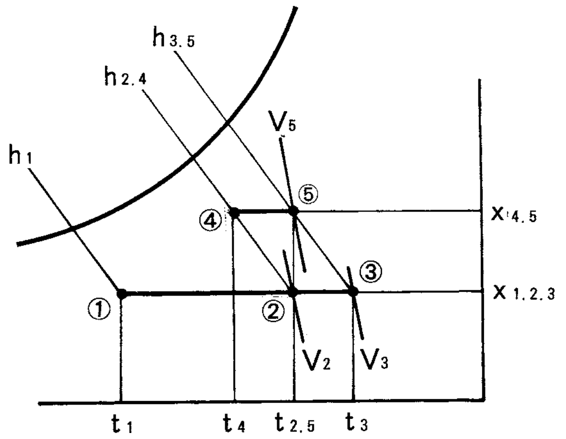
At this time, the dehumidifying capacity L (drain water quantity [kg/h] will be

$$L = G(X_1-X_2) = Q \times \frac{1}{V_2} \times (X_1-X_2) \quad \cdots\cdots\cdots\cdots (4.7)$$

2. Equations for heating and humidifying rate calculations

For changing the state of moist air from ① into ⑤:

Fig.11-19



2.1 When steam humidifier is used

(a) Heating rate in order to heat ① up to ②.

$$q_H=G(h_2-h_1)=Q\times\frac{1}{V_2}\times(h_2-h_1)[\text{kcal/h}] \cdots\cdots (4.8)$$

$$q_H=\frac{1}{3600}G(h_2-h_1)=\frac{1}{3600}Q\times\frac{1}{V_2}(h_2-h_1)\{\text{kw}\} \cdots\cdots (4.8)$$

(b) Humidifying rate to humidify ② up to ⑤

$$L_S=G(X_5-X_2)=Q\times\frac{1}{V_5}\times(X_5-X_2)[\text{kg/h}] \cdots\cdots (4.9)$$

2.2 When water spray humidifier is used

(a) Heating rate in order to heat up ① up to ③

$$q_H=G(h_3-h_1)=Q\times\frac{1}{V_3}\times(h_3-h_1)[\text{kcal/h}] \cdots\cdots (4.10)$$

$$q_H=\frac{1}{3600}G(h_3-h_1)=\frac{1}{3600}Q\times\frac{1}{V_3}(h_3-h_1)\{\text{kw}\} \cdots\cdots (4.10)$$

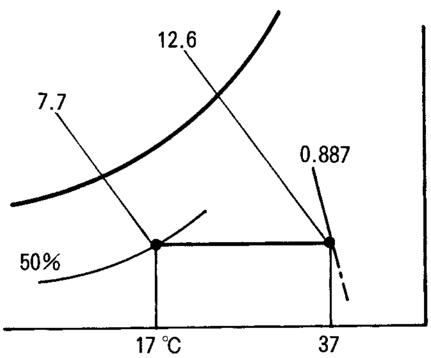
(b) Humidifying rate to humidify ③ up to ⑤

$$L_W=G(X_5-X_3)=Q\times\frac{1}{V_5}\times(X_5-X_3)[\text{kg/h}] \cdots\cdots (4.11)$$

Example 2

As the result of passing moist air having a dry-bulb temperature of 17˚C and a relative humidity of 50% at the heater inlet through the heater, find the heater capacity (i.e., heating rate) at a dry-bulb temperature of 37˚C and an airflow rate of 6000 m^3/h.

Fig.11-20



[Solution] From Equation (4.8),

$$q=Q\times\frac{1}{V_2}\times(h_2-h_1)[\text{kcal/h}]$$

$$q=\frac{1}{3600}\times Q\times\frac{1}{V_2}\times(h_2-h_1)\{\text{kw}\}$$

$$=6000\times\frac{1}{0.887}\times(12.6-7.7)$$

$$=\frac{6000\times4.9}{0.887}\fallingdotseq 33{,}145[\text{kcal/h}]$$

$$q=\frac{1}{3600}\times Q\times\frac{1}{V_2}\times(h_2-h_1)\{\text{kw}\}$$

$$=\frac{1}{3600}\times6000\times\frac{1}{0.887}(52.7-32.2)$$

$$=38.52\{\text{kw}\}$$

Exercise 3

When the heater capacity is 25,000 kcal/h {29.07 kW}, find the moist air temperature after passing through the heater, provided, however, that the heater inlet air has a dry-bulb temperature of 16˚C, a relative humidity of 50%, and an airflow rate of 120 m^3/min. (V = 0.86)

Exercise 4

By sucking indoor air having a dry-bulb temperature of 27˚C and a relative humidity of 50%, moist air is discharged from the evaporator at a dry-bulb temperature of 17˚C and a relative humidity of 90%. Find the capacity of the evaporator at this time, provided, however, that the airflow rate passing through the the evaporator is 13,800 m^3/h.

11.5 Psychrometric chart and air conditioning planning

* For the symbols of Points hereunder, refer to the following explanation (in cooling operation).

① Design indoor temperature and humidity conditions
② Design outdoor temperature and humidity conditions
③ Mixing point of outdoor air and indoor air (conditions at inlet to air conditioner)
④ Design air outlet temperature and humidity conditions
⑤ Air conditioner discharging air temperature and humidity conditions
⑥ Dew point of equipment

11.5.1 Airflow rate calculations in cooling operation

1. Sensible heat factor

Calculate the cooling load required for rooms to be air-conditioned, and assume that the total indoor heat load is qt [kcal/h] *{kW}*, the sensible heat load qs [kcal/h] {kW}, the latent heat load is qL [kcal/h] *{kW}*, and the water evaporation heat is r [kcal/kg] *{kJ/kg}*. Thus, the following equations are obtained.

$$SHF=\frac{q_S}{q_T}=\frac{q_S}{q_S+q_L} \quad \cdots\cdots (5.1)$$

$$U=\frac{r\times q_T}{q_L} \quad \cdots\cdots (5.2)$$

SHF : This stands for the Sensible Heat Factor, which represents the ratio of to the total heat to the sensible heat.

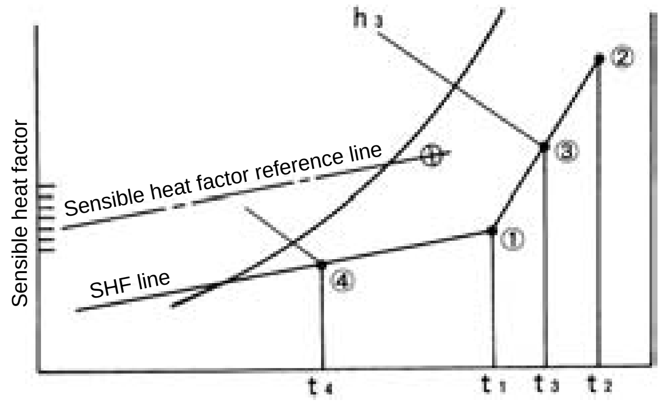
U : Enthalpy-humidity difference ratio

Now, cool air discharged in the air-conditioned room absorbs the indoor heat load, that is, the sensible heat and the latent heat and reaches a target room temperature (design indoor conditions). In other words, it is required to represent the sensible heat factor (SHF) with a line taking the target room temperature as a base point so that cool air is discharged at any point on the line. This line is called SHF line.

2. SHF line

In order to draw the SHF line on the psychrometric chart, draw a reference line. A straight line, which connects the reference point shown in Fig.11-21 and a point on the sensible heat factor scale, is defined as the reference line.

Fig.11-21



In the case of cooling, taking the indoor design condition as the starting point, draw a line to the left in parallel with the reference line. This line is defined as the SHF line.

3. How to find airflow rate (air conditioner discharging air quantity)

The airflow rate is determined according to the demands (i.e., ventilation rate, temperature distribution, and cooling/heating load) on the system side, equipment specifications, and others.

Equations:

$$G\ [kg/h]=\frac{q_S}{0.24\times(t_1-t_4)}=\frac{3600\times q_S}{1.005(t_1-t_4)} \quad \cdots\cdots (5.3)$$

G	: Airflow rate (discharging air quantity)	[kg/h]
t_4	: Design discharge temperature	[°C]
q_S	: Indoor sensible heat load	[kcal/h]{kw}
0.24	: Specific heat of standard air	[kcal/kg·deg]
t_1	: Design indoor dry-bulb temperature	[°C]
1.005	: Specific heat of standard air	{kJ/kg·K}

$$Q\ [m^3/h]=\frac{q_S}{0.24\times\frac{1}{V}\times(t_1-t_4)}=\frac{3600\times q_S}{1.005\times\frac{1}{V}(t_1-t_4)} \quad \cdots\cdots (5.4)$$

$$Q\ [m^3/h]=\frac{q_S}{0.29\times(t_1-t_4)}=\frac{3600\times q_S}{1.21\times(t_1-t_4)} \quad \cdots\cdots (5.5)$$

Q : Airflow rate (discharging air quantity) [m^3/h]

0.29 : The above 0.24 (specific heat of standard air) was obtained from the following equation on the assumption that the air specific volume V is 0.83 m^3/kg.

$$\frac{0.24[kcal/kg^\circ C]}{0.83[m^3/h]} \fallingdotseq 0.29[kcal/m^3deg]=\frac{1.005\{kJ/kg\cdot K\}}{0.83\{m^3/kg\}} \fallingdotseq 1.21\{kJ/m^3\cdot K\}$$

1.21: The above 1.005 (specific heat of standard air) was obtained from the following equation on the assumption that the air specific volume V is 0.83 m^3/kg.

$$\frac{1.005}{0.83} \fallingdotseq 1.21\{kJ/m^3\cdot K\}$$

How to find the design discharge temperature t:

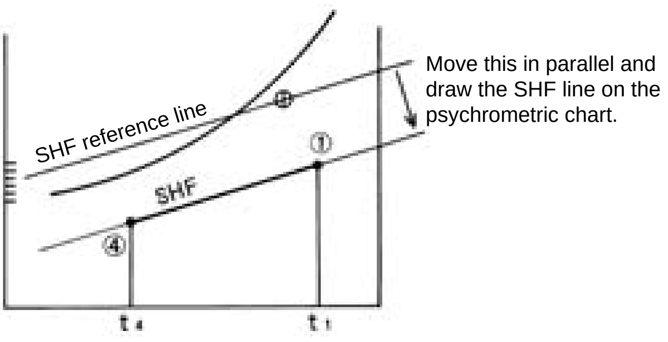
(a) <u>When the airflow rate has been determined</u>, from Equation 5.4,

$$t_4[^\circ C]=t_1-\frac{q_S}{0.24\times Q\times\frac{1}{V}}=t_1-\frac{3600\times q_S}{1.005\times Q\times\frac{1}{V}} \quad \cdots\cdots (5.6)$$

$$t_4[^\circ C] \fallingdotseq t_1-\frac{q_S}{0.29\times Q} \fallingdotseq t_1-\frac{3600\times q_S}{1.21\times Q}=\frac{2975\times q_S}{Q} \quad \cdots\cdots (5.7)$$

On Fig. 11-22 Psychrometric Chart, in the case of cooling, draw the SHF line on the left of the point of indoor design condition, in parallel with the SHF reference line. The Point ④ on the line is defined as the design discharge point corresponding to the indoor load.

Fig.11-22



(b) **<u>When the airflow rate has not been determined</u>**

In this case, it is required to assume the discharge temperature. For ordinary air conditioners, assume that the discharge temperature is lower than indoor design dry-bulb temperature by the neighborhood of 10˚C and the relative humidity at the discharge point is the neighborhood of 85%RH, thus proceeding with the planning.

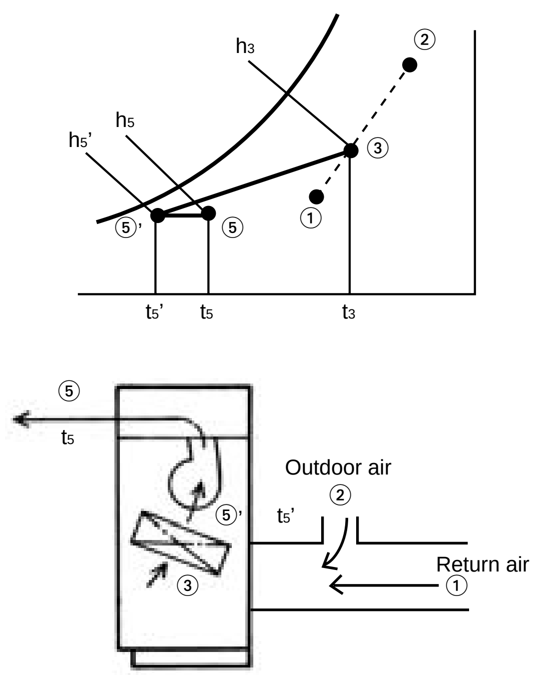
11.5.2 Selection of model

1. When a model has been assumed

(a) How to find the enthalpy h_5 of moist air at the outlet of air conditioner

Take the General-purpose Air Conditioner SRY Type for example to show the enthalpy on the psychrometric chart. This air conditioner cools and dehumidifies moist air sucked by the evaporator and discharges it through the fan. Power energy, which is generated during the above operations, tuns into heat to heat cool air. This state change is represented on the psychrometric chart, as shown in Fig. 11-23 below.

Fig.11-23



t_3, h_3 : State of moist air at the inlet of air conditioner evaporator (If no outdoor air is taken in, Point ③ comes to Point ①.)

$t_{5'}$, $h_{5'}$: State of moist air at the outlet of the evaporator

t_5, h_5 : State of discharge point of air conditioner

G : Airflow weight of air conditioner [kg/h]

Q : Airflow volume of air conditioner [m³/h]

According to the above conditions, the cooling capacity (capacity listed in the catalog) of air conditioner is calculated by the use of the following equation.

$$q_P=G(h_3–h_5)[kcal/h] \quad \cdots\cdots (5.8)$$

$$q_P=\frac{1}{3600}\times G(h_3–h_5)\{kw\}$$

Furthermore, heat (power for fan use) consumed inside the air conditioner is calculated by the use of the following equation.

$$q_F=G(h_5–h_{5'})[kcal/h] \quad \cdots\cdots (5.9)$$

$$q_F=\frac{1}{3600}\times G(h_5–h_{5'})\{kw\}$$

Consequently, the capacity required for equipment is calculated in the following equation.

(Capacity of evaporator)

$$q_E=G(h_1–h_2)+G(h_5–h_{5'})[kcal/h] \quad \cdots\cdots (5.10)$$

$$q_E=\frac{1}{3600}\times G(h_1–h_2)+\frac{1}{3600}\times G(h_5–h_{5'})\{kw\}$$

As for ordinary air conditioning systems using air conditioner, the cooling capacity listed in the catalog is represented by Equation (5.8). Therefore, from Equation (4.6) for the selection of model

$$h_5=h_3–\frac{q_P}{G}\fallingdotseq h_3–\frac{q_P}{1.2\times Q}[kcal/kg] \quad \cdots\cdots (5.11)$$

$$h_5=h_3–\frac{3600\times q_P}{G}\fallingdotseq h_3–\frac{3000\times q_P}{G}\{kw\}$$

The cooling capacity is found in the following manner on the assumption that 1.2 = Specific volume of air is 0.83 m³/kg.

$$\frac{1}{V}\fallingdotseq\frac{1}{083}=1.2[kg/m^3]$$

(b) How to find air conditioner outlet temperature t_5

(b-1) How to find bypass factor

Air is cooled and dehumidified while passing through the evaporator. Practically, however, the whole air is not cooled to the same state. In other words, cooled air and non-cooled air come out in a mixture.

The cooled air is called <u>contact air</u>, while the non-cooled air is called <u>bypass air</u>, which are represented in the following manner.

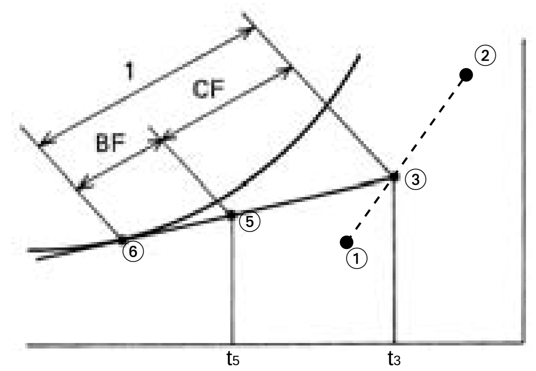
$$BF=1–CF \quad \cdots\cdots (5.12)$$

BF: Bypass factor

CF: Contact factor

Fig. 11-24 shows them on the psychrometric chart. Point C is called "apparatus dew-point temperature".

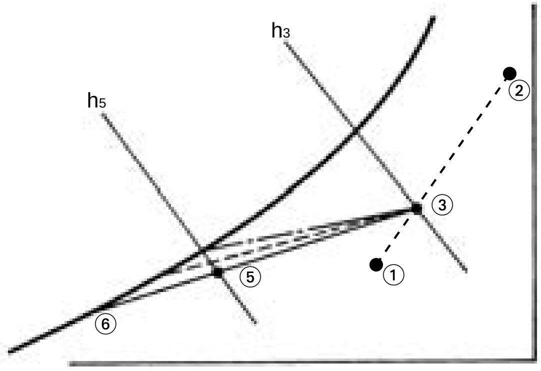
Fig.11-24



Furthermore, the bypass factor varies with the number of lines of evaporators, fin pitches, passing velocity, and others.**The bypass factor of air condition is found according to the technical data.**

If the bypass factor varies, the discharge point of the evaporator varies even though the evaporating capacity is the same.

Fig.11-25

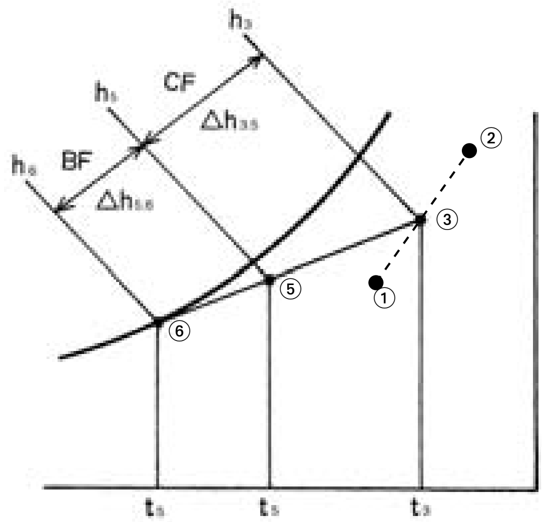


For example, it is assumed that even an evaporator, which can cool and dehumidify air from the enthalpy h_3 of Point ③ down to the enthalpy h_5 of Point ⑤, according to the bypass factor of the evaporator, discharges air in the state of discharge at the discharge point (i.e., evaporator outlet) not from a point on the saturated curve but from some point on the enthalpy h_5 line. In other words, according to the value of the bypass factor, air at the discharge point moves closer to or away from the saturated curve on the enthalpy h_5 line and, at the same time, dry-bulb temperature varies. Therefore, if the bypass factor of evaporator selected is determined, Point ⑤ (evaporator discharge point) and Point ⑥ (apparatus dew point) are determined. Usually, find Point ⑥ first, then draw a straight line between Point ③ and Point ⑥, and define the intersection of the enthalpy h_5 line and the straight line between Points ③ and ⑥ as Point ⑤. And finally find the evaporator discharge point. Thus, the following section describes the method of finding Point ⑥ (apparatus dew point) referring to Fig. 11-26.

(b-2) How to find apparatus dew point enthalpy h_6

According to Fig. 11-26, the following equations are held to find the h_6.

Fig.11-26

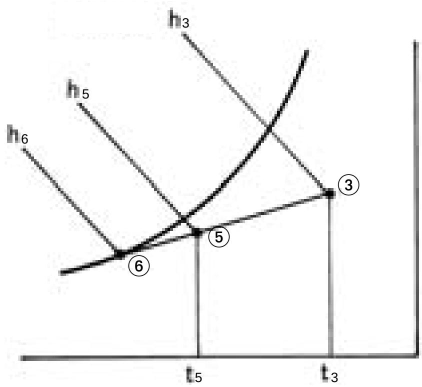


$$\Delta h_{3.5} : \Delta h_{5.6} = CF : BF$$
$$= (1\quad BF) : BF$$
$$\Delta h_{5.6} = \frac{\Delta h_{3.5} \times BF}{1\quad BF}$$
$$\Delta h_{5.6} = h_5 \quad h_6$$
$$\Delta h_{3.5} = h_3 \quad h_5$$
$$h_5 \quad h_6 = \frac{(h_3 \quad h_5) \times BF}{CF}$$
$$h_6 = h_5 \quad \frac{(h_3 \quad h_5) \times BF}{CF} \quad \cdots (5.13)$$

(b-3) How to find air conditioner outlet temperature t_5

On ordinary air conditioners, check for model assumed through the air conditioner outlet enthalpy h_5 found by Equation (5.8). First, write the conditions of air at the inlet of the evaporator on the psychrometric chart and connect them to the apparatus dew-point enthalpy h_6 founded in Section (b-2) with a straight line. Then, write the outlet air enthalpy h_5 found by Equation (5.8) in Section (b). Thus, the intersection of the enthalpy h_5 line and the line connecting between the written point of air at the inlet of the evaporator and the apparatus dew-point enthalpy h_6 is defined as the air conditioner outlet temperature t_5.

Fig.11-27



[Example of calculation]

① From Equation (5.8),

$$q_p = G\,(h_3 \quad h_5)\ \text{[kcal/h]}$$

$$q_p = \frac{1}{3000} \times G\,(h_3 \quad h_5)\ \{\text{kw}\}$$

$$h_5 = h_3 \quad \frac{q_P}{G} \doteq h_5 \quad \frac{q_P}{1.2 \times Q}$$

$$h_5 = h_3 \quad \frac{3600 \times q_P}{G} \doteq h_3 \quad \frac{3000 \times q_P}{Q}\ \{\text{kJ/kg}\}$$

② Substituting h_3 and h_5 into Equation (5.13), the Equation will be

$$h_5 = \frac{(h_3 \quad h_5) \times BF}{CF}$$

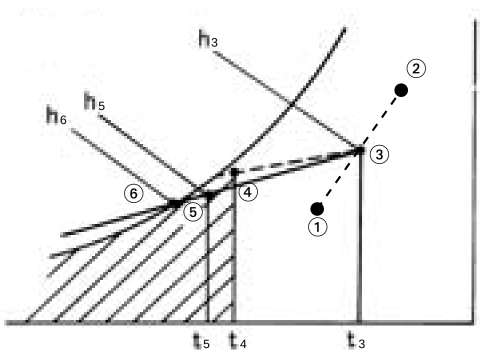
Find BF according to the technical data to calculate the h_6.

③ Draw a straight line between Point ③ and Point ⑥ obtained from h_5 on the psychrometric chart and find t_5 through the intersection of the straight line and h_5.

(c) Availability of model assumed

If the air conditioner outlet temperature t_5 found in Section (b-3) is lower than the design discharge temperature t_4 and located below the apparatus SHF line found by Equation (5.1), the design air conditions are satisfied, making it possible to proceed with calculations according to the model assumed. Fig. 11-28 shows that on the psychrometric chart.

Fig.11-28



It is good if the air conditioner outlet temperature t_5 falls in the shaded area in the above figure. If there is too large difference between the air conditioner outlet temperature t_5 and the design discharge temperature t_4, it is required to use a model of smaller capacity and reexamine the planning since the capacity of the assumed model is too large.

2. When a model is not assumed

Generally speaking, in this case, set up conditions and proceed with planning with a concept to newly produce an air conditioner conforming to the apparatus. Namely, Referring to information in Section 5-1 (3) "(b) When the airflow rate has not been determined", tentatively determine the airflow rate, then, take this airflow rate as a reference to determine the model of air conditioner.

Example

When finding a cooling load required to maintain the conditions of a given room at 26˚CDB and 50%RH, qs = 8,000 kcal/h {9.30kw} and qL = 2,000 kcal/h {2.32kw}. Find the SHF of this room. When the bypass factor BF of the evaporator is 0.11, what is the dry-bulb temperature required to discharge air at a point on the SHF line?

[Solution]

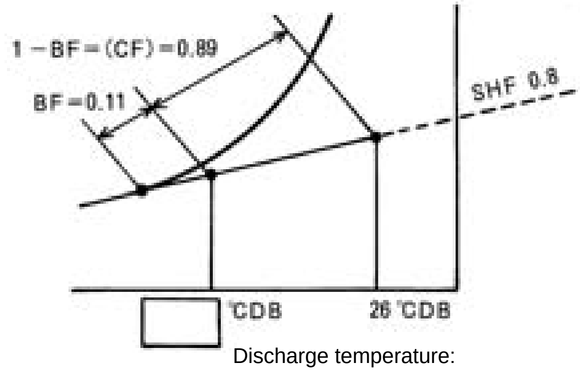
From Equation (5.1),

$$SHF = \frac{q_S}{q_S + q_L} = \frac{8{,}000}{8{,}000 + 2{,}000} = 0.8$$

Use the psychrometric chart of discharge temperature to find the SHF.

$$SHF = \frac{q_S}{q_S + q_L} = \frac{9.32}{9.30 + 2.32} = 0.8$$

Fig.11-29



Exercise 5

Temperature and humidity at the inlet and outlet of air conditioner in a given room were measured. The room had dry-bulb temperature of 25˚C and relative humidity of 60%, while the discharge air has dry-bulb temperature of 15˚C and relative humidity of 90%. Find the sensible heat factor in the room at this time.

Exercise 6

The indoor conditions of dry-bulb temperature of 27˚C and relative humidity of 50% is to be kept constant when a given room has a sensible heat value of qs = 6,800 kcal/h and a latent heat value of q_L = 1,200 kcal/h.
Assuming that the air conditioner discharges air of relative humidity of 85% according to the characteristic of the air conditioner, find the airflow rate (indoor circulated air quantity).

Exercise 7

When an air conditioner, which has BF = 0.1, 23,500kcal/h capacity, and 85m^3/min. airflow rate, is used under the indoor conditions of 27˚C dry-bulb temperature and 50% relative humidity, find the dry-bulb temperature and the wet-bulb temperature at the outlet of the air conditioner.

11.5.3 How to find airflow rate and discharge temperature in heating operation

(1) When a room subject to the calculation is cooled, unless there is any particular reason, take the airflow rate in cooling operation as that in heating operation with no changes and find the discharge temperature according to Equation (5.6).

(2) In the case of heating only, determine the value of (t_1- t_4) of Equation (5.4) according to the equipment applied with consideration given to the ventilation rate of the room, thus finding the airflow rate according to Equation (5.4).
Reference value of (t_1- t_4):
10 to 20˚C when a heating coil is used
30 to 40˚C when a hot-air oven is used

11.6 How to select air conditioners through psychrometric chart

11.6.1 When using discharge air quantity of air conditioner for standard air quantity

1. Select an assumed model according to cooling/heating load for selection of model.

Cooling load (full load): q_T [kcal/h] q_T {kw}
Heating load (full load): q_H [kcal/h] q_H {kw}

Find a model that provides required capacity larger than q_T and q_H according to the standard specifications sheet (JIS conditions) and tentatively determine it.

[Example at 60Hz]

(1) Cooling/heating load for selection of model
Cooling load 28,664 [kcal/h] = 33.33 {kw}
Heating load 23,713 [kcal/h] = 27.57 {kw}
Temperature/humidity conditions (JIS conditions) in standard specifications sheet
Cooling type (air cooling type)

	DB˚C	WB˚C
Indoor conditions	27	19.0
Outdoor-air conditions	35	—

Heating type (air cooling type)

	DB˚C	WB˚C
Indoor conditions	20	—
Outdoor-air conditions	7	6

Check for tentative determination

Find according to **Catalog or Technical data**

On **SRYJ355**

Cooling capacity

Standard 35.5 {kw} > 33.33 {kw}

Heating capacity

Standard 37.5 {kw} > 27.57 {kw}

2. Calculate the capacity of the equipment determined tentatively

There are the following five determinant factors.
(a) Design outdoor air conditions
(b) Conditions of air at inlet of evaporator in cooling operation
(c) Conditions of air at inlet of heater in heating operation
(d) On air-cooling type, correction of capacity according to the length and the difference in levels of refrigerant piping
(e) Defrost correction of heating capacity (Air-cooling heat pump)

The factors (a) through (d) can be omitted from the determinant factors, provided that the design conditions coincide with standard specifications.

(2) Determination of equipment capacity of SRYJ355

(a) Design conditions

In cooling operation

	DB˚C	WB˚C
Indoor conditions	26	18.7
Outdoor-air conditions	34.4	26.9

In heating operation

	DB˚C	WB˚C
Indoor conditions	20	13.8
Outdoor-air conditions	–1.9	–3.9

Based on the above-mentioned, find a variety of data and determine the equipment capacity according to Daikin's Technical Data.

Calculations of factors (b) and (c)

Planned conditions of SRYP355PA

Airflow rate (SA) = $105m^3$/min×60= $6300m^3$/h

Return air rate (RA) = $5575m^3$/h

Outdoor air rate (OA) = $725m^3$/h

(Outdoor air intake rate K = 725/6300 = 0.115)

Furthermore, as for the factors (b) and (c) conditions of air at inlet of evaporator and heater, if the suction air is all indoor return-air, the planned design conditions are used. If outdoor intake air is mixed in the indoor return-air, the air is defined as mixed air, which is required to find the mixing point according to Equation (2.1).

(a) Planned outdoor air conditions

Subject to customer request or drawing of air conditioning equipment

(b) Conditions of air at inlet of evaporator in cooling operation

(c) Conditions of air at inlet of heater in heating operation

Calculate according to the psychrometric chart or Equation (2.1) subject to whether or not intake outdoor air is required and the method.

Follow the psychrometric chart and Equations on the basis of factors (a), (b), and (c).

Conditions of air at inlet of evaporator:

In cooling operation; 27.0˚CDB and 19.8˚CWB

Conditions of air at inlet of heater:

In heating; 17.5˚CDB

Determination of equipment capacity

Use the SRYJ355PA Capacity Characteristic Sheet in the Technical Data to proportionally find the capacity for the intermediate point that is not listed in the Sheet.

From the Technical Data,

Cooling capacity **36.72** kw

Heating capacity **31.67** kw

(Outdoor air D.B. of -3.9˚CWB at humidity of 85% is -3.2˚CD.B..)

(d) On air-cooled type, correction of capacity according to the length and the difference in levels of refrigerant piping

Calculate the length and difference in level of refrigerant piping according to the drawing of air conditioning equipment or a survey on the installation locations of indoor and outdoor units and the correction values according to the Technical Data.

Using the capacity correction according to the refrigerant piping length and the design drawings, assume that the refrigerant piping equivalent length (Lm) = 35 meters and the difference of level (Hpm) = 5 meters.

From the Technical Data,

Cooling capacity variation ratio = **0.989**

Heating capacity variation ratio = **0.948**

(e) Defrost correction of heating capacity (Air-cooled heat pump)

Calculate the correction value according to the Technical Data on the basis of the planned conditions.

Design conditions of capacity correction according to defrosting in heating operation

From the Technical Data,

Integral correction coefficient at the time of frost formation = 0.876 (outdoor air: -3.2˚CD.B.)

According to the above data, the actual equipment capacity will be

Cooling capacity = 36.72 × 0.989

= 36.32 kw > 33.33kw

Heating capacity = 31.67 × 0.948 × 0.876

= 26.30 kw < 27.57kw

Thus, the cooling load can be compensated, while it is required to consider the incorporation of auxiliary electric heater due to the insufficient heating capacity.

According to the Technical Data, the type of the auxiliary electric heater SRYJ355PA is defined as KEHY12E 15 and the auxiliary electric heater capacity as 12 kW.

Therefore, the heating capacity will be

26.30 + 12 = 38.30 kw > 27.57 kw

3. Check whether or not the assumed model coincides with the planned design conditions.

In cooling operation:

3.1 Check for the discharge point.

(a) Find the sensible heat factor of the room.

From Equation (5.1),

$$SHF=\frac{q_S}{q_S+q_L}$$

SHF ; Sensible heat factor

q_S ; Sensible heat load (kcal/h)

q_L ; Latent heat load (kcal/h)

Check the assumed model for the availability

(a) Find the sensible heat factor of the room.

Sensible heat load q_S 19437 kcal/h = 22.60 kw

Latent heat load q_L 1595 kcal/h = 1.85 kw

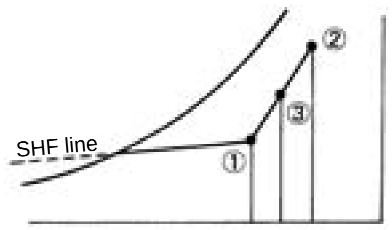
Sensible heat factor

$$SHF=\frac{19437}{19437+1595}=0.92$$

$$=\frac{22.60}{22.60+1.85}=0.92$$

(b) Plot proven conditions on the psychrometric chart.

Fig.11-30



① Indoor conditions
② Outdoor-air conditions
③ Evaporator inlet conditions (Mixing point)

Write the following on the psychroimetric chart.

Indoor conditions: (26.0˚CDB, 18.7˚CWB)

Outdoor-air conditions: (34.4˚CDB, 26.9˚CWB)

SHF line = 0.92

(c) Find the design discharge-air condition t_4.

When cool air is discharged in the room, it absorbs the indoor heat load (sensible heat + latent heat), thus keeping residential space at the indoor design temperature and humidity. Therefore, find the discharge temperature t_4 in the following manner.

From Equation (5.6),

$$t_4 = t_1 \quad \frac{q_s}{0.24 \times Q \times \frac{1}{V_4}}, = t_1 \quad \frac{3600 \times q_s}{1.005 \times Q \times \frac{1}{V_4}}$$

Furthermore, from Equation (5.7),

$$t_4 \fallingdotseq t_1 \quad \frac{q_s}{0.29 \times Q}, \fallingdotseq t_1 \quad \frac{2957 \times q_s}{Q}$$

Find the design discharge air conditions.

(Discharge conditions ④ as the apparatus)

Use Equation (5.7) here.

$$t_4 \fallingdotseq 26 \quad \frac{19437 \times 1.05}{0.29 \times 6300} = 14.8 \{ C\}$$

(1.05 is an allowance for the load used to select a model.)

$$t_4 \fallingdotseq 26 \quad \frac{2975 \times 22.6 \times 1.05}{6300} = 14.8 \{ C\}$$

(d) Find the evaporator's suction cooler inlet condition t_3.

The point found in Section (2) (b) is defined as ③ evaporator's suction temperature and humidity.

However, if no outdoor air is taken in, the aforementioned Point ① is defined as the suction conditions of the evaporator.

Write the suction condition point ③ of the evaporator on the psychrometric chart.

Mixing point ③ (27˚C DB, 19.7˚C WB)

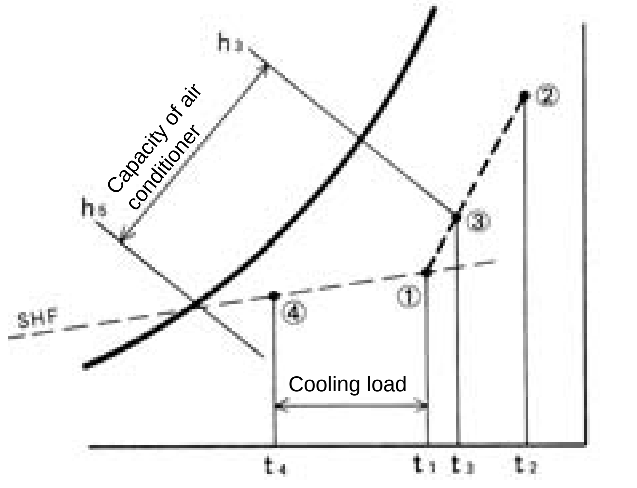
(e) Find the enthalpy h_5 of air at the outlet of the evaporator.

Through Equation (5.11),

$$h_5 = h_3 \quad \frac{q_P}{Q \times \frac{1}{V_5}} = h_3 \quad \frac{3600 \times q_P}{Q \times \frac{1}{V_5}} \{kJ/kg\}$$

$$h_5 \fallingdotseq h_3 \quad \frac{q_P}{1.2 \times Q} \fallingdotseq h_3 \quad \frac{3600 \times q_P}{Q} \{kJ/kg\}$$

Fig.11-31



Enthalpy h_5 of air at outlet of evaporator

$$h_5 = 13.5 \quad \frac{36.32 \times 860}{1.2 \times 6300}$$

$$= 9.36 \text{ [kcal/kg]}$$

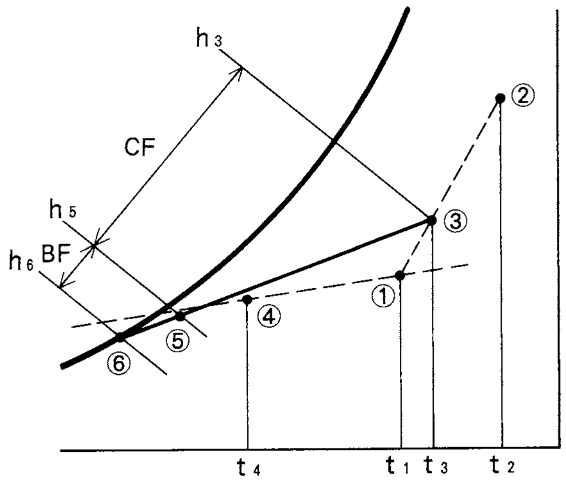
$$h_5 = 56.5 \quad \frac{3000 \times 36.32}{6300}$$

$$= 39.2 \{kJ/kg\}$$

(f) Find the enthalpy h_6 of the dew point of equipment (apparatus). Find the bypass factor (BF) from the data on the equipment tentatively selected, then find the enthalpy according to the following Equation and chart.

$$h_6 = h_5 \quad \frac{(h_3 \quad h_5) \times BF}{(1 \quad BF)} \cdots\cdots \quad (5.12)$$

Fig.11-32



Find the enthalpy h of the dew point of air conditioner.

$$h_6 = 9.36 \quad \frac{(13.5 \quad 9.36) \times 0.08}{1 \quad 0.08}$$

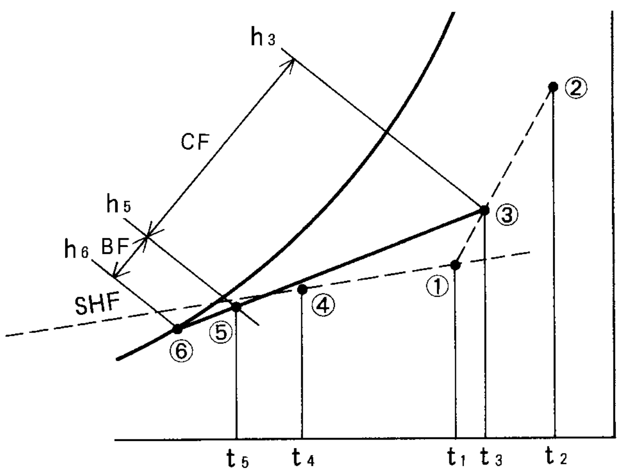
$$= 9.0 \text{ [kcal/kg]}$$

$$t_6 = 39.2 \quad \frac{(56.5 \quad 39.2) \times 0.08}{1 \quad 0.08}$$

$$= 37.7 \text{ \{KJ/kg\}}$$

(g) Find the discharge point t_5 of the equipment (apparatus). Connect with a straight line the suction condition ③ of the evaporator found on the psychrometric chart in (d) and the intersection ⑥ of the enthalpy line of the dew point of the equipment found in (f) and the relative humidity of 100% line. Taking the intersection ⑤ of this straight line and the constant enthalpy line h_5 found in (e) as the outlet of the evaporator, find the t_5 through the psychrometric chart.

Fig.11-33

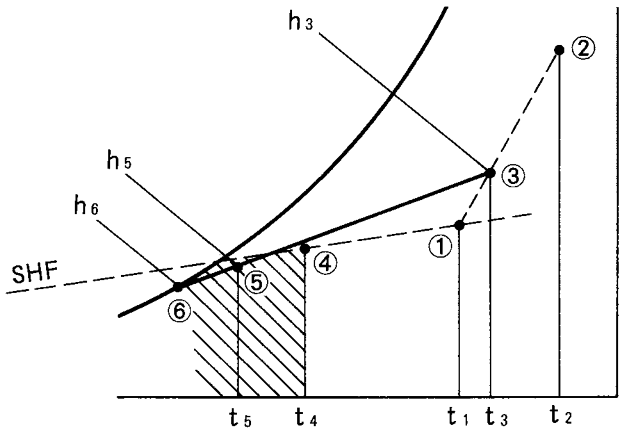


(h) Checking discharge point

If the equipment discharge point ⑤ found in (g) is lower than the design discharge point ④ found in (b) in temperature and is located under the SHF line, it becomes proven that the equipment meets the design conditions.

It is good if the discharge point ⑤ falls in the shaded area in the following figure. If there is too large difference between t_5 and t_4 even in the shaded area, it is required to use a model of smaller capacity and reexamine the planning since the capacity of the assumed model is too large.

Fig.11-34



By calculating and examining the above eight items, determine the model of air conditioner used for ordinary cooling use. Namely, the indoor temperature is assured as the design condition, while the humidity is determined on a go-it-alone basis, thus planning an operating point toward a dehumidifying tendency.

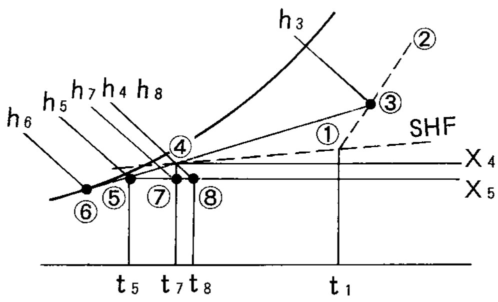
Furthermore, if constant temperature and humidity control other than ordinary air conditioning, yearly constant temperature and humidity conditions, and others are required, plan the equipment based on more accurate calculations and further install a reheating coil, humidifier or the like.

3.2 Coinciding with indoor design conditions

As the result of the aforementioned examination, the discharge point of the apparatus does not coincides with that of the equipment. Apparatuses, which cannot keep the indoor design conditions (e.g. constant temperature and humidity) constant unless they are coincided, must be equipped with reheating coil, humidifier, or the like.

The following section shows an example of the planning in that case.

Fig.11-35



(a)Humidifying weight:

$$L = Q \times \frac{1}{V_{4(7)}} \times (X_4 \quad X_5)$$

•••••••••

Q: Air quantity (value determined in Section (3)) [m³/h]
V: Specific volume at the outlet of humidifier [m³/kg]

(b)Re-heater capacity

a. In the case of evaporative-plate-type humidifier: ⑤ → ⑦

$$q_{Ha} = Q \times \frac{1}{V_7} \times (h_7 \quad h_5) \quad \text{••••••[kcal/h]}$$

$$q_{Ha} = \frac{1}{3600} \times Q \times \frac{1}{V_7} \times (h_7 \quad h_5) \text{ •••[kw]}$$

b. In the case of water-spray-type humidifier: ⑤ → ⑧

$$q_{Hb} = Q \times \frac{1}{V_8} \times (h_8 \quad h_5) \quad \text{•••••••••}$$

[kcal/h]

$$\frac{1}{3600} \qquad \frac{1}{V_8}$$

Thus, $h_8 = h_4$

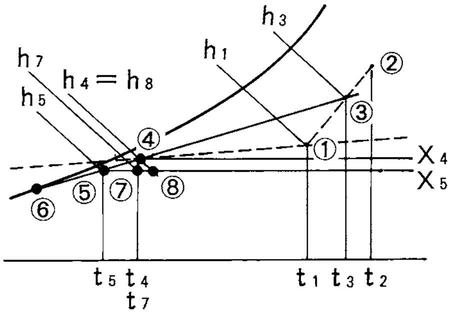
In the case of water-spray-type humidifier, the points change with wet-bulb temperature unchanged, thus changing on the constant line of h_4 (= h_8).

Note) Examine whether or not the capacities of selected humidifier and re-heater can be compensated with optional accessories of model to be used.

3.3 Summary in cooling operation

The cycle is shown on the psychrometric chart.

Fig.11-36



① Indoor point
② Outdoor-air point
③ Mixing point = Evaporator suction point
④ Design discharge point (assumed discharge point of air conditioner)
= Outlet of humidifier
⑤ Evaporator discharge point = Inlet of re-heater
⑥ Dew point of apparatus
⑦ Outlet of re-heater = Inlet of evaporative-plate-type humidifier
⑧ Outlet of re-heater = Inlet of water-spray-type humidifier

○ Evaporating capacity = h_3 - h_5

Breakdown
a. Indoor load: h_1 - h_4
b. Outdoor-air load: h_3 - h_1
c. Reheating load: (Heater capacity)
d. In the case of evaporative-plate-type humidifier: h_7 – h_5
e. In the case of water-spray-type humidifier: h_8 - h_5

○ Humidifier capacity = X_4 - X_5

[In heating operation]

3.4 Check for the discharge point

(a)Find the sensible heat factor of the room.

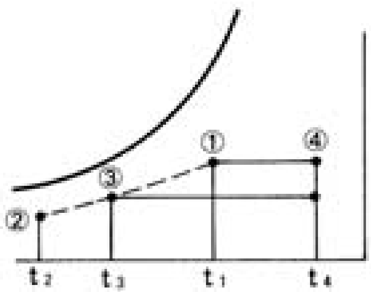
From Equation (5.1)

$$SHF = \frac{q_{HS}}{q_{HS} + q_{HL}}$$

SHF :Sensible heat factor
q_{HS} :Sensible heat load [kcal/h] {kw}
q_{HL} :Latent heat load [kcal/h] {kw}

(b)Plot proven conditions on the psychrometric chart.

Fig.11-37



① Indoor conditions
② Outdoor-air conditions
③ Heater suction conditions (Mixing point)

(c)Find the heater suction point ③.

Point found in Section (2)-(c) .... Point ③

However, if no outdoor air is taken in, the aforementioned Point ① is defined as the suction conditions of the evaporator.

In heating operation

	DB˚C	WB˚C
Indoor conditions	20	13.8
Outdoor-air conditions	–1.9	–3.9

From the above table,
the heater suction temperature becomes 17.5˚CDB.

(d)Find the design discharge air condition t_4.

$$Q\ (m^3/h) = \frac{q_{HS}}{0.24 \times \frac{1}{V_4} \times (t_4 \quad t_1)}$$

$$= \frac{3600 \times q_{HS}}{1.005 \times \frac{1}{V_4} \times (t_4 \quad t_1)}$$

$$t_4 = t_1 + \frac{q_{HS}}{0.24 \times \frac{1}{V_4} \times Q}$$

$$\fallingdotseq t_1 + \frac{q_{HS}}{0.27 \times Q}$$

$$t_4 = t_1 + \frac{3600 \times q_{HS}}{1.005 \times Q \times \frac{1}{V_4}}$$

$$\fallingdotseq t_1 + \frac{3600 \times q_{HS}}{Q}$$

$$t_4 = 20 + \frac{17111 \times 1.10}{0.27 \times 6300}$$

$= 31.1$ [C]

- 17111[kcal/h]{19.90kw} represents the indoor sensible heat load.
- 1.10 represents the allowance for the load used to select a model.

$$t_4 = 20 + \frac{3200 \times 19.9 \times 1.1}{6300}$$

$= 31.1$ { C}

Q : Airflow rate (same as that in cooling operation) (m^3/h)

V : Specific volume of air at discharge point (m^3/kg)

0.27 : The specific heat at constant pressure 0.24 of air was found on the assumption that the specific volume of air at the discharge point of hot air is 0.875.

$$0.24 \times \frac{1}{0.875} = 0.27$$

Furthermore, calculate the specific volume V_4 of air at the discharge point for more accurate calculation by Equation (5.6) once and determine the V_4 according to the calculation result. Then, re-calculate the specific volume again to make sure the results coincide each other.

(e)Find the outlet point of the heater.

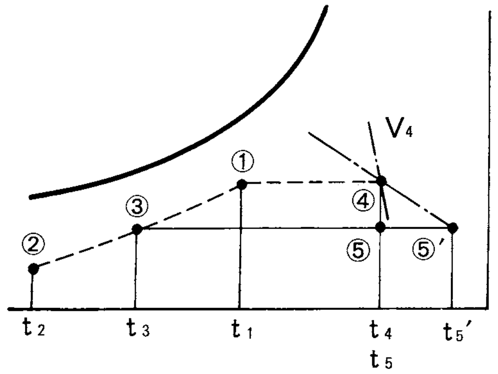
$$t_5 = t_3 + \frac{q_{PH}}{0.24 \times Q \times \frac{1}{V_5}} \ (\ C)$$

$$\fallingdotseq t_3 + \frac{q_{PH}}{0.27 \times Q}$$

$$t_5 = t_3 + \frac{3600 \times q_{PH}}{1.005 \times Q \times \frac{1}{V_5}}$$

$$\fallingdotseq t_3 + \frac{3200 \times q_{PH}}{Q}$$

Fig.11-38



(In the case of no electric heaters used)

$$t_5 = 17.5 + \frac{26.3 \times 860}{0.27 \times 6300}$$

$= 30.8$ [C]

$$t_5 = 17.5 + \frac{3200 \times 26.3}{6300}$$

$= 30.8$ [C]

As for the changes of air in the heater, only the dry-bulb temperature increases with the absolute humidity kept constant.
In Fig. 11-38, Point ⑤ represents the outlet point of the heater in the case of steam-spray-type or evaporative-plate-type humidifier, while Point ⑤' represents that in the case of water-spray-type one.

(f) Check for the outlet point of the heater: It is good if $t_4 < t_5$. (Check for the heating capacity.)
If the discharge point ⑤ found in (e) has a temperature higher than that at Point ⑤ in the case of evaporative-plate-type or steam-spray-type humidifier, or higher than that of Point ⑤' in the case of water-spray-type humidifier, it becomes proven that the heating capacity can coincide with the heating load.

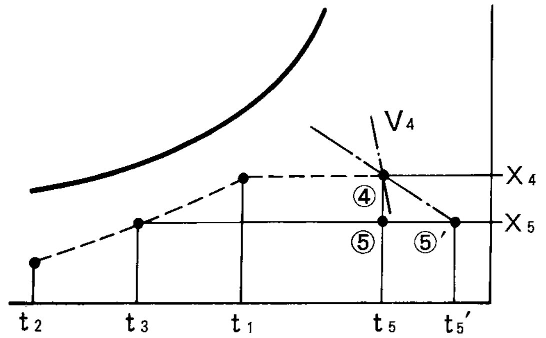
(g)Find the humidifier capacity L (kg/h).

$$L = Q \times \frac{1}{V_4} \times (X_4 \quad X_5)\ (kg/h)$$

$$L = 6{,}300 \times \frac{1}{0.875} \times (0.0073 \quad 0.0067)$$

$= 4.3$ (kg/h)

Fig.11-39

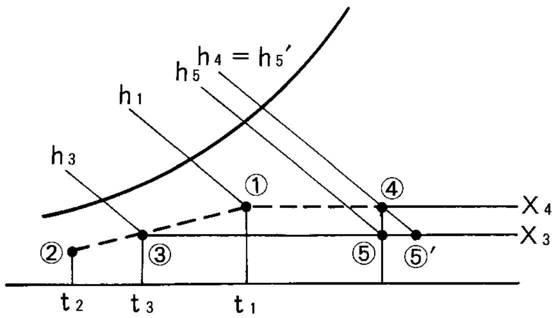


X_4: Absolute humidity at outlet point ④ of humidifier
.... (kg/kg)
X_5: Absolute humidity at inlet point ⑤ or ⑤' of heater
.... (kg/kg)
When the humidifying weight is determined, specify the type from the optional accessories list in the Technical Data.

When selecting with evaporative-plate-type humidifier,
Type: KEM104D15,
Humidifying capacity: 5.2 (kg/h), and
Power consumption: 4 (kW)

(h) Summary in heating operation
The cycle is shown on the psychrometric chart.

Fig.11-40



① Indoor point
② Outdoor-air point
③ Mixing point = Heater suction point
④ Design discharge point = Outlet point of humidifier
⑤ Heater outlet point = Inlet of evaporative-plate-type humidifier
⑤' Heater outlet point = Inlet of water-spray-type humidifier
- ○ Heater capacity = h_5' or h_5 - h_3
  (h_5': In the case of water-spray-type humidifier
  h_5: In the case of evaporative-plate-type humidifier)
- ○ Indoor load: h_4 - h_1
- ○ Outdoor-air load: h_1 - h_3
- ○ Humidifying load: h_4 - h_5
- ○ Humidifying capacity: X_4 - X_5

11.6.2 Selection of model with priority given to apparatus and airflow rate

In cooling operation

1. Find the sensible heat factor.

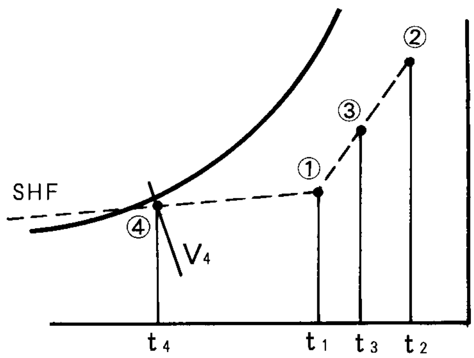
From Equation (5.1),

$$SHF= \frac{q_S}{q_S+q_L}$$

2. Plot the proven conditions on the psychrometric chart.

Indoor condition ....Point ①
Outdoor-air condition
(When outdoor air is taken in) ....Point ②
SHF line...SHF line found in ①.

Fig.11-41



3. Find the airflow rate of apparatus.

$$Q= \frac{q_S}{0.24 \quad \frac{1}{V_4} \quad (t_1-t_4)} = \frac{3600 \quad q_S}{1.005 \quad \frac{1}{V_4} \quad (t_1-t_4)}$$ (q_S : kcal, q_S : kw)

V_4: Assuming the discharge point ④ of apparatus, calculate the specific volume of air. [m^3/kg]
t_4 : Assume the discharge point ④ of apparatus. [˚C]

How to assume t_4

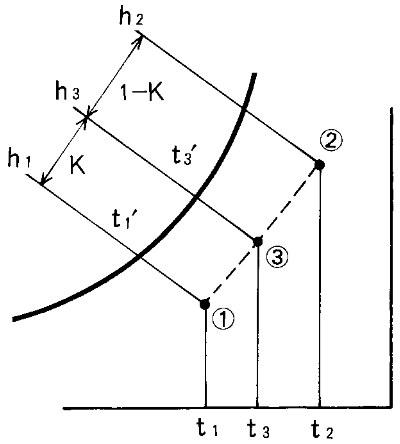
In the case of ordinary cooling operation, assume that the difference (t_1- t_4) in temperature between suction and discharge is 8 to 12 deg. and the relative humidity at the discharge point falls in the range of 80 to 90%.

4. Find the conditions of air at the inlet of evaporator.

(a) When outdoor air is taken in the air conditioner
Find the mixing point ③, which is present on the straight line connecting the outdoor-air point ② and the indoor point ①. The point ③ is defined as the suction point.
(From Equation (2.1))

$t_3 \fallingdotseq K \cdot t_2 + (1 - K) \cdot t_1$............... [˚C]
$h_3 \fallingdotseq K \cdot h_2 + (1 - K) \cdot h_1$............ [kcal/kg]{kJ/kg}

Fig.11-42



t_3, h_3	:	Dry-bulb temperature and enthalpy at the mixing point ③
t_2, h_2	:	Dry-bulb temperature and enthalpy at the outdoor-air point ②
t_1, h_1	:	Dry-bulb temperature and enthalpy at the indoor point ①
K	:	Mixing ratio of outdoor air
$t_{3'}$	:	Wet-bulb temperature at the suction point ③

(b) If no outdoor air is taken in, the indoor point ① is defined as the suction point. $t_{1'}$ = Wet-bulb temperature at the suction point ①.

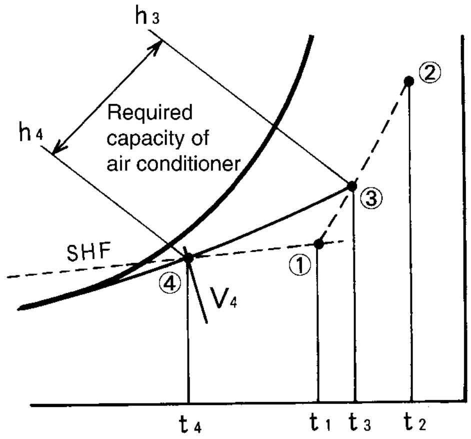
5. Find the required capacity of air conditioner. (From Equation (4.6))

$$q = Q \frac{1}{V_4} (h_3 - h_4) \cdots\cdots [kcal/h]$$

$$q = \frac{1}{3600} Q \frac{1}{V_4} (h_3 - h_4) \cdots\cdots \{kw\}$$

Q	:	Airflow rate (determined in (3)) [m^3/h]
V_4	:	Specific volume at the discharge point ④ [m^3/kg]
h_3	:	Enthalpy at the suction point ③ (when outdoor air is mixed) [kcal/kg] {kJ/kg}
(Note)		If no outdoor air is taken in, the indoor point ① is defined as the suction point. .... h_1
h_4	:	Enthalpy at the discharge point ④ [kcal/kg] {kJ/kg}

Fig.11-43



6. Selection of model

From the Technical Data,

(a) Tentatively determine the model.

Tentatively determine the model, which can meet the airflow rate found in (3) and the capacity found in (5).

(b) Calculate the cooling capacity of the model tentatively determined.

Pay attention to a variety of correction items according to the Technical Data.

(Conditions of evaporator suction air, outdoor-air conditions, cooling water temperature, airflow rate, length and difference in level of refrigerant piping, and others)

7. Find the enthalpy h_5 at the outlet of air conditioner.

From Equation (5.11),

$$h_5 = h_3 - \frac{q_P}{Q \frac{1}{V_5}} [kcal/kg] = h_3 - \frac{3600\ q_P}{Q \frac{1}{V_5}} \{kJ/kg\}$$

q_P:		Cooling capacity of model tentatively determined in (6)-(b) [kcal/h]{kw}
V_5:		Since the specific volume of air at the discharge point has not determined at this stage, assume it. Tentatively substitute V_4 of Section (5).

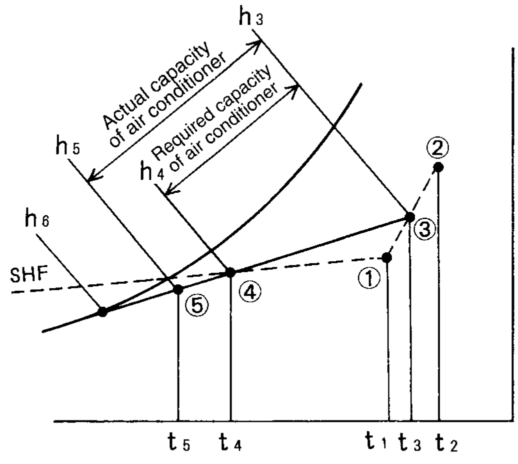
8. Find the enthalpy h_6 of apparatus dew point.

From Equation (5.12),

BF: Find according to the Technical Data of assumed model.

$$h_6 = \frac{(h_3\quad h_5) \times BF}{(1\quad BF)}$$

Fig.11-44



9. Find the discharge temperature t_5 of air conditioner of assumed model.

Connect the apparatus dew point ⑥ found in the above Section (8) and the suction point ③ with a straight line. The intersection of this straight line and the h_5 line is determined as the discharge point of the assumed model.

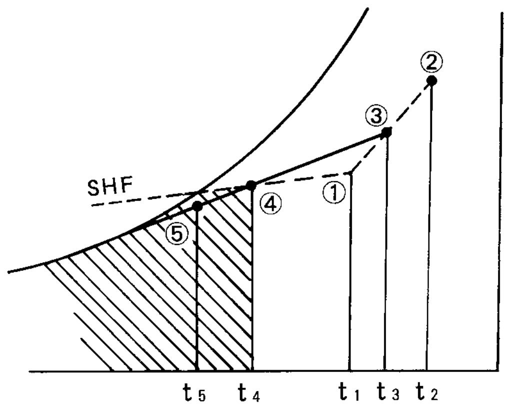
10. Selection of model

If the discharge dry-bulb temperature t_5 of air conditioner found in Section (9) is lower than the discharge temperature t_4 assumed at the time of determination of airflow rate in Section (3), and the discharge point ⑤ is located below the SHF line passing the indoor point ①, the assumed model can be used.
It is good if the discharge point ⑤ falls in the shaded area.

Note) If there is large difference between t_4 and t_5 even though they fall in the shaded area, reduce the size of the assumed model by one step to reexamine.

By calculating and examining the above ten items, determine the model of air conditioner used for ordinary cooling use.
Furthermore, if constant temperature and humidity control and yearly constant temperature and humidity conditions are required, further install a reheating coil, humidifier or the like.

Fig.11-45



11. Others

If the design discharge point ④ does not coincide with the actual discharge point ⑤ (in the case of the assumed model used) or the planned indoor conditions cannot be kept constant unless they are coincided (if constant temperature and humidity control and yearly constant temperature and humidity conditions are required), a reheating coil and humidifier must be added.

(a) Humidifying weight: $L = Q \times \frac{1}{V_4} \times (X_4\ X_5)$ ....[kg/h]

Q: Airflow rate (determined in (3)) ....[m³/kg]
V_4: Specific volume at the out3let of humidifier...[m³/kg]

(b) Re-heater capacity

a. In the case of evaporative-plate-type humidifier ⑤ → ⑦

$$q = Q \frac{1}{V_7} (h_7 - h_5) \cdots\cdots [\text{kcal/h}]$$

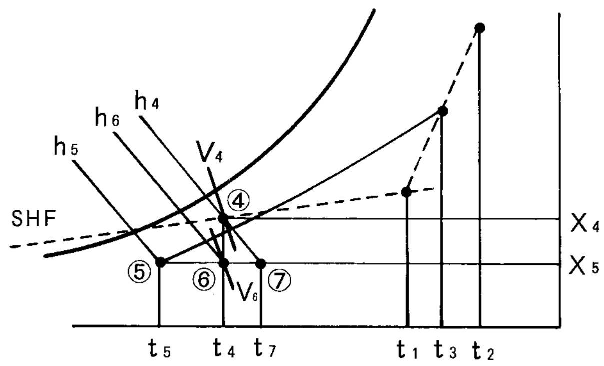
$$q = \frac{1}{3600} Q \frac{1}{V_7} (h_7 - h_5) \cdots\cdots \{\text{kw}\}$$

b. In the case of water-spray-type humidifier ⑤ → ⑧

$$q = Q \frac{1}{V_8} (h_8 - h_5) \cdots\cdots [\text{kcal/h}]$$

$$q = \frac{1}{3600} Q \frac{1}{V_8} (h_8 - h_5) \cdots\cdots \{\text{kw}\}$$

Fig.11-46



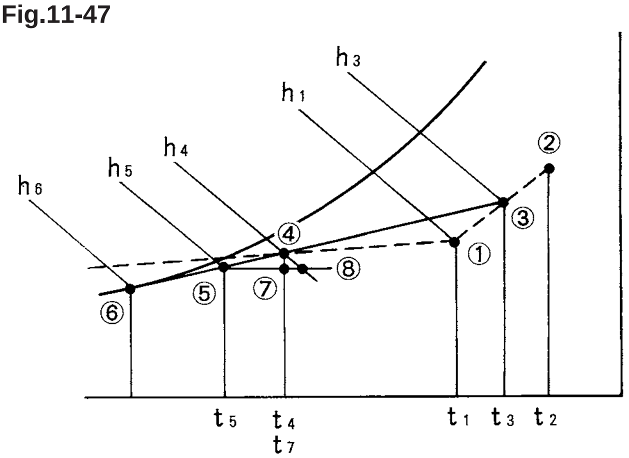
In the case of water-spray-type humidifier, the points change with wet-bulb temperature unchanged, thus changing on the constant line of h_4 .

Note) Examine whether or not the capacities of selected humidifier and re-heater can be compensated with optional accessories of model to be used.

12. Summary in cooling operation

The cycle is shown on the psychrometric chart.

Fig.11-47



① Indoor point
② Outdoor-air point
③ Mixing point = Evaporator suction point
④ Design discharge point (assumed discharge point of air conditioner) = Outlet of humidifier
⑤ Evaporator discharge point = Inlet of re-heater
⑥ Dew point of apparatus
⑦ Outlet of re-heater = Inlet of evaporative-plate-type humidifier
⑧ Outlet of re-heater = Inlet of water-spray-type humidifier

In heating operation

As for heating, find the data according to the method and procedure in Section 6.1. Furthermore, find the heater capacity in the following procedure and determine the model.

1. Find the required heater capacity.

The required heater capacity varies depending on whether the evaporative-plate-type (steam-spray-type) humidifier or water-spray-type one is used.

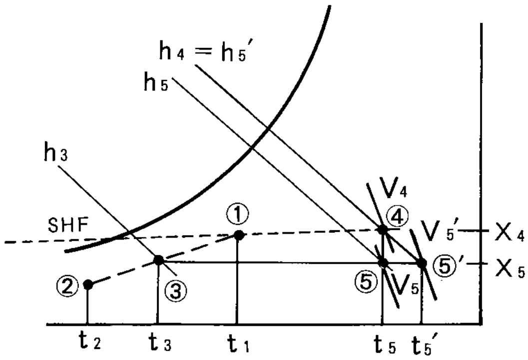
(a) In the case of evaporative-plate-type humidifier: ③ → ⑤

$$q_{HS} = Q \frac{1}{V_5} (h_5 - h_3) \cdots\cdots \text{[kcal/h]}$$

$$q_{HS} = \frac{1}{3600} Q \frac{1}{V_5} (h_5 - h_3) \cdots\cdots \text{\{kw\}}$$

Q : Airflow rate [m³/h]
V_5 : Specific volume at the heater outlet ⑤ [m³/kg]
h_5 : Enthalpy at the heater outlet ⑤ [kcal/kg] {kJ/kg}
h_3 : Enthalpy at the heater inlet ③ [kcal/kg] {kJ/kg}

Fig.11-48



(b) In the case of water-spray-type humidifier: ③ → ⑤'

$$q_{HW} = Q \frac{1}{V_{5'}} (h_{5'} - h_3) \cdots\cdots \text{[kcal/h]}$$

$$q_{HW} = \frac{1}{3600} Q \frac{1}{V_{5'}} (h_{5'} - h_3) \cdots\cdots \text{\{kw\}}$$

Q : Airflow rate [m³/h]
$V_{5'}$: Specific volume at the heater outlet ⑤' [m³/kg]
$h_{5'}$: Enthalpy at the heater outlet ⑤' [kcal/kg] {kJ/kg}
h_3 : Enthalpy at the heater inlet ③ [kcal/kg] {kJ/kg}

Note) As for the required heater capacity q_{HS} or q_{HW}, it is required to examine whether or not the optional accessories heater (electricity, hot water, steam, or else is used as the heat source, which is required to determine at first) of model determined to use is applicable.

2. Find the required humidifier capacity.

Find the humidifying capacity through the psychrometric chart.

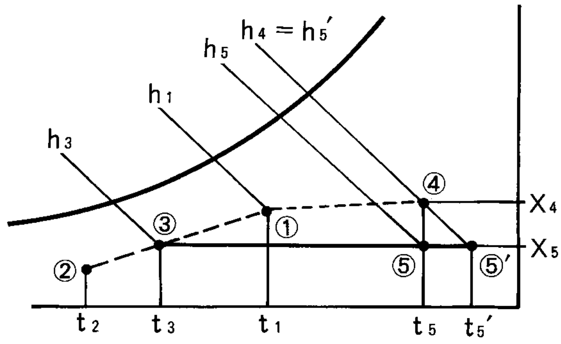
$$L = Q \frac{1}{V_4} (X_4 - X_5)$$

L: Humidifier capacity [kg/h]

3. Summary in heating operation

The cycle is shown on the psychrometric chart.

Fig.11-49

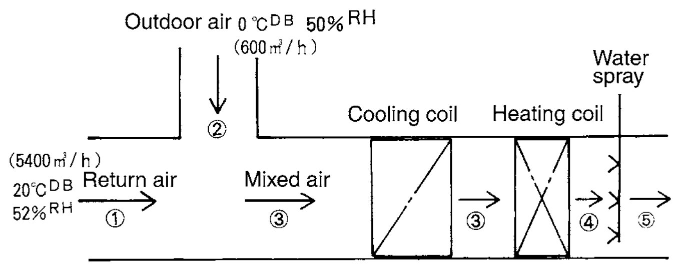


① Indoor point
② Outdoor-air point
③ Mixing point = Heater suction point
④ Design discharge point = Outlet point of humidifier
⑤' Heater outlet point = Inlet of water-spray-type humidifier
⑤ Heater outlet point = Inlet of evaporative-plate-type humidifier

Exercise 8

Draw the state changes of air with the following apparatuses on the psychrometric chart.

Fig.11-50



Heating heat value: 28000 [kcal/h]
Humidifying weight: 10 kg/h

Exercise 9

There is a room having a sensible heat load of 8,500 kcal/h and a latent heat load of 7,000 kcal/h. What is the design discharge temperature required to provide the indoor condition of 26˚CDB and 50%RH Furthermore, is any re-heater required? If required, calculate the capacity of the re-heater. However, the capacity of air conditioner shall be 20,000 kcal/h with BF = 0.1 and airflow rate = 3000m³/h.

11.7 Answers to exercises

Answers to Exercise 1

Enthalpy	9.21	[kcal/kg]
Dew-point temperature	9	[˚C]
Specific volume	0.84	[m^3/kg]
Wet-bulb temperature	13.7	[˚C]
Absolute humidity	0.0072	[kg/kg]

Answers to Exercise 2

Dry-bulb temperature	= 28.8	[˚C]
Enthalpy	= 16.42	[kcal/kg]
Absolute humidity	= 0.0156	[kg/kg]

Answers to Exercise 3

From Equation: $q_H = Q \frac{1}{V} (h_2 - h_1)$

$$h_2 - h_1 = \frac{25000}{120 \quad 60 \quad \frac{1}{0.86}} = 2.99$$

$h_1 = 7.28 + 2.99 = 10.27$ kcal/kg

∴ From psychrometric chart,
Answers: Dry-bulb temperature 28.1 [˚C]
Relative humidity 24 [%]

Answer to Exercise 4

From Equation: $q_T = Q \frac{1}{V} (h_1 - h_2)$

Through the psychrometric chart

$$q_T = 13800 \quad \frac{1}{0.836} \quad (13.3 - 10.72)$$

=42,589 [kcal/h]

$$Q = \frac{q_S}{0.24 \quad \frac{1}{V} \quad (t_1 - t_2)}$$

$$= \frac{6800}{0.24 \quad \frac{1}{0.836} \quad (27 - 17.3)}$$

=2,442 [m^3/h]

Answer: 2,442 [m^3/h]

Answer to Exercise 5

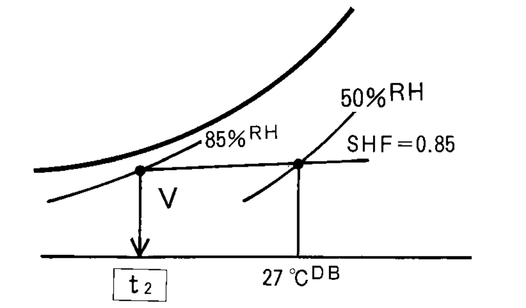
From psychrometric chart, SHF = 0.63
Answer : SHF = 0.63

Answer to Exercise 6

$$SHF = \frac{6800}{6800+1200} = 0.85$$

Find the discharge temperature and specific volume through the psychrometric chart.

Fig.11-51



Answers to Exercise 7

From Equation $h_5 = h_3 - \frac{q_p}{G} = h_3 - \frac{q_p}{1.2Q}$

Through the psychrometeric chart

① $h_5 = 13.3 - \frac{23500}{1.2 \quad 85 \quad 60}$

=13.3 - 3.84

=9.46 [kcal/kg]

② Find the enthalpy at the dew point of apparatus.

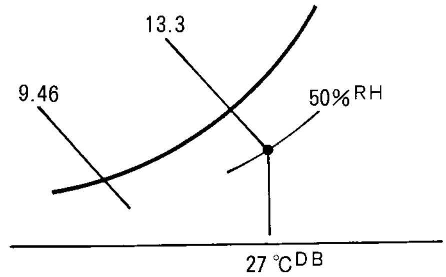
From Equation $h_6 = h_5 - \frac{(h_3 - h_5)\ BF}{CF}$

$= 9.46 - \frac{(13.3 - 9.46)\ 0.1}{(1 - 0.1)}$

=9.46-0.43

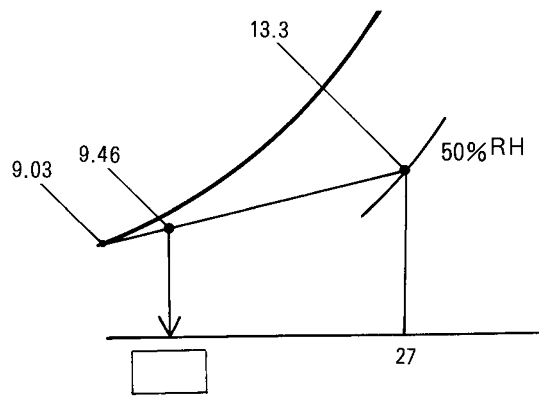
=9.03 [kcal/kg]

Fig.11-52



Find the answer through the psychrometric chart.

Fig.11-53



Answers
Dry-bulb temperature : 14.8˚C
Wet-bulb temperature : 14.1˚C

Answers to Exercise 8

①Find the mixed air ③.

From Equation (2.1), $t_3=K\ \ t_2+(1-K)t_1$

$t_3=0.1\ 0+(1-0.1)\ 20$

$=18\ [\ C]$

$h_3=K\ \ h_2+(1-K)h_1$

$=0.1\ 1.1+(1-0.1)\ 9.4$

$=0.11+8.46$

$=8.57$ [kcal/kg]

According to the above calculation, the mixed air ③ reaches 18 CDB and 54.5%RH.

②Find the state ④ at the outlet of heating coil.

Substituting numerical value through Equation (4.10):

$$q_H=Q\ \ \frac{1}{V_3}(h_3\ \ h_1)$$

$$2800=6000\ \ \frac{1}{V}\ \ (h_4-8.57)$$

$$h_4=8.57+\frac{2800}{6000\ \ \frac{1}{V(0.882)}}$$ Assume that V=0.882.

$$=8.57+4.12$$

$$\fallingdotseq 12.7\ [\text{kcal/kg}]$$ Thus, make sure through the psychrometric chart.

③Find the state ⑤ of air after humidification

Substituting numerical value through Equation (4.11):

$$L_W=Q\ \ \frac{1}{V_3}(X_5\ \ X_3)$$

$$10=6000\ \ \frac{1}{V}\ \ (X_5-0.0069)$$

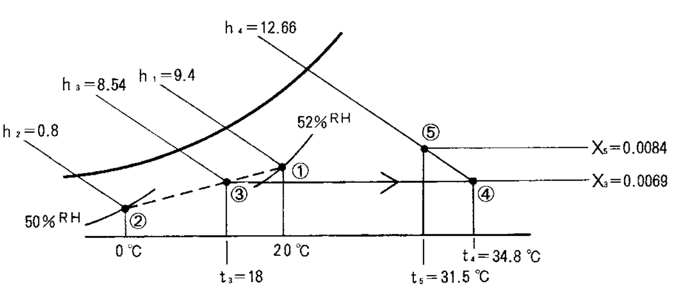
$$X_5=0.0069+\frac{10}{6000\ \ \frac{1}{V}}$$ Assume that V=0.875.

$$X_5\fallingdotseq 8.57+4.12$$

$$=0.0084$$

④Write the numerical values found in the above ①, ②, and ③ on the psychrometric chart.

Fig.11-54



Answers to Exercise 9

① Find the sensible heat factor SHF.

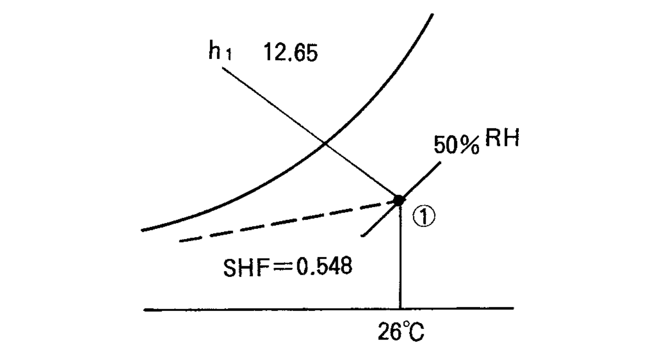
From Equation (4.1): $SHF=\frac{q_S}{q_S+q_L}$

$=\frac{8500}{8500+7000}$

$=0.548$

Write the SHF on the psychrometric chart and find the conditions of suction air of air conditioner.
Enthalpy h_1 of inlet air =12.65 [kcal/kg]

Fig.11-55



②Find the discharge point of air conditioner.

From Equation (5.11): $h_5\fallingdotseq h_3-\frac{q_p}{1.2\ Q}$

$h_2=12.65-\frac{2000}{1.2\ 3000}$

$=12.65-5.56$

$=7.09$ [kcal/kg]

Write the enthalpy h_5 at the outlet of air conditioner on the psychrometric chart.

From Equation (5.13): $h_6=h_5-\frac{(h_3-h_5)\ BF}{CF}$

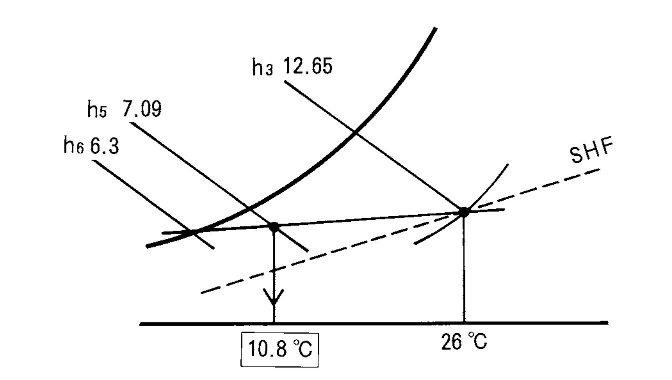
$h_6=7.09-\frac{(12.65-5.56)\ 0.1}{(1-0.1)}$

$=7.09-0.79$

$=6.3$ [kcal/kg]

In order to provide the discharge point of air conditioner on the SHF line.

Fig.11-56



Install a re-heater and determine the re-heater capacity.

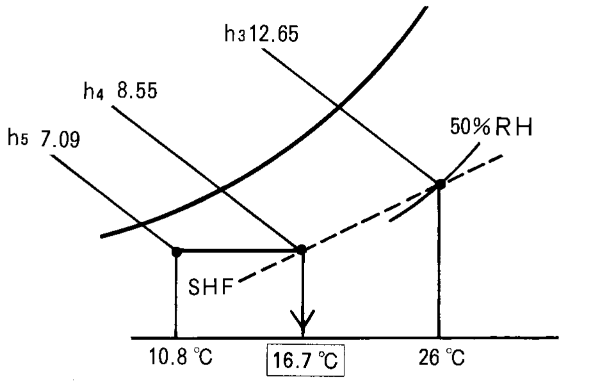
③ Find the re-heater capacity

$$q_H = Q \quad \frac{1}{V} (h_4 \quad h_5)$$

$$= 3000 \quad \frac{1}{0.831} \quad (8.55 - 7.09)$$

$$\fallingdotseq 5{,}271 \text{ [kcal/h]}$$

Fig.11-57



Answers

Discharge temperature: 16.7 [˚C]

Reheating capacity 5,271 [kcal/h]

Chapter 12 Simple cooling / heating load calculation

Chapter 12 Simple cooling / heating load calculation

This chapter is prepared with the purpose to make service technicians know the concept of heat load calculations necessary for service work. Although the factors used for load calculation differ with districts more or less, in this chapter, the factors used in Japan are used. Therefore, it is a little dangerous to obtain actual heat load accurately with the values shown in this chapter. (But, the only exception will be shown on the temperature difference between outdoor and indoor temperature in heating load calculation where eight cities over the world have been chosen for the example. Heating load (Heat loss) is mainly depends on the temperature difference. Therefore rough calculation can be gained in the heating calculation process).

12.1 Purposes and applications

This calculation list is made for finding the approximate cooling load quickly and easily.
Therefore, it is not recommended to use this method in case of necessity of exact calculation.

12.2 Kinds of heat load

Fig.12-1

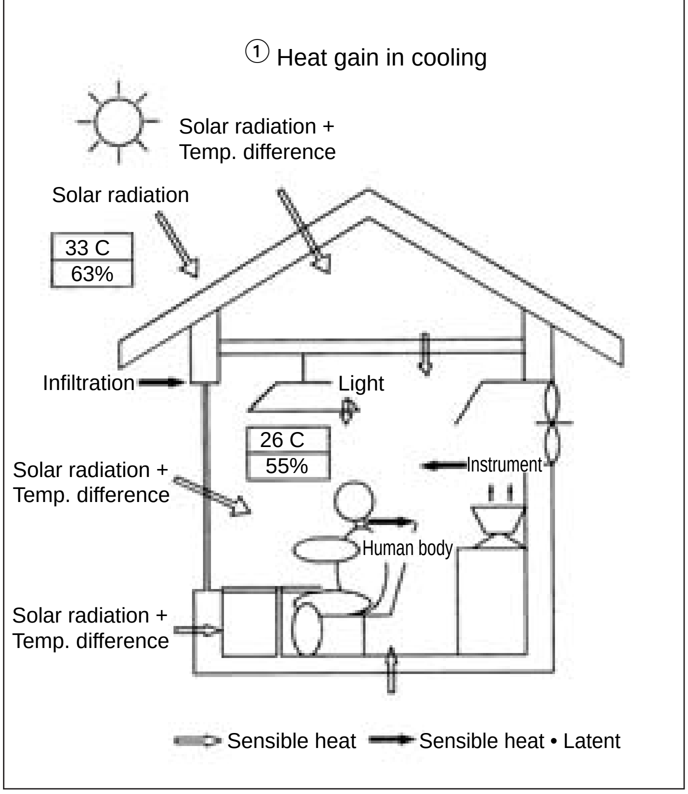
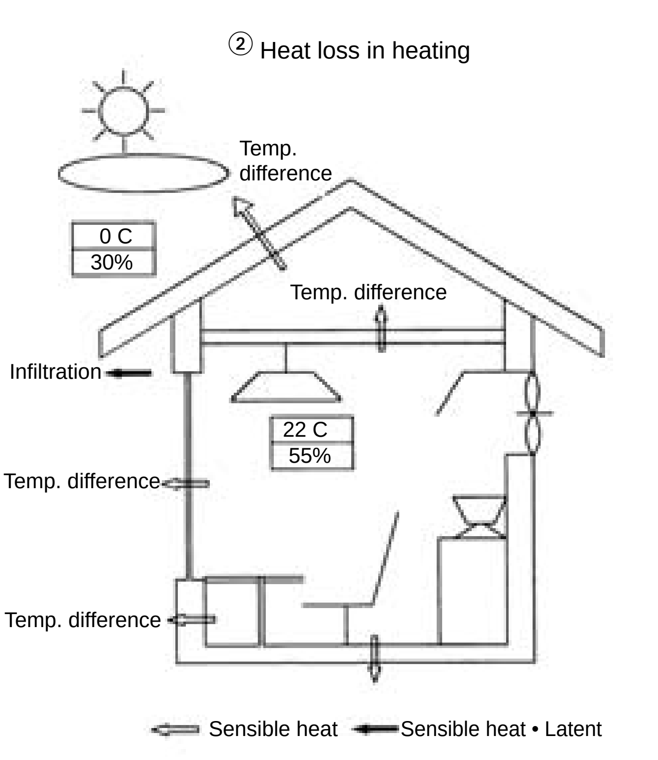


Fig.12-2



12.3 Design Conditions

Table 12-1 Composition of heat load

		Heat source	Heat		Heat gain (Cooling load)	Heat loss (Heating load)
			Sensible heat	Latent heat		
Indoor load	External load	1. Roof·wall·partition·floor·ceiling «Solar radiation, night radiation, temp. difference»	○		□	■
		2. Window glass «Solar radiation, night radiation, temp. difference»	○		□	■
		3. Infiltration «Temperature and humidity of infiltrated air»	○	◉	□	■
	Internal load	4. Illuminant «Generated heat»	○		□	
		5. Human body·equipment «Generated heat»	○	◉	□	
Outdoor air		6. Intake fresh air «Temperature and humidity in outdoor air»	○	◉	□	■

Table 12-2 Cooling load conditions

	Dry bulb temp. (DB)	Wet bulb temp. (WB)	Relative humidity (RH)
Outdoor conditions	33˚C	27˚C	63˚C
Indoor conditions	26˚C	19.5˚C	55˚C

Note:
Since these conditions about indoor and outdoor are included in the coefficient "B" in the Cooling/Heating load list, the figuring out of temperature difference is not required.

Table 12-3 Heating load conditions
Figure out the temperature difference from the following table.

Outdoor temperature ˚C	Brussels Belgium	Shanghai China	Hong Kong China	Tokyo Japan	Riyadh Saudi Arabia	Buenos Aires Argentina	Paris France	Sydney Australia
	-7	-3	10	-2	4	1	-4	5

Note:
1) These data are drawn out from ASHRAE HANDBOOK
2) When night heating is regarded as importance, reduce further 2 degrees from the above temp.

Table 12-4

Indoor temperature ˚C	State of action	Examples
22	Seated at rest or very light work	Office, theater, residence, restaurant, etc.
20	Little active	Factory (light work), school, store, etc.
18	Very active	Factory (Heavy work), dance hall, etc.

12.4 Coefficient of cooling load

12.4.1 Wall faced to the outdoor

Table 12-5

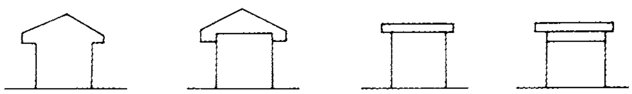
Sort of wall	Coefficient B W/m² (kcal/m²h)								Coefficient E W/m²°C (kcal/m²h°C)
	E	SE	S	SW	W	NW	N	NE	
Light construction (wooden, mortar)	43 (37)	40 (34)	34 (29)	50 (43)	59 (51)	49 (42)	20 (17)	33 (28)	2.9 (2.5)
Medium construction (concrete block)	47 (40)	44 (38)	40 (34)	56 (48)	65 (56)	52 (45)	17 (15)	37 (32)	
Heavy construction (concrete 200mm t)	40 (34)	40 (34)	36 (31)	47 (40)	43 (37)	30 (26)	19 (16)	34 (29)	3.5 (3.0)

12.4.2 Roof

Table 12-6

Sort of roof		Coefficient B W/m² (kcal/m²h)	Coefficient E W/m²°C (kcal/m²h°C)
Light construction (slate, mortar or sheet zinc)	No Ceiling	192 (165)	3.5 (3)
	Ceiling	70 (60)	1.7 (1.5)
Medium construction (thin concrete insulation)	No Ceiling	107 (92)	23 (2)
	Ceiling	44 (38)	1.7 (1.5)
Heavy construction (thick concrete insulation)	No Ceiling	50 (43)	1.2 (1)
	Ceiling	27 (23)	1.2 (1)

(Reference)



No ceiling Ceiling No ceiling Ceiling

12.4.3 Window glass

Table 12-7

Sort of wall	Coefficient B W/m² (kcal/m²h)									Coefficient E W/m²°C (kcal/m²h°C)
	Shady window	Sunny window								
		E	SE	S	SW	W	NW	N	NE	
Normal glass plate (3mm thick)	70 (60)	686 (590)	500 (430)	361 (310)	616 (530)	826 (710)	628 (540)	174 (150)	512 (440)	64 (5.5)
Normal glass plate (6mm thick)	64 (55)	628 (550)	454 (390)	337 (290)	558 (480)	756 (650)	570 (490)	163 (140)	465 (400)	
Insulation type (3mm thick)	41 (35)	430 (370)	314 (270)	256 (220)	395 (340)	512 (440)	395 (340)	105 (90)	314 (270)	
Dual glass (6mm thick inside)	35 (30)	337 (290)	244 (210)	198 (170)	302 (260)	395 (340)	302 (260)	81 (70)	250 (215)	2.6 (2.2)
Glass block	29 (25)	384 (330)	221 (190)	151 (130)	302 (260)	419 (360)	279 (240)	47 (40)	233 (200)	2.9 (2.5)

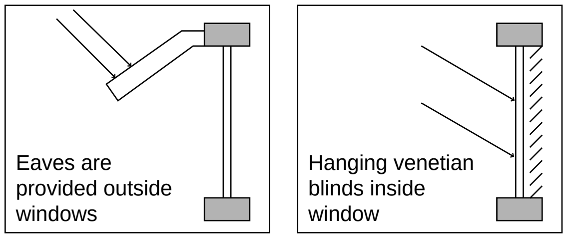
Note:
In case more than two windows are provided in different directions, the coefficient B of the window having the largest value of A×B only is taken from the column of "Sunny window" and those of other windows are taken from the column of "Shady window".
A: Area of window
B: Coefficient B

12.4.4 Coefficient shade to window

Table 12-8

Sort of blind	Coefficient f
Eaves are provided outside windows	0.25
Hanging venetian blinds inside window	0.7
Hanging comparatively heavy curtain	0.8
Hanging comparatively thin curtain	0.9

Fig.12-3



12.4.5 Partition of the room (In case adjoind rooms are not cooled)

Table 12-9

Sort of partition	Coefficient B W/m²(kcal/m²h)	Coefficient E W/m²°C (kcal/m²h°C)
Glass or paper slide door	15 (13)	5.2 (4.5)
Others	9 (8)	3.1 (27)

12.4.6 Ceiling and floor (In case upper and lower rooms are not cooled)

Table 12-10

Sort of ceiling and floor	Coefficient B W/m²(kcal/m²h)	Coefficient E W/m²°C (kcal/m²h°C)
Only concrete	12 (10)	3.5 (3)
Linoleum or carpet placed on the floor	8 (7)	2.3 (2)
Grass mat placed on the wooden floor	5 (4)	1.2 (1)
Floor attached on the ground directly	0 (0)	1.2 (1)

12.4.7 Outdoor air

Heat load by outdoor air should be calculated in both ways; required air volume and infiltrated air and then chose whichever large one.
On the calculation list, the occupant number and the volume of the room should be filled in the columns for the required air volume and the infiltration respectively.

Table 12-11 Required outdoor air intake

Application	Coefficient B W / person (kcal/h · person)	Coefficient E W/˚C · person (kcal / h˚C · person)
Bank, Department store, Theater, No smoking area	158 (136)	5.8 (5)
Office, Meeting room, Hotel, Restaurant, Hospital, Condominium	242 (208)	8.7 (7.5)
Private room, Smoking area	465 (400)	17.5 (15)

<Reference> If the occupant number are unknown, set the occupants based on the following data.
· Hotel room·Single room in hospital
………………………… 1 person /10 m^2 floor area
· General office, Beauty parlor, Barber shop, Photo shop
………………………… 2 persons/10 m^2 floor area
· General store, Residence, Condominium
………………………… 3 persons/10 m^2 floor area
· Meeting room, Tea shop, Restaurant, Family room in restaurant, Bar
………………………… 6 persons /10 m^2 floor area
· Department store
………………………… 1 person/2~3 m^2 floor area
· Theater
………………………… 1 person/0.8 m^2 audience floor

Table 12-12 Infiltration air

	Coefficient B W/m^3 $(kcal/m^3h)$	Coefficient E $W/m^3{}^\circ C$ $(kcal/m^3h^\circ C)$
Standard	9.3 (8)	0.4 (0.3)
the room with frequent coming in/out or with wide area of the windows exposed to outdoor	14 (12) ~ 19 (16)	0.5 (0.45) ~ 0.7 (0.6)

12.4.8 Area correction for outdoor temperature

Table 12-13

Area (district)	Coefficient f
Standard	1.0
Higher temperature area	1.1
Highest temperature area	1.2

12.4.9 Occupants

Table 12-14

Condition of occupants	Application	Coefficient E W / person (kcal/h·person)
Sitting on the chair	Theater, tea room	116 (100)
Office working	Office, hotel, restaurant, department store	140 (120)
Physical working	Factory, dance-hall	233 (200)

12.4.10 Gas

Table 12-15

Sort of gas	Coefficient B W/m^3 $(kcal/m^3h)$
Town gas (Tokyo)	5,815 (5,000)
Town gas (Osaka)	5,234 (4,500)
Propane (Specific weight 1.5 to the air)	27,680 (23,800)

12.5 Example

Example: Find the cooling load of an office based on the following conditions, and select a suitable model.

Specifications of construction

Building : Five-story building (second floor)
Outside wall : Medium construction (concrete block 150mm t)
Window glass : Normal (6mm t) with blind
Floor : Concrete with linoleum
Lights : Flurescent light (40w × 20 = 800w)
Persons : 20 (office work)
Area : Standard temperature area
*** Adjoined upper and lower rooms are not air conditioned.

Fig.12-4

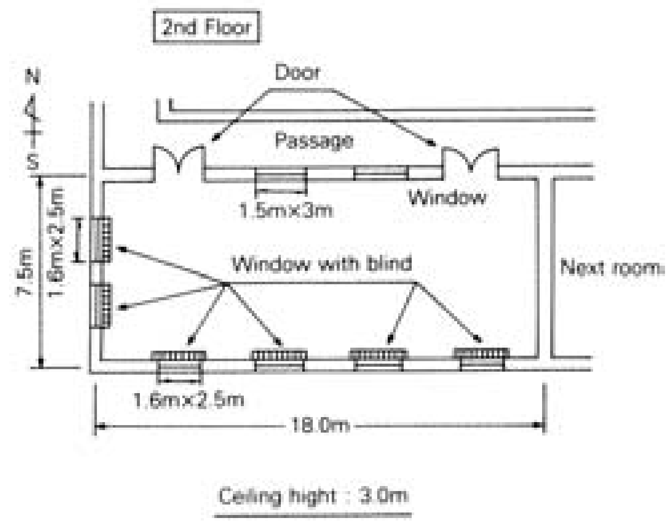


Table 12-16 Cooling / Heating load list

Name of the building ________________ Date: ________________

Location ________________ Name of the person in charge ________________

Name of the room ________________ Room floor area = (W) m × (L) m = m^2

Floor ________________ Room volume = (Area) m^2 × (H) m = m^3

Items				A	Cooling				Heating		
					Coefficient B	Coefficient f		Heat load Q = A × B × f	Coefficient E	IN/OUT temp.diff.	Heat load H = A × E × T
1	Wall faced to the outdoor			m^2							
				m^2							
				m^2							
				m^2							
2	Roof			m^2							
3	Window glass			m^2		Coefficient of shade					
				m^2							
				m^2							
				m^2							
4	Partition			m^2						*1	
				m^2							
				m^2							
5	Ceiling · Floor	Ceiling		m^2						*1	
		Floor		m^2							
6	Outdoor air	Required outdoor air intake		person		Area correction		Whichever large one			Whichever large one
		Infiltration air		m^3							
7	Heat generation in the room	Occupants		person		Rate of simultaneous use		2800			
		Lights	Fluorescent lights	kW				930.4			
			Incandescent lights	kW							
		Electrical appliances		kW							
		Gas	Town gas	m^3 / h							
			Propane gas	m^3 / h							
Total heat load					Total load Q ____ W (kW)				Total load H ____ W (kW)		

Note:
*1: In the items of partition, ceiling, floor, if the adjoined upper and / or lower spaces are not heated, the temperature difference between indoor and outdoor (T) must apply ≪Indoor design temperature - (outdoor design temperature + 5˚C)≫. (If those spaces are in heating, the temperature difference is zero, resulting in no need of calculation).

Table 12-17 Cooling / Heating load list (Solution)

Name of the building	Exercise building	Date:	
Location	TOKYO	Name of the person in charge	
Name of the room	Office 1	Room floor area = (W) 18 m ×(L) 7.5 m = 135 m^2	
Floor	Second floor	Room volume = (Area) 135 m^2 ×(H) 3 m = 405 m^3	

No.	Items			A	Cooling: Coefficient B	Cooling: Coefficient f	Cooling: Heat load Q = A × B × f	Heating: Coefficient E	Heating: IN/OUT temp.diff.	Heating: Heat load H = A × E × T
1	Wall faced to the outdoor	S	18 × 3 – 16	38.0 m^2	40	1	1520	2.9	22	2424.4
		W	7.5 × 3 – 8	14.5 m^2	65		942.5	2.9		925.1
				m^2						
				m^2						
2	Roof			m^2						
3	Window glass	S	1.6 × 2.5 × 4	160 m^2	64	Coefficient of shade 0.7	716.8	6.4		2252.8
		W	1.6 × 2.5 × 2	8.0 m^2	756	0.7	4233.6	6.4		1126.4
				m^2						
				m^2						
4	Partition	E	7.5 × 3	22.5 m^2	9	1	202.5	3.1	*1 17	1185.8
		N	Glass 1.5 × 3 × 4	9.0 m^2	15		135	5.2		795.6
		N	18 × 3 – 9	45.0 m^2	9		405	3.1		2371.5
5	Ceiling·Floor	Ceiling	18 × 7.5	135.0 m^2	8		1080	2.3	*1 17	5278.5
		Floor	18 × 7.5	135.0 m^2	8		1080	2.3		5278.5
6	Outdoor air	Required outdoor air intake		20 person	242	Area correction 1	4840 Whichever large one (3766.5)	8.7	22	8828 Whichever large one (3564)
		Infiltration air		405 m^3	9.3			0.4		
7	Heat generation in the room	Occupants		20 person	140	Rate of simultaneous use 1	2800			
		Lights	Fluorescent lights	0.8 kW	1163	1	930.4			
			Incandescent lights	kW	1000					
		Electrical appliances		kW	1000					
		Gas	Town gas	m^3 / h						
			Propane gas	m^3 / h						
Total heat load					Total load Q		18885.8 W (18.89 kW)	Total load H		25466.6 W (25.47 kW)

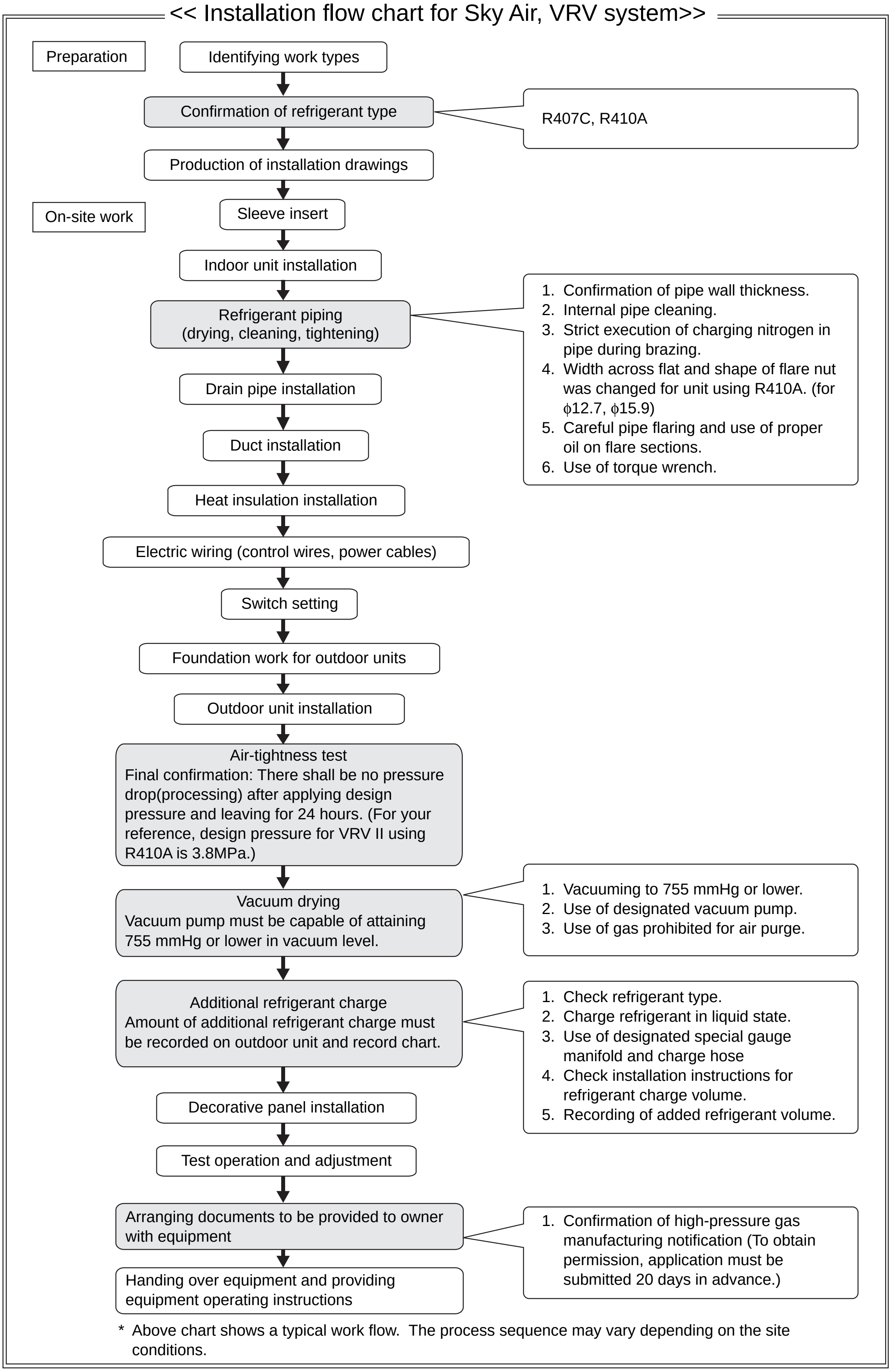
Note:

*1: In the items of partition, ceiling, floor, if the adjoined upper and / or lower spaces are not heated, the temperature difference between indoor and outdoor (T) must apply ≪Indoor design temperature - (outdoor design temperature + 5˚C)≫. (If those spaces are in heating, the temperature difference is zero, resulting in no need of calculation).

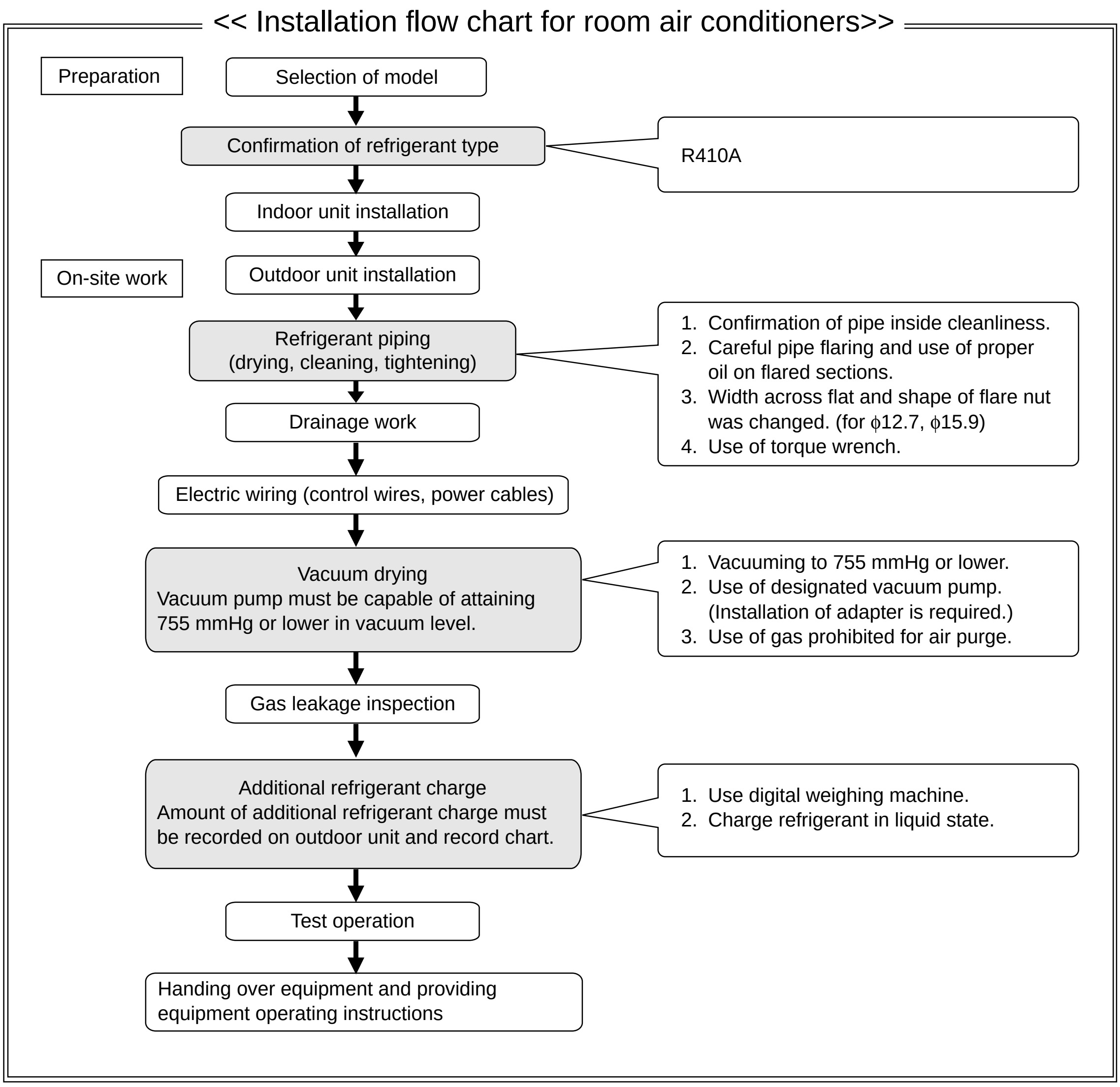
Chapter 13 R-407C and R-410A refrigerants

Chapter 13 R407C and R410A refrigerants

13.1 Installation flow chart



(Z0128)



<< Installation flow chart for room air conditioners>>
Preparation
Selection of model
Confirmation of refrigerant type
R410A
Indoor unit installation
On-site work
Outdoor unit installation
Refrigerant piping
(drying, cleaning, tightening)
1. Confirmation of pipe inside cleanliness.
2. Careful pipe flaring and use of proper oil on flared sections.
3. Width across flat and shape of flare nut was changed. (for ϕ12.7, ϕ15.9)
4. Use of torque wrench.
Drainage work
Electric wiring (control wires, power cables)
Vacuum drying
Vacuum pump must be capable of attaining 755 mmHg or lower in vacuum level.
1. Vacuuming to 755 mmHg or lower.
2. Use of designated vacuum pump. (Installation of adapter is required.)
3. Use of gas prohibited for air purge.
Gas leakage inspection
Additional refrigerant charge
Amount of additional refrigerant charge must be recorded on outdoor unit and record chart.
1. Use digital weighing machine.
2. Charge refrigerant in liquid state.
Test operation
Handing over equipment and providing equipment operating instructions

(Z0129)

13.2 Changes required for refrigerants

13.2.1 HFC refrigerant

The following two types of refrigerant are being used in place of the HCFC22 (R22) refrigerant. Main differences in specification are pressure difference (higher) and compatible refrigerant oil type.

	New alternative refrigerant (HFC)		Previous refrigerant (HCFC)
Refrigerant name	R407C	R410A	R22
Principal use	Packaged air conditioner	Packaged Air conditioner Room air conditioner	Packaged air conditioner Room air conditioner
Composing substances	Non-azeotropic mixture★1 of R32, R125 and R134a	Quasi-azeotropic mixture★2 of R32 and R125	Single-component refrigerant
Standard design pressure★3	3.2 MPa G	4.15 MPa G★3	2.75 MPa G
Refrigerant oil	Synthetic oil (ether)		Mineral oil (suniso)
Ozone destruction factor (ODP)	0	0	0.05
Combustibility	None	None	None
Toxicity	None	None	None

★1 Non-azeotropic mixture refrigerant: mixture of two or more refrigerants having different boiling points.

★2 Quasi-azeotropic mixture refrigerant: mixture of two or more refrigerants having similar boiling points.

★3 Since the design pressure differs with model, the design pressure should be confirmed with machine nameplate, or installation manual attached to the outdoor unit. For example, the design pressure of VRV II R410A Series (RXYQ5~48MY1B) is 3.8MPa G.

13.2.2 Refrigerant

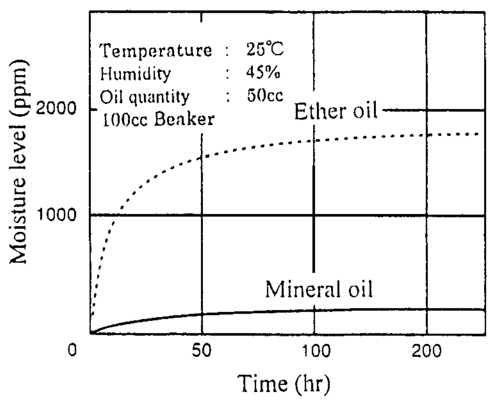
Main characteristics of refrigerant oil are shown in the following table.

	Synthetic oil Ether oil	Mineral oil
Applicable refrigerants (Daikin products) ★1	R410A · R407C	R22
Density (g/cm^3)	0.94	0.92
Total acid number (mgKOH/g)	0.01	0.01
Saturated moisture level (ppm)	2000	100
Volume insulation resistivity (Ω cm)	3×10^{13} or less	5×10^{14} or less
Hydrolysis (stability range)	No degradation	No degradation
Oxidation degradation (stability range)	0.03% or less	0.03% or less
Moisture absorption	(As shown in graph below)	(As shown in graph below)
Solubility in refrigerant	(As shown in graph below)	(As shown in graph below)

★1 Applicability may differ in products of other manufactures.

Moisture absorption

The graph on the right shows how the moisture absorption (moisture level) changes over time in mineral oil and ether oil.

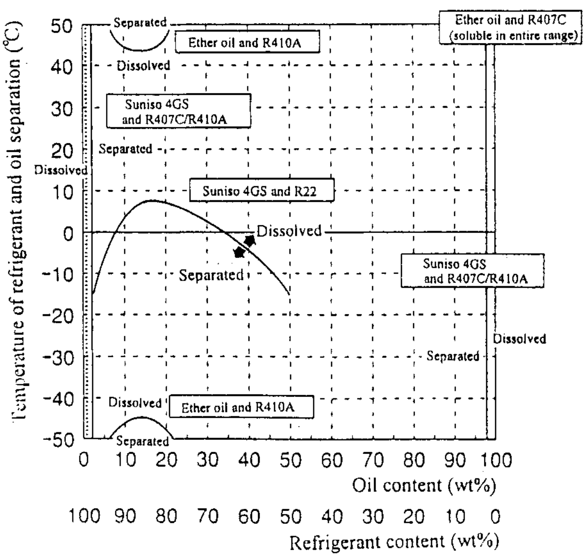


Solubility in refrigerant

The graph on the right shows the oil solubility of different combinations of refrigerant and refrigerant oil.

→ A combination of suniso and HFC refrigerant results in a separation of refrigerant and oil in almost the entire range. (No solubility)

→ A combination ether oil and HFC refrigerant remains dissolved in a wide range.



13.2.3 Cautions in handling R407C and R410A

The new R407C and R410A refrigerants differ from the previous refrigerant (R22) in the following characteristics. Utmost caution must be exercised after precautions are thoroughly understood when handling the new refrigerants.

	Different points	Precautions to be noted
1	The new refrigerants are extremely susceptible to mixing of impurities (oil, water, oxidized film) in the refrigerant system as compared to the previous refrigerant.	• Be sure to charge a nitrogen gas into the pipe during brazing. • Careful storage and management of pipes • Prohibition of mixing of impurities
2	The pressure is high. The pressure of R407C is about 10% higher than that of the previous refrigerant, while the pressure of R410A is about 60% higher.	Tools and devices (charge hose, gauge manifold) used with the previous refrigerant cannot be used for the new refrigerants since their pressure withstanding capability is lower.
3	HFC407C consists of three kinds of non-azeotropic substances, while HFC410A is composed of two kinds of non-azeotropic substances.	Charge the refrigerant in the liquid state. Do not charge the refrigerant in the gaseous state. (Charging the refrigerant in the gaseous state causes the refrigerant composition to change.)
4	The required refrigerant oil is ether oil. Mixing of the previous mineral oil causes sludge generation.	Gauge manifolds and charge hoses used with the previous refrigerant cannot be used for the new refrigerants.

13.2.4 Refrigerant piping materials

<Pipes and joints>

Copper pipes, steel pipes and joints are used in refrigerant piping. Be sure to select proper materials and thickness in accordance with local code.

<Piping Materal>

Select the piping material to be used from the next table according to piping size.

Piping Size (O / D)	Temper grade of Material
ϕ15.9 or less	O
ϕ19.1 or more	1 / 2H or H

Note ; O : Soft (Annealed)
H : Hard (Drawn)

13.2.5 Required tools and devices

Some tools and devices may be shared for use with the new refrigerant (HFC) and previous refrigerant (HCFC), while others cannot.

<On-site work>

	R407C R410A
Refrigerant piping	Prevention for mixing of foreign items such as moisture, dust in the refrigerant pipe. (Thorough management for pipe at site) Ensuring of nitrogen charge during brazing. Vacuum drying with vacuum pump (Air purge with gas is strictly prohibited.)
Refrigerant charging, refrigerant oil application	Charge the refrigerant in the liquid state. Prevention for mixing of R22 in refrigerant oil because of difference in liquid type. (R22: mineral oil, R410A, R407C: synthetic oil, HFC is not soluble in mineral oil.)

	Tool name	Use	Changed point
Tools to be procured newly or modified	Flaring tool	Flaring of pipe	For change of flared dimension
	Refrigerant oil	Application on flared section	Ether or alkyl benzene series oil is required due to change of oil type.
	Torque wrench	Connection of flare nut	Due to dimension change in width across flat of flare nut for ϕ12.7 and ϕ15.9 pipe used in R410A unit.
	Gauge manifold	Refrigerant charge with vacuum pump and operation check	Change in graduation of gauge scale due to high-pressure Conventional gauge can not be used to measure pressure.
	Charge hose		Changed into pressure resistance hose. Sharing of use with R22 is impossible. (Due to different in oil type)
	Charging cylinder	Refrigerant charge	Conventional devices can not be used due to the characteristics of refrigerant. Digital weighing machine is used.
	Digital weighing machine		Because a charging cylinder can not be used.
	Vacuum pump	Vacuum drying	Oil reverse flow preventive adapter is required, while the vacuum pump has compatibility with previous use.
	Gas leak detector	Check on gas leakage	A fleon leak tester can not be used because the new refrigerants do not contain chlorine.

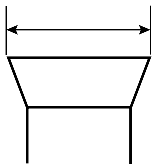
- **Pipe cutter, expander, bender, nitrogen and welder can be used for new refrigerant unit.**

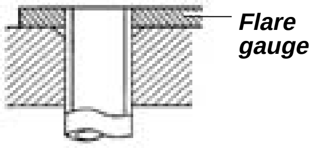
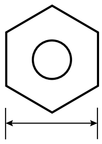
Tools to Be Procured Newly or Modified.

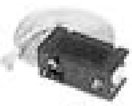
Tasco Japan

<table>
<tr><th>Tool name</th><th>Difference from previous tool</th><th>New tool specifications</th></tr>
<tr>
<td>1. Flaring tool

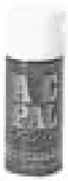

Flare gauge
</td>
<td>• Enlargement of dimension A

Dimension A

Class-1 pipes: R407C
Class-2 pipes: R410A

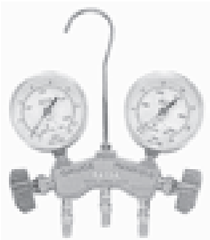
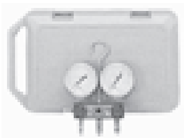
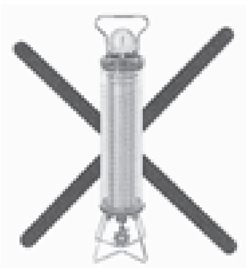
Size 12mmx72mm
Thickness 1.0x0.5mm Each
</td>
<td>Dimension A
Unit: mm
<table>
<tr><th>Nominal size</th><th>Class-1</th><th>Class-2</th><th>Previous</th></tr>
<tr><td>1/4</td><td>9.0</td><td>9.1</td><td>8.6~9.0</td></tr>
<tr><td>3/8</td><td>13.0</td><td>13.2</td><td>12.6~13.0</td></tr>
<tr><td>1/2</td><td>16.2</td><td>16.6</td><td>15.8~16.2</td></tr>
<tr><td>5/8</td><td>19.4</td><td>19.7</td><td>19.0~19.4</td></tr>
<tr><td>3/4</td><td>23.3</td><td>24.0★</td><td>22.9~23.3</td></tr>
</table>
Note 1 The copper pipe to be flared should be made of O or OL material.
2 ★ Flaring with ϕ19.1(3/4), class 2 pipe is not required for any model of DAIKIN products.
Use a flare gauge to take out the pipe from the gauge bar, adjust it, and then carry out the flare processing.
Size from the dice surface to the copper tip (in mm)
<table>
<tr><th rowspan="3">Name</th><th rowspan="3">Outer diameter</th><th rowspan="3">Wall thickness</th><th colspan="2">New rank compatible flare tool</th></tr>
<tr><th>The conventional flare tool</th><th>The conventional flare tool</th></tr>
<tr><th>Clutch type (class1)</th><th>Clutch type (class2)</th></tr>
<tr><td>1/4</td><td>6.35</td><td>0.8</td><td>0~0.5</td><td>1.0~1.5</td></tr>
<tr><td>3/8</td><td>9.52</td><td>0.8</td><td>0~0.5</td><td>1.0~1.5</td></tr>
<tr><td>1/2</td><td>12.70</td><td>0.8</td><td>0~0.5</td><td>1.0~1.5</td></tr>
<tr><td>5/8</td><td>15.88</td><td>1.0</td><td>0~0.5</td><td>1.0~1.5</td></tr>
</table></td>
</tr>
<tr>
<td>2. Torque wrench
</td>
<td>• Change of dimension B
Size increase only for 1/2" and 5/8" pipes

Dimension B
Class-1 pipes: R407C
Class-2 pipes: R410A</td>
<td>Dimension B
Unit: mm
<table>
<tr><th>Nominal size</th><th>Class-1</th><th>Class-2</th><th>Previous</th></tr>
<tr><td>1/2</td><td>24</td><td>26</td><td>24</td></tr>
<tr><td>5/8</td><td>27</td><td>29</td><td>27</td></tr>
</table>
No change in tightening torque
No change in pipes of other sizes</td>
</tr>
<tr>
<td>3. Vacuum pump with check


Reverse flow preventive vacuum adaptor
</td>
<td>• Must be equipped with a mechanism to prevent reverse oil flow.

• Previous vacuum pump can be used by installing adaptor.</td>
<td>• Discharge speed 50 L/min (50 Hz)
60 L/min (60 Hz)
• Maximum degree of vacuum 5 x 10^{-6} Torr

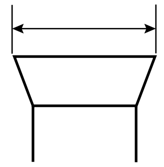
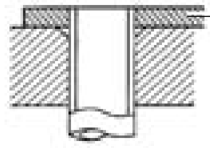
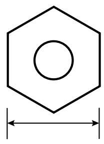
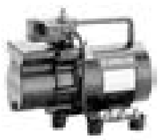
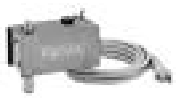
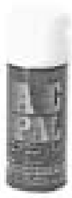
• Suction port • UNF7/16-20 (1/4" flare)
UNF1/2-20 (5/16" flare) with adaptor</td>
</tr>
<tr>
<td>4. Leak tester
</td>
<td>• Previous testers detected chlorine.
Since HFCs do not contain chlorine, new testers detect hydrogen.</td>
<td>• Hydrogen detecting type
• Applicable refrigerants
R410A, R407C, R404A, R507A, R134a
• With automatic balancing function</td>
</tr>
<tr>
<td>5. Refrigerant oil (AIRCOMPAL)
</td>
<td>• Can be used for HFC and HCFC units.</td>
<td>• Contains synthetic oil, therefore it can be used for pipes for all types of refrigerating cycle.
• Offers high rust resistance and stability over long period of time.</td>
</tr>
</table>

(Z0130)

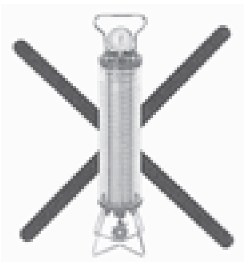
Tool name	Difference from previous tool	New tool specifications
6. Gauge manifold for R410A 	• Pressure change • Service port diameter change	• High pressure gauge -0.1 to 5.3 MPa (-76 cm Hg to 53 kg/cm²) Low pressure gauge -0.1 to 3.7 MPa (-76 cm Hg to 38 kg/cm²) • 1/4" → 5/16" • No oil is used in pressure test of gauges. →Prevention of gauge contamination
7. Charge hose for R410A  (Hose adaptor with ball valve) Charge valve 	• Pressure-resistant hose • Service port diameter change • Nylon coating for HFC resistance series refrigerant	• Operating pressure: 5.08 MPa (51.8 kg/cm²) • Rupture pressure: 25.4 MPa (259 kg/cm²) • Equipped with local valve that prevents refrigerant from escaping from hose. • Prevents gases from blowing out at the both ends of charge hose and equipment.
8. Gauge manifold for R407C  Charge hose (Hose adaptor with ball valve) 	• Oil and refrigerant types are different. (Previous gauge manifold cannot be used.)	• High pressure gauge -0.1 to 3.5 MPa (-76 cm Hg to 35 kg/cm²) Low pressure gauge -0.1 to 1.5 MPa (-76 cm Hg to 15 kg/cm²) • 1/4" • Equipped with local valve that prevents refrigerant from escaping from hose. • No oil is used in pressure test of gauges. →Prevention of gauge contamination • Equipped with sight glass for checking of liquid refrigerant • Color of hose is black in order to distinguish from conventional hose.
9. Charging cylinder 	• Cannot be used since charging cylinders cause change in mixing ratio in multi-substance refrigerants during charging.	• Use "weighing machine for refrigerant charge listed below".
10. Weighing machine for refrigerant charge 	• Measurement is based on weight to prevent change of mixing ratio during charging.	• High accuracy TA101A (for 10-kg cylinders): = ± 2g TA101B (for 20-kg cylinders): = ± 5g • Equipped with pressure-resistant sight glass for checking of liquid-state refrigerant • Standardized manifold with separate ports for HFCs and previous refrigerants enabling use of new and previous refrigerants)

(Z0131)

Robinair Inc.

<table>
<tr><th>Tool name</th><th>Difference from previous tool</th><th>New tool specifications</th></tr>
<tr><td>1. Flaring tool
</td><td>• Enlargement of dimension A
Dimension A

Class-1 pipes: R407C
Class-2 pipes: R410A</td><td>Dimension A
Unit: mm
<table>
<tr><th>Nominal size</th><th>Class-1</th><th>Class-2</th><th>Previous</th></tr>
<tr><td>1/4</td><td>9.0</td><td>9.1</td><td>8.6~9.0</td></tr>
<tr><td>3/8</td><td>13.0</td><td>13.2</td><td>12.6~13.0</td></tr>
<tr><td>1/2</td><td>16.2</td><td>16.6</td><td>15.8~16.2</td></tr>
<tr><td>5/8</td><td>19.4</td><td>19.7</td><td>19.0~19.4</td></tr>
<tr><td>3/4</td><td>23.3</td><td>24.0★</td><td>22.9~23.3</td></tr>
</table>
Note 1 The copper pipe to be flared should be made of O or OL material.
2 ★ Flaring with ϕ19.1(3/4), class 2 pipe is not required for any model of DAIKIN products.</td></tr>
<tr><td>Flare gauge
</td><td>Size 12mmx72mm
Thickness 1.0x0.5mm Each

</td><td>Use a flare gauge to take out the pipe from the gauge bar, adjust it, and then carry out the flare processing.
Size from the dice surface to the copper tip (in mm)
<table>
<tr><th rowspan="3">Name</th><th rowspan="3">Outer diameter</th><th rowspan="3">Wall thickness</th><th colspan="2">New rank compatible flare tool</th></tr>
<tr><th>The conventional flare tool</th><th>The conventional flare tool</th></tr>
<tr><th>Clutch type (class1)</th><th>Clutch type (class2)</th></tr>
<tr><td>1/4</td><td>6.35</td><td>0.8</td><td>0~0.5</td><td>1.0~1.5</td></tr>
<tr><td>3/8</td><td>9.52</td><td>0.8</td><td>0~0.5</td><td>1.0~1.5</td></tr>
<tr><td>1/2</td><td>12.70</td><td>0.8</td><td>0~0.5</td><td>1.0~1.5</td></tr>
<tr><td>5/8</td><td>15.88</td><td>1.0</td><td>0~0.5</td><td>1.0~1.5</td></tr>
</table></td></tr>
<tr><td>2. Torque wrench
</td><td>• Change of dimension B
Size increase only for 1/2" and 5/8" pipes

Dimension B
Class-1 pipes: R407C
Class-2 pipes: R410A</td><td>Dimension B
Unit: mm
<table>
<tr><th>Nominal size</th><th>Class-1</th><th>Class-2</th><th>Previous</th></tr>
<tr><td>1/2</td><td>24</td><td>26</td><td>24</td></tr>
<tr><td>5/8</td><td>27</td><td>29</td><td>27</td></tr>
</table>
No change in tightening torque
No change in pipes of other sizes</td></tr>
<tr><td>3. Vacuum pump with check valve
</td><td>• Must be equipped with a mechanism to prevent reverse oil flow.</td><td>• Discharge speed 22.5 L/min (50 Hz)
27 L/min (60 Hz)
• Maximum degree of vacuum 5×10^{-2} Torr</td></tr>
<tr><td>Reverse flow preventive vacuum adaptor
</td><td>• Previous vacuum pump can be used by installing adaptor.</td><td>• Suction port UNF7/16-20 (1/4" flare)
UNF1/2-20 (5/16" flare) with adaptor</td></tr>
<tr><td>4. Leak tester
</td><td>• Previous testers detected chlorine.
Since HFCs do not contain chlorine, new testers detect hydrogen.</td><td>• Corona discharge type
• Applicable refrigerants
R410A, R407C, R404A, R134a
• Leakage is displayed with LED indicator and sound.</td></tr>
<tr><td>5. Refrigerant oil (AIRCOMPAL)
</td><td>• Can be used for HFC and HCFC units.</td><td>• Contains synthetic oil, therefore it can be used for pipes for all types of refrigerating cycle.
• Offers high rust resistance and stability over long period of time.</td></tr>
</table>

(Z0132)

Tool name	Difference from previous tool	New tool specifications
6. Gauge manifold for R410A 	• Pressure change • Service port diameter change	• High pressure gauge -0.1 to 5.3 MPa (-76 cm Hg to 53 kg/cm²) Low pressure gauge -0.1 to 3.7 MPa (-76 cm Hg to 38 kg/cm²) • 1/4" → 5/16" • No oil is used in pressure test of gauges. →Prevention of gauge contamination • Equipped with a protector to absorb shock.
7. Charge hose for R410A  (Hose adaptor with ball valve)	• Pressure-resistant hose • Service port diameter change • Nylon coating for HFC resistance series refrigerant	• Operating pressure: 5.08 MPa (51.8 kg/cm²) • Rupture pressure: 25.4 MPa (259 kg/cm²) • Equipped with local valve that prevents refrigerant from escaping from hose.
8. Gauge manifold for R407C 	• Oil and refrigerant types are different. (Previous gauge manifold cannot be used.)	• High pressure gauge -0.1 to 3.5 MPa Low pressure gauge -0.1 to 1.7 MPa • Charge hose with valve • Equipped with sight glass
9. Charging cylinder 	• Cannot be used since charging cylinders cause change in mixing ratio in multi-substance refrigerants during charging.	• Use "weighing machine for refrigerant charge listed below".
10. Weighing machine for refrigerant charge 	• Measurement is based on weight to prevent change of mixing ratio during charging.	• Accuracy: 5 g Weight limit: 50 kg • With overload protecting function • Solenoid valve built-in and automatic weighing type

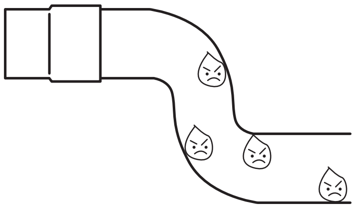
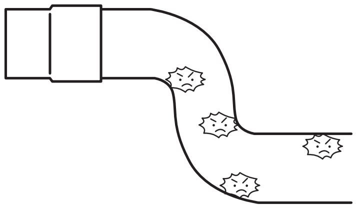
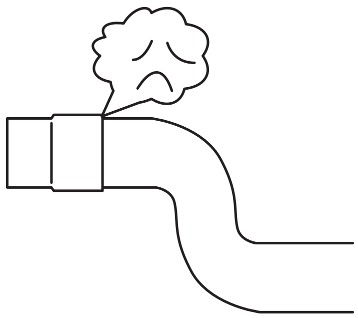
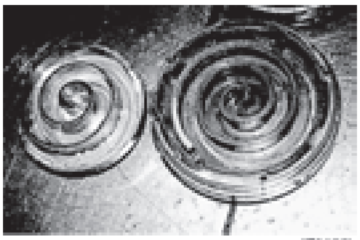
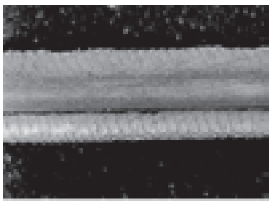
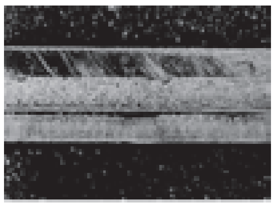
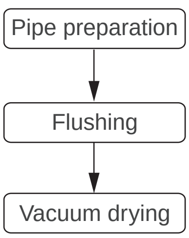
(Z0133)

13.2.6 Cautions in working with HFC refrigerants

	R407C	R410A
Charging a nitrogen gas into pipe during brazing	When brazing for R407C and R410A models that require brazing, it is mandatory to charge a nitrogen gas into the pipe. A thorough service work control more severe than previous models is required.	
Flaring	It is necessary to apply an appropriate amount of oil on the inside and outside of the flared section. Be sure to use ether-base or alkylbenzene-base oil. "Air Compal" (brand name) can be also used.	
Refrigerant charge	Previous HCFCs could be charged in either liquid or gaseous state. For some RA models, the refrigerant had to be charged in the gaseous state. For the new refrigerants, however, it is very important to charge in the liquid state.	

13.3 Refrigerant piping

13.3.1 Three basic rules of refrigerant piping

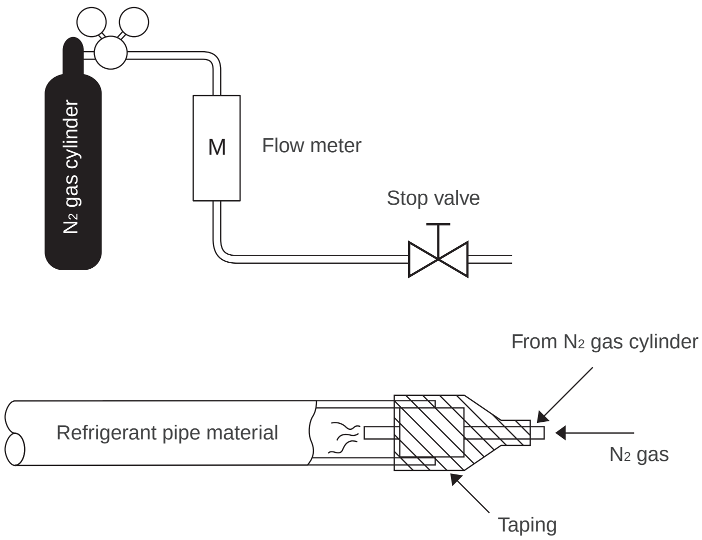
	(1)Drying (no moisture)	(2)Cleaning (free of contamination)	(3)Tightening (air-tightness)
	There shall be no moisture in the pipe.	There shall be no dust in the pipe.	There shall be no refrigerant leak.
Item	 (Z0134)	 (Z0135)	 (Z0136)
Cause	• Water entering from outside, such as rain. • Moisture due to dew condensation occurring inside the pipe.	• Oxidized film generated during brazing. • Entering of foreign items such as dust, particles and oil from outside.	• Insufficient brazing • Inadequate flaring or insufficient tightening torque. • Inadequate tightening of flange connection.
Problem	• Clogging of expansion valve, capillary tube, etc. • Insufficient cooling or heating. • Degradation of refrigerant oil. • Malfunction of compressor.	• Clogging of expansion valve, capillary tube, etc. • Insufficient cooling or heating. • Degradation of refrigerant oil. • Malfunction of compressor.	• Gas shortage • Insufficient cooling or heating. • Temperature increasing of discharge gas. • Degradation of refrigerant oil. • Malfunction of compressor.
	<For reference>  (Z0186) Compressor is corroded due to moisture.	 Not clogged (Z0187) Capillary is clogged with dust.	 Clogged (Z0188)
Preventive measure	 (Z0137)	• Same as the items on the left. • Do not use tools or devices previously used with a different type of refrigerant.	• Follow the basic brazing procedure. • Follow the basic flaring procedure. • Follow the basic flange connection procedure. • Conduct an air-tightness test (gas leak check).
Remarks	Pipe preparation ---See page 13. Flushing ---See page 14. Vacuum drying ---See page 22.	Basic brazing procedure ---See page 15. Basic flaring procedure ---See page 16. Air-tightness testing procedure ---See page 19. Gas leak check ---See page 20.	

13.3.2 Nitrogen charge method

If a nitrogen gas is not supplied into a pipe during brazing, a large amount of oxidized film is produced on the inside surface of the pipe. The oxidized film can clog the solenoid valve, capillary tube, accumulator's oil return and compressor's internal oil inlet port, thereby causing the equipment to malfunction.
To prevent those problems, it is necessary to supply a nitrogen gas into a pipe to remove air from the pipe during brazing.
This work is so called "nitrogen gas charge" and this is very important when brazing refrigerant pipes.

< Work method >

(1) Attach a reducing valve and a flow meter to nitrogen cylinder.
(2) Use small copper pipe for connection piping to the refrigerant pipe material while the other end of copper pipe at cylinder side can be connected to the flow meter.
(3) The gap between the refrigerant pipe material and the inserting copper pipe should be sealed in order to prevent nitrogen gas from reverse flow.
(4) When supply nitrogen gas, be sure to open the other end of refrigerant pipe material.
(5) Desirable flow rate of nitrogen gas is 0.05 m^3/h or less, or the pressure of gas is 0.02 MPa (0.2 kg/cm^2) or less.
(6) Nitrogen gas should be supplied until the temperature of refrigerant pipe is lowered (possible to touch with hand) after the brazing work is completed.
(7) Remove flux completely after brazing work.



Prevention of oxidation during brazing

(Z0138)

< Cautions >

1. Be sure to use a nitrogen gas. (Do not use oxygen, carbon dioxide or flon gas.)
2. Do not start brazing work immediately after nitrogen gas supplying started.

↓

Wait for filling of the gas inside refrigerant pipe.

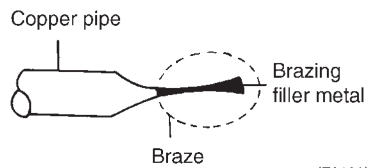
13.3.3 Preparation work for refrigerant pipes

Preparation of pipes is very important for the prevention of the entry of moisture, dust and foreign particles into the pipes. Many problems that occurred in the past were caused by moisture entering the pipes. To prevent equipment malfunctions, be sure to prepare the pipes properly.

All pipe ends must be properly prepared. The surest way to prepare pipe ends is the "pinch method". The taping method may also be used depending on the processing location and work schedule.

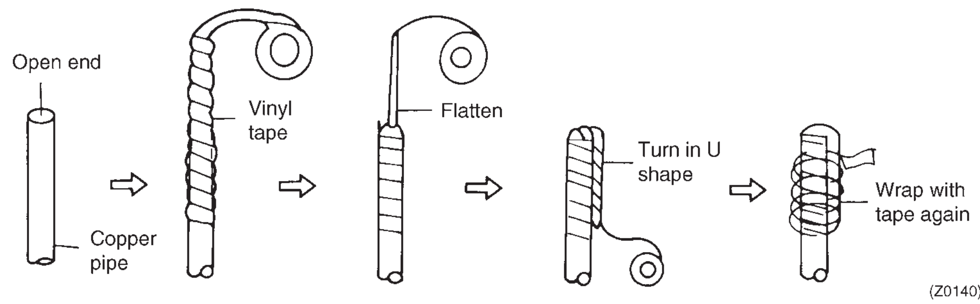
	Location	Schedule	Preparation method
Conventional	Outdoor	3 months or longer	Pinch method
		Shorter than 3 months	Pinch or taping method
	Indoor	Any length	
New	Outdoor	1 month or longer	Pinch method
		Shorter than 1 month	Pinch or taping method
	Indoor	Any length	

1. Pinch method
   In this method, a copper pipe end is blocked and brazed to close the opening completely.
2. Taping method
   In this method, a copper pipe end is covered by wrapping a vinyl tape.



(Z0139)

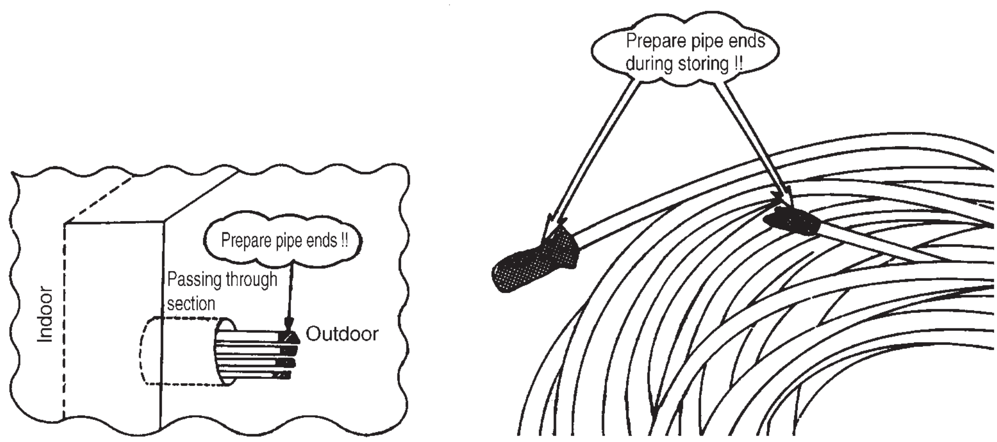
< Taping method >



(Z0140)

< Work conditions requiring special caution >

- When inserting a copper pipe through a hole in a wall. (Dust can enter easily.)
- When the end of a copper pipe is located outdoor. (Rain can enter.)
  (Special attention is required for vertical outdoor piping.)



(Z0141)

13.3.4 Refrigerant pipe flushing

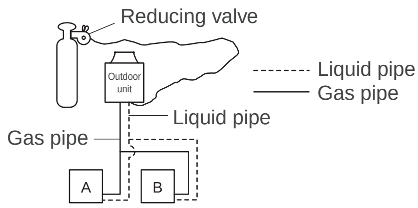
Flushing removes foreign particles from the inside of pipes by means of gas pressure.

< Three main effects >

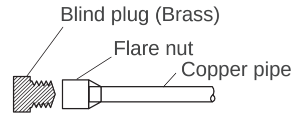
1. Removes oxidized film inside copper pipes generated by insufficient charging of nitrogen gas during brazing.
2. Removes foreign particles and moisture that entered pipes due to inadequate preparation.
3. Confirms connection of pipes between indoor and outdoor units (for both liquid and gas pipes).

< Procedure >

① Mount a pressure reducing valve on the nitrogen cylinder.
* Be sure to use a nitrogen gas.
(Dew condensation may occur if a flon or carbon dioxide gas is used. Oxygen gas may cause an explosion.)

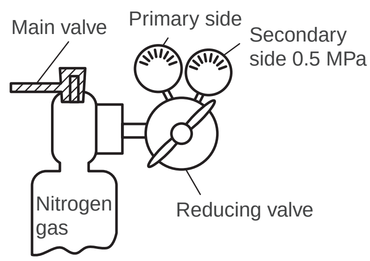


② Connect the charge hose of the pressure reducing valve to the service port of the liquid pipe of the outdoor unit.



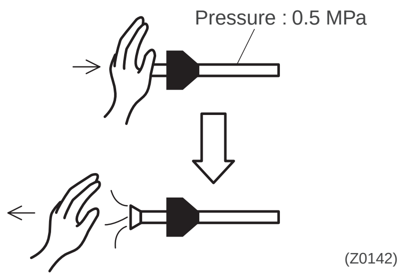
③ Mount a blind plug on indoor unit (B). Do not mount a blind plug on unit A.

④ Open the main valve of the nitrogen cylinder, and adjust the pressure reducing valve until the pressure becomes 0.5 MPa.



⑤ Make sure that the nitrogen gas is released through the liquid pipe of unit A.

⑥ Flushing
- Close the pipe end with the palm of the hand.
↓
- When the pressure becomes high, move the hand quickly.
(1st flushing)
↓
- Close the pipe end with the palm of the hand again.
↓
(Conduct the 2nd flushing.)



* During the flushing process, place a clean cloth at the pipe end, and check the content and amount of the removed foreign particles. If even a small amount of moisture is found, be sure to remove all moisture from inside the pipe.
Procedure (1) Conduct flushing using a nitrogen gas (until no moisture comes out).
(2) Conduct vacuum drying completely. (See page 331~332)

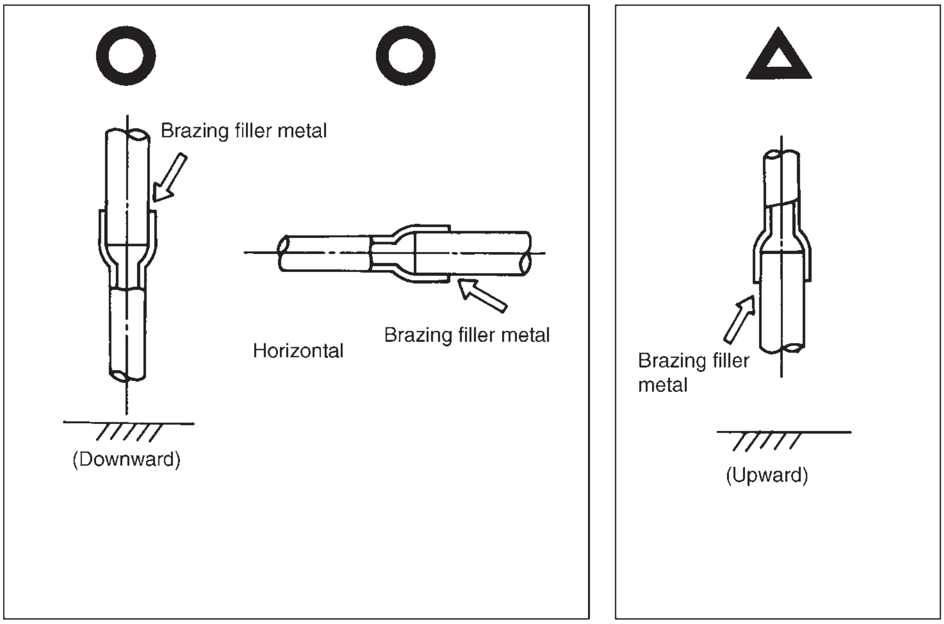
⑦ Close the main valve of the nitrogen cylinder.

⑧ Repeat the same procedure for unit B.

⑨ After completing the flushing for the liquid pipes, conduct flushing for the gas pipes.

13.3.5 Brazing

1. Conduct brazing with the pipe end pointed downward or positioned horizontally. Do not place the pipe end upward when brazing (to prevent leaks).



(Z0143)

2. Be sure to use the designated branch joint for both liquid and gas pipes. Pay attention to the mounting direction and angle (to prevent oil return and irregular flow).
3. A nitrogen gas must be supplied into the pipe during brazing.

< Cautions >

1. Take measures to prevent a possible fire. (preparing the brazing site and keeping a fire extinguisher and water nearby)
2. Be careful of burning skins.
3. Check to make sure that the space between the pipe and joint is appropriate. (leak prevention)
4. Make sure that the pipe is supported properly.
   - Horizontal pipes (copper pipes) should be supported at the following pitches.

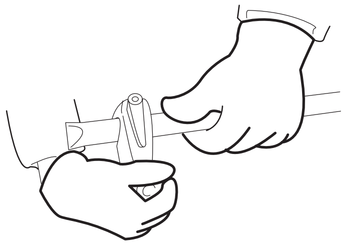
Pitch of copper pipe support (Source: HASS 107-1977)

Nominal diameter	20 or less	25~40	50
Maximum pitch (m)	1.0	1.5	2.0

   - Do not fix the copper pipe with metal fixture directly.

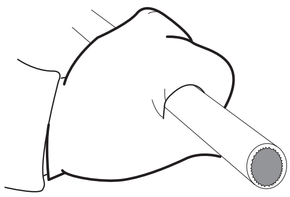
13.3.6 Flaring procedure

1. Cut the pipe using a pipe cutter.



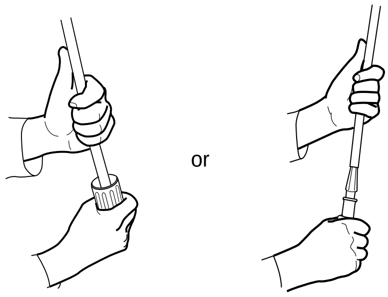
(Z0144)

2. The cut edge has burrs.



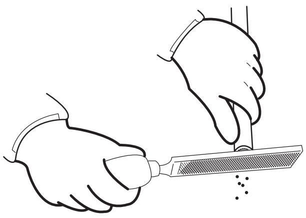
(Z0145)

3. Remove the burrs using a reamer.
   (Be careful not to let particles enter in the pipe. Point the pipe end downward during deburring.)



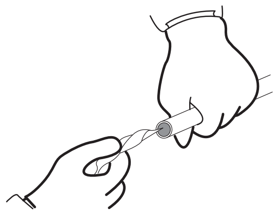
(Z0146)

4. Remove the burrs using a file
   (Be careful not to let particles enter in the pipe. Point the pipe end downward during filing.)



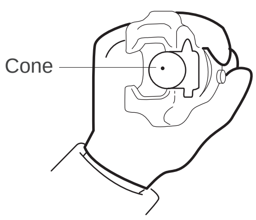
(Z0147)

5. Clean the inside of the pipe.
   (Use a thin stick with a cloth wrapped around it.)



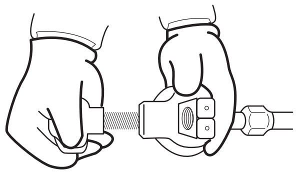
(Z0148)

6. Before flaring, clean the cone section of the flaring tool.



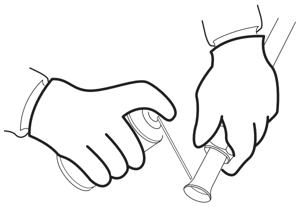
(Z0149)

7. Flare the pipe.
   Rotate the flaring tool 3 or 4 turns after a clicking sound is produced. This results in a fine flared surface.



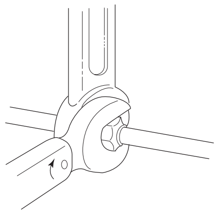
(Z0150)

8. Apply ether oil on the inside and outside of the flared section.
   Never use mineral oil (suniso etc.)!
   (Be careful to keep dust away.)
   Spray-type oil products (AIRCONPAL) are now available on the market.



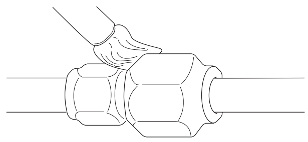
(Z0151)

9. Tighten the flare nut.
   (Use a torque wrench to apply the proper tightening force.)
   1/2 and 5/8 flare nuts for R410A equipment are enlarged in width across flat.
   1/2 24mm→26mm
   5/8 27mm→29mm



(Z0152)

10. Check for gas leaks.
    (Check at the threaded section of the flare nut for gas leaks.)
    Spray-type gas leak detecting products are available on the market. Soap water may be used to check for leaks, but use only neutral soap to prevent corrosion of the flare nut.
    Be sure to wipe out the nut area clean after the gas leak check.



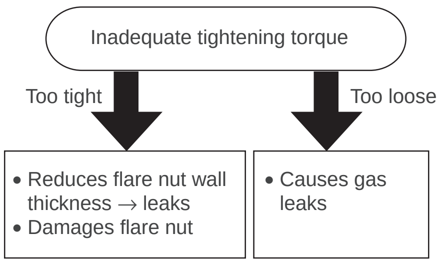
(Z0153)

Tighten the flare nut with proper torque.
It takes a lot of experience to tighten the flare nut properly without the use of a torque wrench.

Tighten the flare nut using the following torque.

Flare nut size	Standard tightening torque	
	kgf·cm	N·cm
1/4	144~176	1420~1720
3/8	333~407	3270~3990
1/2	504~616	4950~6030
5/8	630~770	6180~7540
3/4	990~1210	9720~11860

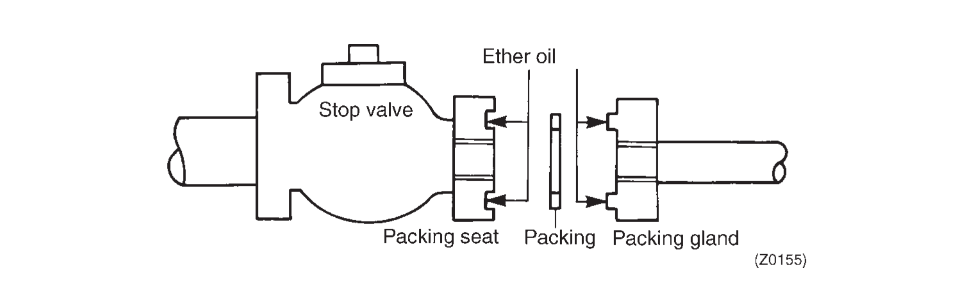
Be sure to select the torque wrench with the above mentioned range when purchasing it.



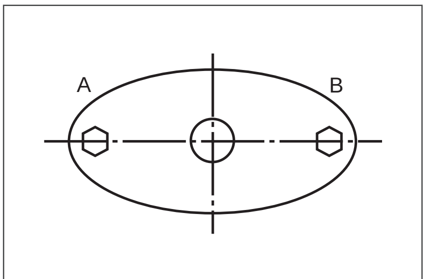
(Z0154)

13.3.7 Flange connection

1. Make sure that the flange seat surfaces are clean and free of scratches. (If dirty, clean with a cloth and check for scratches.)
2. Apply ether oil (AIRCONPAL) on the seat surfaces of the flanges, and install a packing. (The material of the packing is different from the one used before. Be sure to use the packing provided with the product.)



3. Tighten the bolts evenly by moving to the bolt located diagonally opposite to the one being tightened.



< Example > Tightening sequence: A→B→A→B

Repeat the above sequence in tightening the bolts, so that the two bolts are tightened with an equal torque.

(Z0156)

< Caution items >

1. Use AIRCONPAL to apply oil. (Make sure that the flange surface is free of dirt and moisture.)
2. Tighten the flange bolts with a proper torque.

- Standard tightening torque for screw/bolt

Size \ Type	5T	10T
M8	1.23 (kN·cm)	2.96 (kN·cm)
M10	2.52 (kN·cm)	6.07 (kN·cm)
M12	4.27 (kN·cm)	10.3 (kN·cm)
M16	10.3 (kN·cm)	24.9 (kN·cm)
M20	20.2 (kN·cm)	48.7 (kN·cm)

13.4 Air-tightness test (Air-tightness test using nitrogen gas pressure)

- **What is Air-Tightness Test?**
  Air-tightness (hermetic seal) is one of the three requirements for refrigerant piping. When piping work is complete, it is necessary to conduct a thorough leak test for all refrigerant pipes before insulating work of pipes.

Excerpt of air-tightness test section from Refrigerating Equipment Safety Regulations

Air-tightness test

The air-tightness test shall comply with the following.

(1) The air-tightness test is a gas pressure test conducted for assembled containers or vessels that passed a pressure-resistance test and for refrigerant systems connecting those containers or vessels.

(2) The air-tightness test shall be conducted with a pressure higher than the lowest value of the design pressure or allowable pressure.

(3) The gas used in the air-tightness test shall be air or non-flammable gas (excluding sour or toxic gases). If an air compressor is used to supply compressed air, the air temperature shall be 140 °C or lower.

(4) In the air-tightness test, maintain the test sample's internal gas pressure at the test pressure level, then immerse the sample in water or apply a foaming liquid on the external surfaces. Check for the generation of foams to determine whether there is a leak. If there is no foam generation, the sample shall be considered acceptable. If a felon gas is used in the test, a gas leak detector may be used to check for leaks.

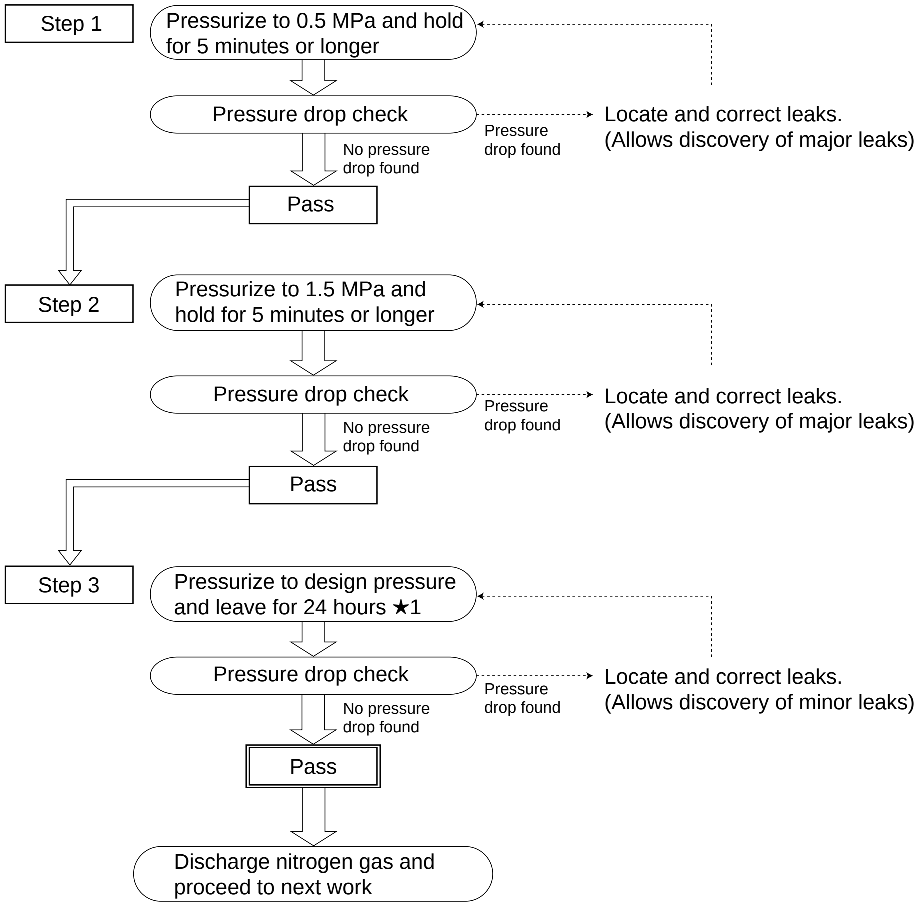
(5) The pressure gauges used in the air-tightness test shall have gauge panels measuring 75 mm or larger, and their maximum scale shall be 1.5 times the air-tightness test pressure or higher, and lower than 2 times the air-tightness test pressure. Two or more pressure gauges shall be used in the test as a rule. If a stop valve is mounted between the pressurizing air compressor (or similar equipment) and the test sample, at least one pressure gauge shall be mounted between the stop valve and test sample.

(6) For pumps built in with hermetic compressors or vessels, the air-tightness test shall be conducted on the casings that form the outer bodies of those devices.

< Cautions >

1. Be sure to use a nitrogen gas (use of oxygen and other gasses prohibited).
2. Be extra careful during air-tightness test since the test pressure is high.
3. After air-tightness-test, discharge nitrogen gas before proceeding to the next work stage.

■Work Process



(Z0157)

★1 For an example, the design pressure of VRV II R410A Series is 3.8 MPa.

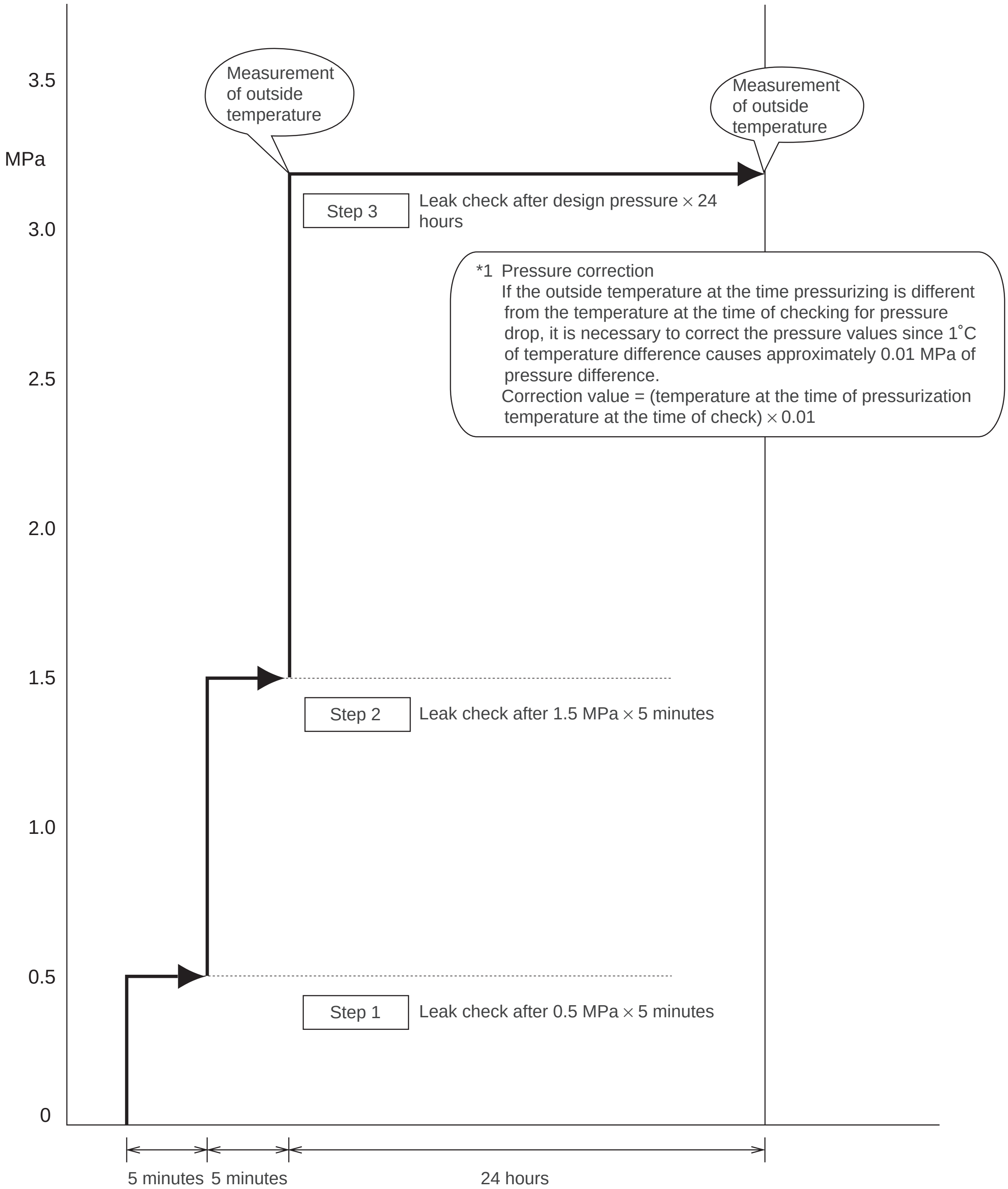
■ **Leak Check**

Check method — When a pressure drop is detected in steps 1 to 3 in the previously described work process;

- Check by listening .... Listen attentively for major leaks.
- Check by touching.................. Touch pipe joints to check for major leaks.
- Check with soapy water .... Apply soapy water on pipes. Leaks cause soapy water to form bubbles.

For long pipes, it is recommended divide pipes into blocks and conduct an air-tightness test for each block at a time. This allows easier discovery of leaks.

■ **Time chart**



* Pressure values are shown in gauge pressure.

<For reference>
Since the design pressure differs with model, the pressure should be confirmed with machine nameplate.
(For an example, the design pressure of VRV II is 3.8 MPa.)

(Z0158)

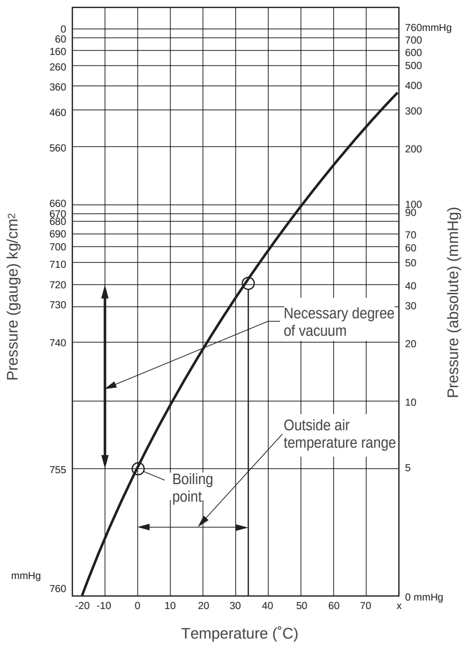
13.5 Vacuum drying

■ **What is vacuum drying?**

Vacuum drying is a method of drying the inside of a pipe by converting moisture (liquid) inside the pipe into steam (vapor) and removing it from the pipe by using a vacuum pump.
At one atmospheric pressure (760 mmHg), The boiling point (evaporation temperature) of water is 100°C.
When a vacuum pump is used to reduce the pressure inside the pipe to achieve a near-vacuum condition, the boiling point lowers.
When the boiling point drops below the outside air temperature, water evaporates.

<Example>
When outside air temperature is 7.2°C
As shown in the table, the degree of vacuum must be lowered below -752 mmHg. →

Boiling point of water (°C)	Pressure (gauge)	
	mmHg	Pa
40	-705	7333
30	-724	4800
26.7	-735	3333
24.4	-738	3066
22.2	-740	2666
20.6	-742	2400
17.8	-745	2000
15.0	-747	1733
11.7	-750	1333
7.2	-752	1066
0	-755	667



(Z0159)

The exhausting piping to vacuum of air conditioner provides the following effects.
1. Vacuum drying
2. Removes air and nitrogen (used in air-tightness test) from the inside of pipes.
   It is necessary to achieve both purposes sufficiently.

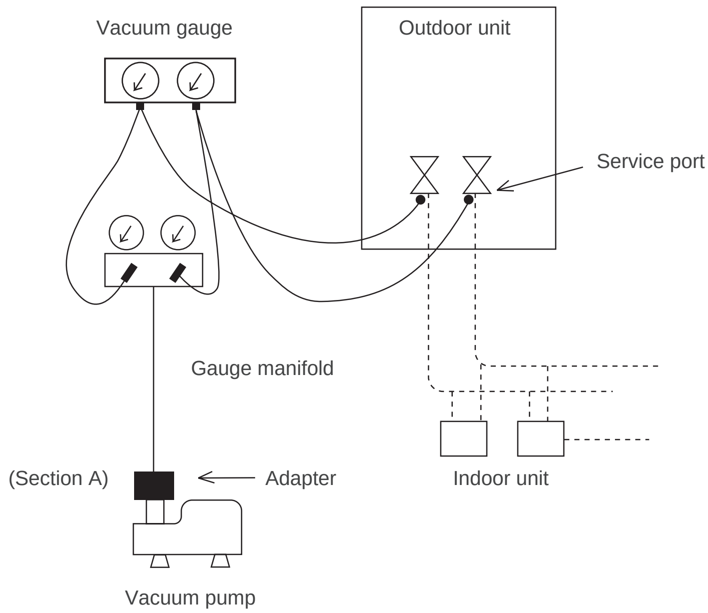
■ **Work procedure**

1. Connect gauge manifold and vacuum pump as shown in the diagram below.
2. Fully open the valve of gauge manifold, and turn on the switch of the vacuum pump.
3. Check to make sure the gauge shows a pressure level of -755 mmHg.
4. After a level of -755 mmHg is reached, continue operation the vacuum pump in the following manner.
   [VRV-system air conditioners : 1 hour or longer
   Room air conditioners: 15 minutes or longer]
5. Close the valve of the gauge manifold.
6. Loosen the hose connected to the vacuum pump (at section A), and stop the pump.
7. After approximately 1 minute, check to make sure the pressure indicated on the gauge does not increase.
   (If the indicated pressure increases, there is a leak.)
8. Vacuum drying is complete.
9. If additional refrigerant is necessary, charge more refrigerant.
10. Open the stop valves of both liquid and gas pipes of the outdoor unit.

Note 1 Be sure to use a vacuum pump designed for HFCs or install an adapter.
When the power supply shut down during operation, the built-in check valve (solenoid valve) prevents the refrigerant from flowing in the reverse direction.

Note 2 Before vacuum drying, make sure that the power switches of the outdoor and indoor units are turned OFF.

== Key point ==
Make sure that a vacuum level of -755 mmHg or lower is attained.
Stricter control of vacuum drying operation is necessary for new refrigerants.

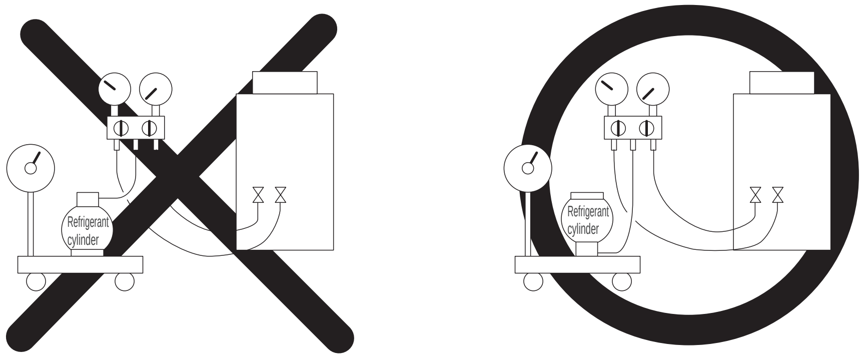


(Z0160)

13.6 Procedure of additional refrigerant charging

■ **Additional refrigerant charging after the piping work is complete**

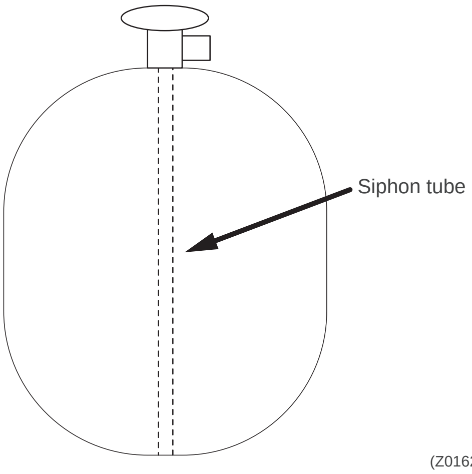
Since R407C and 410A is non-azeotropic or quasi-azeotropic mixture, be sure to charge those refrigerants in liquid state.
Therefore, the refrigerant cylinder should be turned upside down to charge refrigerant.



Item to be observed strictly : Refrigerant should be charged from the lower side of cylinder (in liquid state). Never charge from the upper side (in gaseous state).

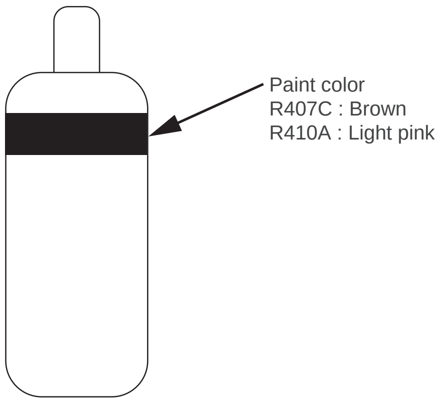
(Z0161)

<Caution>
Structure of certain refrigerant cylinder is as shown in the figure below other than above mentioned.
(A siphon tube is provided inside the cylinder not to turn upside down.)
Therefore, be sure to check the structure of cylinder before use.



(Z0162)

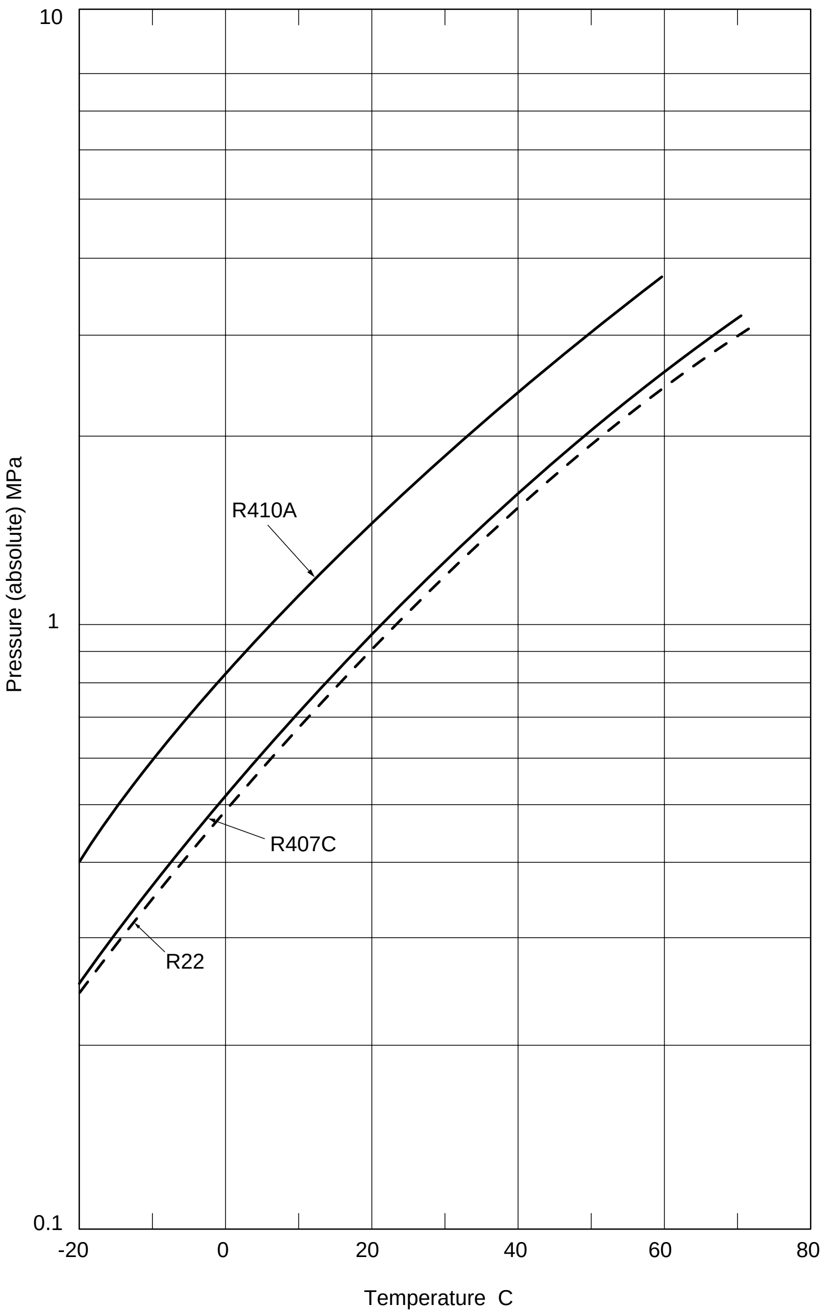
Identification of refrigerant cylinders (Color coding)



(Z0163)

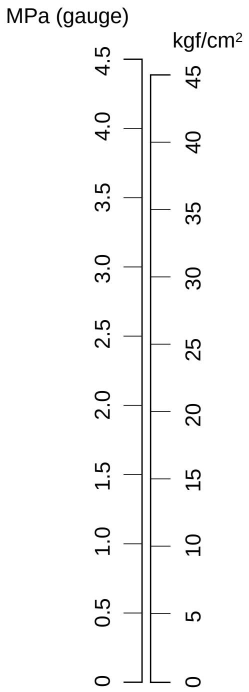
13.7 Temperature-Pressure conversion table for new refrigerants

- Saturation curve



(Z0164)

- **Comparison of MPa to kgf/cm²**



1kgf/cm2=0.098MPa

(Z0165)

Chapter 14 Appendix

14

Chapter 14 Appendix

14.1 Unit conversion tables

- Btu/h =kcal/h×3.97
- kW =kcal/h×1/860
- Inches =mm×0.0394
- Pounds =kg×2.205
- Psi =kgf/cm^2×14.22
- KPa =kgf/cm^2×98.07
- Cfm =m^3/min×35.3
- US Gallons =Liter×0.264
- UK Gallons =Liter×0.220

14.1.1 General conversion tables

Pressure

bar	kgf/cm^2	lb/in^2	OZ/in^2	British atm	Mercury (0°C)	
					mm	in
1	1.0197	14.50	2320	0.9869	750.0	29.53
0.980667	1	14.223	2275.66	0.9678	735.5	28.96
0.06895	0.07031	1	16	0.06804	51.71	0.0355
0.0_24309	0.0_24394	0.0625	1	0.0_24252	3.232	0.1276
1.0113	1.0333	14.70	235.2	1	760	29.921
1.3333	1.3596	19.34	309.4	1.316	1000	39.37
0.03386	0.0_2453	0.4912	7.859	0.03342	25.4	1

Velocity

m/sec	m/min	km/hr	ft/sec	ft/min	mile/hr	Knot
1	60	3.6	3.28091	196.854	2.23698	1.9426
0.016667	1	0.06	0.05468	3.28091	0.03728	0.03237
0.27778	16.66667	1	0.91136	54.6815	0.62138	0.53962
0.30479	18.2874	1.09725	1	60	0.68182	0.59211
0.0_250798	0.30479	0.018287	0.016667	1	0.011364	0.0_398684
0.44703	26.8215	1.60931	1.46667	88	1	0.86842
0.51478	30.8867	1.8532	1.68889	101.337	1.15152	1

Flow rate

l/sec	l/min	m^3/hr	m^3/min	m^3/sec	British gal/min	U.S gal/min	ft^3/hr	ft^3/min	ft^3/sec
1	60	3.6	0.06	0.001	13.197	15.8514	127.14	2.119	0.035317
0.01666	1	0.06	0.001	0.0_416666	0.21995	0.26419	2.119	0.035317	0.0_35886
0.27777	16.666	1	0.016666	0.0_327777	3.66583	4.40316	35.3165	0.58861	0.0_29801
16.666	1000	60	1	0.016666	219.95	264.19	2119	35.3165	0.058861
1000	60×10^3	3600	60	1	13198	15851	127150	2119	35.3165
0.075775	4.5465	0.27279	0.0_245465	0.0_475775	1	1.20114	9.6342	0.16057	0.0_22676
0.063086	3.7852	0.22711	0.0_237852	0.063086	0.83254	1	8.0208	0.13368	0.0_22228
0.0_27865	0.47188	0.028315	0.0_347188	0.0_578647	0.103798	0.12467	1	0.016666	0.0_327777
0.47188	28.3153	1.6989	0.028315	0.0_347188	6.22786	7.48055	60	1	0.016666
28.3153	1698.9	101.935	1.6989	0.028315	373.6716	448.833	3600	60	1

Area

mm^2	cm^2	m^2	In^2	ft^2	yd^2
1	0.01	0.000001	0.00155	—	—
100	1	0.0001	0.15501	0.0010764	0.0_31196
10×10^5	10×10^3	1	1550.1	10.7643	1.196
645.14	6.4514	0.0_364514	1	0.006944	0.0_37716
92900	92.9	0.0929	144	1	0.11111
836090	8360.9	0.83609	1296	9	1

Weight

mg	g	kg	grain	oz	lb
1	0.001	0.0_51	0.015432	0.0435274	0.0_522046
1000	1	0.001	15.4324	0.035274	0.0_222046
10×10^5	1000	1	15432.4	35.27394	2.20462
64.799	0.064799	0.0_464799	1	0.0_222857	0.0_314286
28349.5	28.34954	0.028349	437.5	1	0.0625
453592	453.592	0.45359	7000	16	1

Length

m	km	ft	yd	mile
1	0.001	3.2809	1.09363	0.00062
1000	1	3280.9	1093.63	0.62138
0.30479	0.033048	1	0.33333	0.0_31894
0.91438	0.0_39144	3	1	0.0_35682
1609.31	1.60931	5280	1760	1

Note: 0.0_41=0.00001

14.1.2 SI unit used for refrigeration / air conditioning and conversion table

Amount	SI unit		JIS unit Other units		Units mainly used in integral multiple of 10 of SI unit	Units mainly used in integral multiple of 10 of unit used in combination with SI unit or of unit allowed use in combination	Remarks
Length	m	m	in	ft	km dm cm mm μm		
		1 0.0254 0.3048	39.37 1 12.00	3.281 0.0833 1			
Area	m^2	m^2	in^2	ft^2	km^2 dm^2 cm^2 mm^2		
		1 0.000652 0.09290	1550.0 1 144.0	10.76 0.006944 1			
Volume	m^3	m^3	in^3	ft^3	dm^3 cm^3 mm^3	$k\ell = m^3$ $\ell = 10^3 m^3$ $1d\ell = 10^4 m^3$ $1c\ell = 10^5 m^3$	
		1 1.639×10^5 0.02832	61020 1 1728	35.31 5.787×10^4 1			
Mass	kg	kg	lb		Mg g mg		
		1 0.4536	2.205 1				
Density	kg/m^3	kg/m^3	g/cm^3	lb/ft^3			
		1000 1 16.02	1 0.001 0.01602	62.43 0.06243 1			
Speed	m/s	m/s	ft/s			km/h $1km/h = \frac{1}{3.6}$ m/s	
		1 0.3048	3.281 1				
Temperature	K (℃) (Kelvin) (Celsius)	K	°F				
		1 1.8	0.5555 1				
Force (weight)	N (Newton)	N	kgf	lb	MN kN mN μN		$IN = 1kg\times1m/s^2$
		1 9.807 4.448	0.102 1 0.4536	0.245 2.205 1			
Pressure	Pa (Pascal)	Pa	kgf/cm^2	lb/in^2 (psi)	GPa MPa kPa hPa mPA μPa		$Pa = N/m^2$ hPa＝mmbar
		1 9.807×10^4 6.895×10^3	1.02×10^5 1 0.07031	1.45×10^4 14.22 1			
Work	J (Joule)	J	kcal	BTU	TJ GJ MJ kJ		
		1 4186.05 1055.1	2.39×10^4 1 0.252	9.478×10^4 3.968 1			

14.1.3 Pressure conversion table

kgf/cm^2G →	MPaG →	p.s.i.G	kgf/cm^2G →	MPaG →	p.s.i.G
0.0	0.00	0.0	12.0	1.18	170.6
0.2	0.02	2.8	12.2	1.20	173.5
0.4	0.04	5.7	12.4	1.22	176.3
0.6	0.06	8.5	12.6	1.23	179.2
0.8	0.08	11.4	12.8	1.25	182.0
1.0	0.10	14.2	13.0	1.27	184.9
1.2	0.12	17.1	13.2	1.29	187.7
1.4	0.14	19.9	13.4	1.31	190.5
1.6	0.16	22.8	13.6	1.33	193.4
1.8	0.18	25.6	13.8	1.35	196.2
2.0	0.20	28.4	14.0	1.37	199.1
2.2	0.22	31.3	14.2	1.39	201.9
2.4	0.23	34.1	14.4	1.41	204.8
2.6	0.25	37.0	14.6	1.43	207.6
2.8	0.27	39.8	14.8	1.45	210.5
3.0	0.29	42.7	15.0	1.47	213.3
3.2	0.31	45.5	15.2	1.49	216.1
3.4	0.33	48.3	15.4	1.50	219.0
3.6	0.35	51.2	15.6	1.53	221.8
3.8	0.37	54.0	15.8	1.55	224.7
4.0	0.39	56.9	16.0	1.57	227.5
4.2	0.41	59.7	16.2	1.58	230.4
4.4	0.43	62.6	16.4	1.61	233.2
4.6	0.45	65.4	16.6	1.63	236.1
4.8	0.47	68.3	16.8	1.65	238.9
5.0	0.49	71.1	17.0	1.67	241.7
5.2	0.51	73.9	17.2	1.69	244.6
5.4	0.53	76.8	17.4	1.71	247.4
5.6	0.55	79.6	17.6	1.72	250.3
5.8	0.57	82.5	17.8	1.74	253.1
6.0	0.59	85.3	18.0	1.76	256.0
6.2	0.61	88.2	18.2	1.78	258.8
6.4	0.63	91.0	18.4	1.80	261.6
6.6	0.65	93.9	18.6	1.82	264.5
6.8	0.67	96.7	18.8	1.84	267.3
7.0	0.69	99.5	19.0	1.86	270.2
7.2	0.71	102.4	19.2	1.88	273.0
7.4	0.73	105.2	19.4	1.90	275.9
7.6	0.74	108.1	19.6	1.92	278.7
7.8	0.76	110.9	19.8	1.94	281.6
8.0	0.78	113.8	20.0	1.96	284.4
8.2	0.80	116.6	20.2	1.98	287.2
8.4	0.82	119.4	20.4	2.00	290.1
8.6	0.84	122.3	20.6	2.02	292.9
8.8	0.86	125.1	20.8	2.04	295.8
9.0	0.88	128.0	21.0	2.06	298.6
9.2	0.90	130.8	21.2	2.08	301.5
9.4	0.92	133.7	21.4	2.10	304.3
9.6	0.94	136.5	21.6	2.12	307.2
9.8	0.96	139.4	21.8	2.14	310.0
10.0	0.98	142.2	22.0	2.16	312.8
10.2	1.00	145.0	22.2	2.18	315.7
10.4	1.02	147.9	22.4	2.19	318.5
10.6	1.04	150.7	22.6	2.21	321.4
10.8	1.06	153.6	22.8	2.23	324.2
11.0	1.08	156.4	23.0	2.25	327.1
11.2	1.09	159.3	23.2	2.27	329.9
11.4	1.12	162.1	23.4	2.29	332.7
11.6	1.14	165.0	23.6	2.31	335.6
11.8	1.16	167.8	23.8	2.33	338.4

p.s.i.=14.22×kgf/cm^2
kgf/cm^2=10.2×Mpa

kgf/cm^2=0.0703×p.s.i.
MPa=0.098×kgf/cm^2

p.s.i=145.0×MPa
MPa=0.006896×p.s.i

Note: This conversion system is based on GAUGE pressure.

p.s.i.G →	MPaG →	kgf/cm^2G	p.s.i.G →	MpaG →	kgf/cm^2G
0	0.00	0.0	350	2.41	24.6
5	0.03	0.4	355	2.45	25.0
10	0.07	0.7	360	2.48	25.3
15	0.10	1.1	365	2.52	25.7
20	0.14	1.4	370	2.55	26.0
25	0.17	1.8	375	2.58	26.4
30	0.21	2.1	380	2.62	26.7
35	0.24	2.5	385	2.65	27.1
40	0.27	2.8	390	2.68	27.4
45	0.31	3.2	395	2.72	27.8
50	0.34	3.5	400	2.76	28.1
55	0.38	3.9	405	2.79	28.5
60	0.41	4.2	410	2.83	28.8
65	0.45	4.6	415	2.86	29.2
70	0.48	4.9	420	2.90	29.5
75	0.51	5.3	425	2.93	30.0
80	0.55	5.6	430	2.97	30.2
85	0.59	6.0	435	3.00	30.6
90	0.62	6.3	440	3.03	30.9
95	0.66	6.7	445	3.07	31.3
100	0.69	7.0	450	3.10	31.6
105	0.72	7.4	455	3.14	32.0
110	0.76	7.7	460	3.17	32.3
115	0.79	8.1	465	3.20	32.7
120	0.83	8.4	470	3.24	33.0
125	0.86	8.8	475	3.28	33.4
130	0.89	9.1	480	3.31	33.7
135	0.93	9.5	485	3.34	34.1
140	0.97	9.8	490	3.38	34.5
145	1.00	10.2	495	3.41	34.8
150	1.03	10.5	500	3.45	35.2
155	1.07	10.9	505	3.48	35.5
160	1.10	11.2	510	3.52	35.9
165	1.13	11.6	515	3.55	36.2
170	1.17	12.0	520	3.59	36.6
175	1.21	12.3	525	3.62	36.9
180	1.25	12.7	530	3.65	37.3
185	1.28	13.0	535	3.69	37.6
190	1.31	13.4	540	3.72	38.0
195	1.34	13.7	545	3.76	38.3
200	1.38	14.1	550	3.79	38.7
205	1.41	14.4	555	3.83	39.0
210	1.45	14.8	560	3.86	39.4
215	1.48	15.1	565	3.90	39.7
220	1.52	15.5	570	3.93	40.0
225	1.55	15.8	575	3.97	40.4
230	1.59	16.2	580	4.00	40.8
235	1.62	16.5	585	4.03	41.1
240	1.66	16.9	590	4.07	41.5
245	1.69	17.2	595	4.10	41.8
250	1.72	17.6	600	4.14	42.2
255	1.76	17.9	605	4.17	42.5
260	1.79	18.3	610	4.21	42.9
265	1.83	18.6	615	4.24	43.2
270	1.86	19.0	620	4.28	43.6
275	1.90	19.3	625	4.31	43.9
280	1.93	19.7	630	4.34	44.3
285	1.96	20.0	635	4.38	44.6
290	2.00	20.4	640	4.41	45.0
295	2.03	20.7	645	4.45	45.3
300	2.07	21.1	650	4.48	45.7
305	2.10	21.4	655	4.52	46.0
310	2.13	21.8	660	4.55	46.4
315	2.17	22.1	665	4.58	46.7
320	2.20	22.5	670	4.62	47.1
325	2.24	22.8	675	4.65	47.5
330	2.27	23.2	680	4.68	47.8
335	2.31	23.6	685	4.72	48.2
340	2.34	23.9	690	4.75	48.5
345	2.37	24.3	695	4.79	48.9

14.1.4 Temperature conversion table

°C →	°F	°C →	°F
−10	14.0	50	122.0
−9	15.8	51	123.8
−8	17.6	52	125.6
−7	19.4	53	127.4
−6	21.2	54	129.2
−5	23.0	55	131.0
−4	24.8	56	132.8
−3	26.6	57	134.6
−2	28.4	58	136.4
−1	30.2	59	138.2
0	32.0	60	140.0
1	33.8	61	141.8
2	35.6	62	143.6
3	37.4	63	145.4
4	39.2	64	147.2
5	41.0	65	149.0
6	42.8	66	150.8
7	44.6	67	152.6
8	46.4	68	154.4
9	48.2	69	156.2
10	50.0	70	158.0
11	51.8	71	159.8
12	53.6	72	161.6
13	55.4	73	163.4
14	57.2	74	165.2
15	59.0	75	167.0
16	60.8	76	168.8
17	62.6	77	170.6
18	64.4	78	172.4
19	66.2	79	174.2
20	68.0	80	176.0
21	69.8	81	177.8
22	71.6	82	179.6
23	73.4	83	181.4
24	75.2	84	183.2
25	77.0	85	185.0
26	78.8	86	186.8
27	80.6	87	188.6
28	82.4	88	190.4
29	84.2	89	192.2
30	86.0	90	194.0
31	87.8	91	195.8
32	89.6	92	197.6
33	91.4	93	199.4
34	93.2	94	201.2
35	95.0	95	203.0
36	96.8	96	204.8
37	98.6	97	206.6
38	100.4	98	208.4
39	102.2	99	210.2
40	104.0	100	212.0
41	105.8	101	213.8
42	107.6	102	215.6
43	109.4	103	217.4
44	111.2	104	219.2
45	113.0	105	221.0
46	114.8	106	222.8
47	116.6	107	224.6
48	118.4	108	226.4
49	120.2	109	228.2

°F=9/5×°C+32

°F →	°C	°F →	°C
0	−17.8	120	48.9
2	−16.7	122	50.0
4	−15.6	124	51.1
6	−14.4	126	52.2
8	−13.3	128	53.3
10	−12.2	130	54.4
12	−11.1	132	55.6
14	−10.0	134	56.7
16	−8.9	136	57.8
18	−7.8	138	58.9
20	−6.7	140	60.0
22	−5.6	142	61.1
24	−4.4	144	62.2
26	−3.3	146	63.3
28	−2.2	148	64.4
30	−1.1	150	65.6
32	0.0	152	66.7
34	1.1	154	67.8
36	2.2	156	68.9
38	3.3	158	70.0
40	4.4	160	71.1
42	5.6	162	72.2
44	6.7	164	73.3
46	7.8	166	74.4
48	8.9	168	75.6
50	10.0	170	76.7
52	11.1	172	77.8
54	12.2	174	78.9
56	13.3	176	80.0
58	14.4	178	81.1
60	15.6	180	82.2
62	16.7	182	83.3
64	17.8	184	84.4
66	18.9	186	85.6
68	20.0	188	86.7
70	21.1	190	87.8
72	22.2	192	88.9
74	23.3	194	90.0
76	24.4	196	91.1
78	25.6	198	92.2
80	26.7	200	93.3
82	27.8	202	94.4
84	28.9	204	95.6
86	30.0	206	96.7
88	31.1	208	97.8
90	32.2	210	98.9
92	33.3	212	100.0
94	34.4	214	101.1
96	35.6	216	102.2
98	36.7	218	103.3
100	37.8	220	104.4
102	38.9	222	105.6
104	40.0	224	106.7
106	41.1	226	107.8
108	42.2	228	108.9
110	43.3	230	110.0
112	44.4	232	111.1
114	45.6	234	112.2
116	46.7	236	113.3
118	47.8	238	114.4

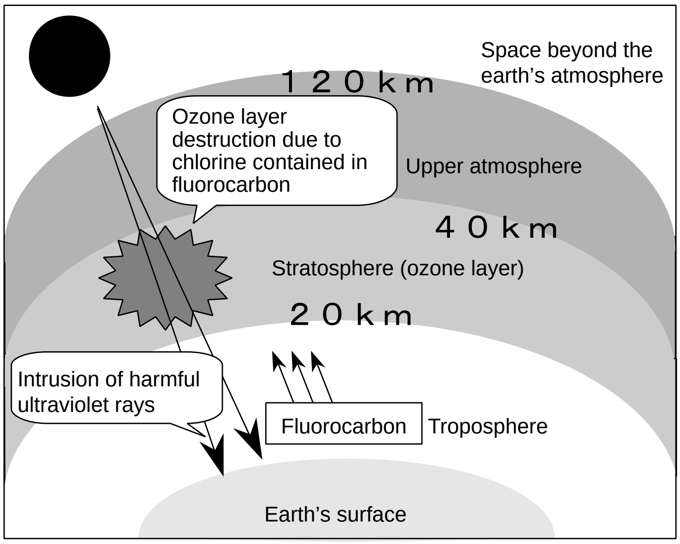
°C=(°F−32)×5/9

14.2 Refrigerant

14.2.1 Fluorocarbon and global environment

Influence of refrigerant given on global environment

(1) Ozone layer destruction



Refrigerants discharged reach the stratosphere without being decomposed.

↓

Refrigerants are decomposed by strong ultraviolet rays radiated from the sun.

▽

Chlorine is discharged.

↓

Ozone (O^3) reaction caused by chlorine discharged.

▽

Resulting in ozone layer destruction.

↓

The strong ultraviolet rays radiated from the sun directly reach Earth's surface.

▽

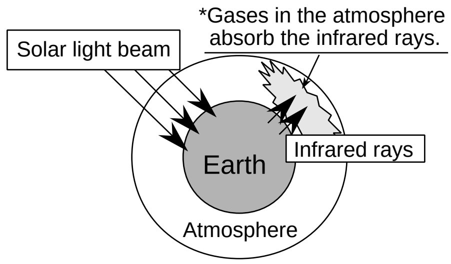
Resulting in the increase of harmful ultraviolet rays.

↓

Cause of skin cancer and others

(2) Global warming

(Principle)
Due to the results of human activities such as a large quantity of consumption of petrochemical fuels (e.g. petroleum, coal, and natural gas) and forest destruction, carbon dioxide, chlorofluorocarbon, methane, and others in the atmosphere have been increasing beyond the limit that natural force can remove them.
As a result, the dissipation of heat from Earth's surface is interrupted (greenhouse effect), thus resulting in global warming.



Carbon dioxide, fluorocarbon, methane, nitride, and others are released from Earth's surface.

↓

Infrared rays (heat rays) from Earth's surface are absorbed.

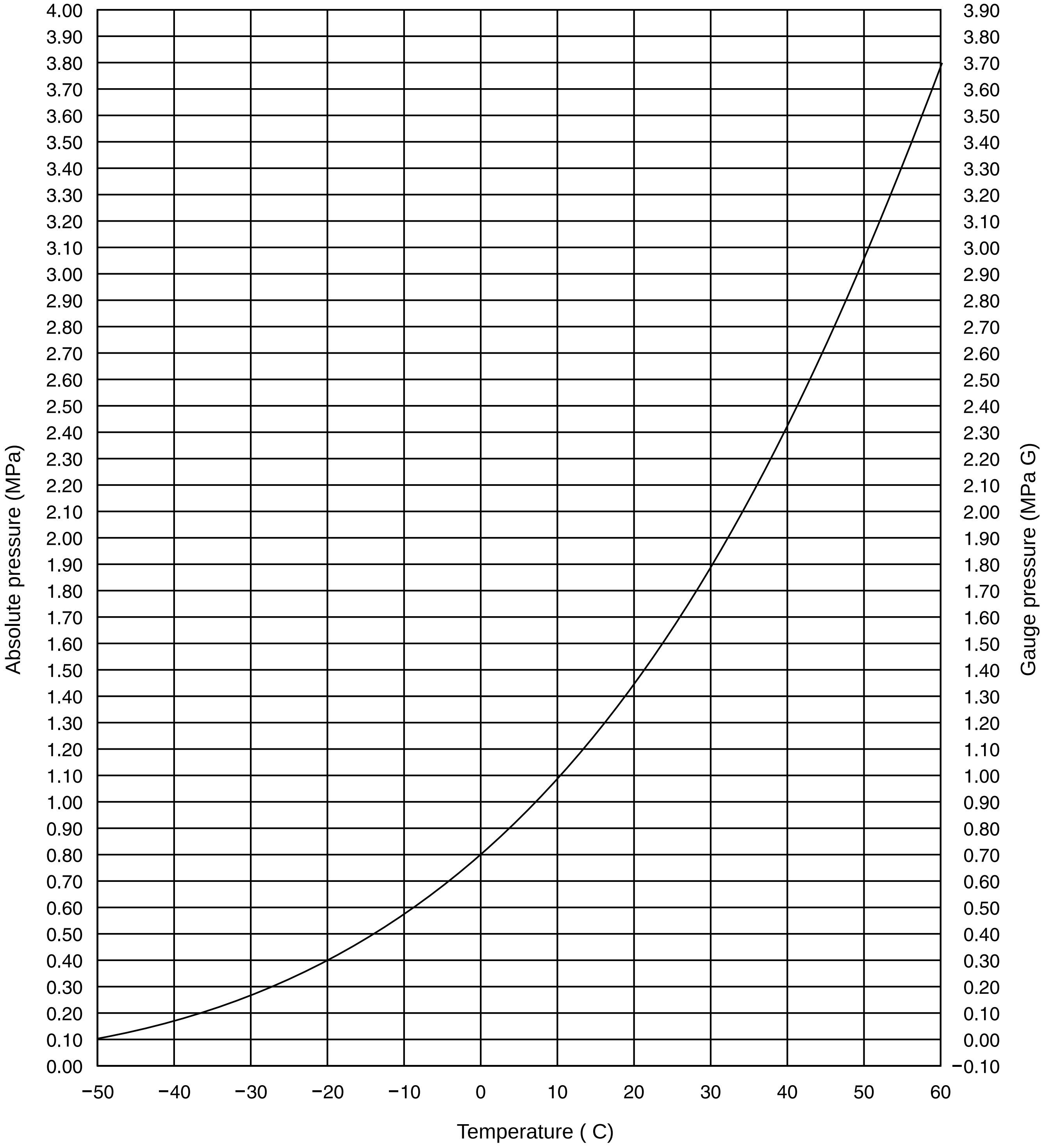
↓

Heat (temperature) cannot be dissipated from Earth's surface.

↓

Resulting in temperature rise and sea level rise.

14.2.2 Refrigerant R410A saturation curve



14.2.3 R410A Saturation pressure (gauge pressure) chart

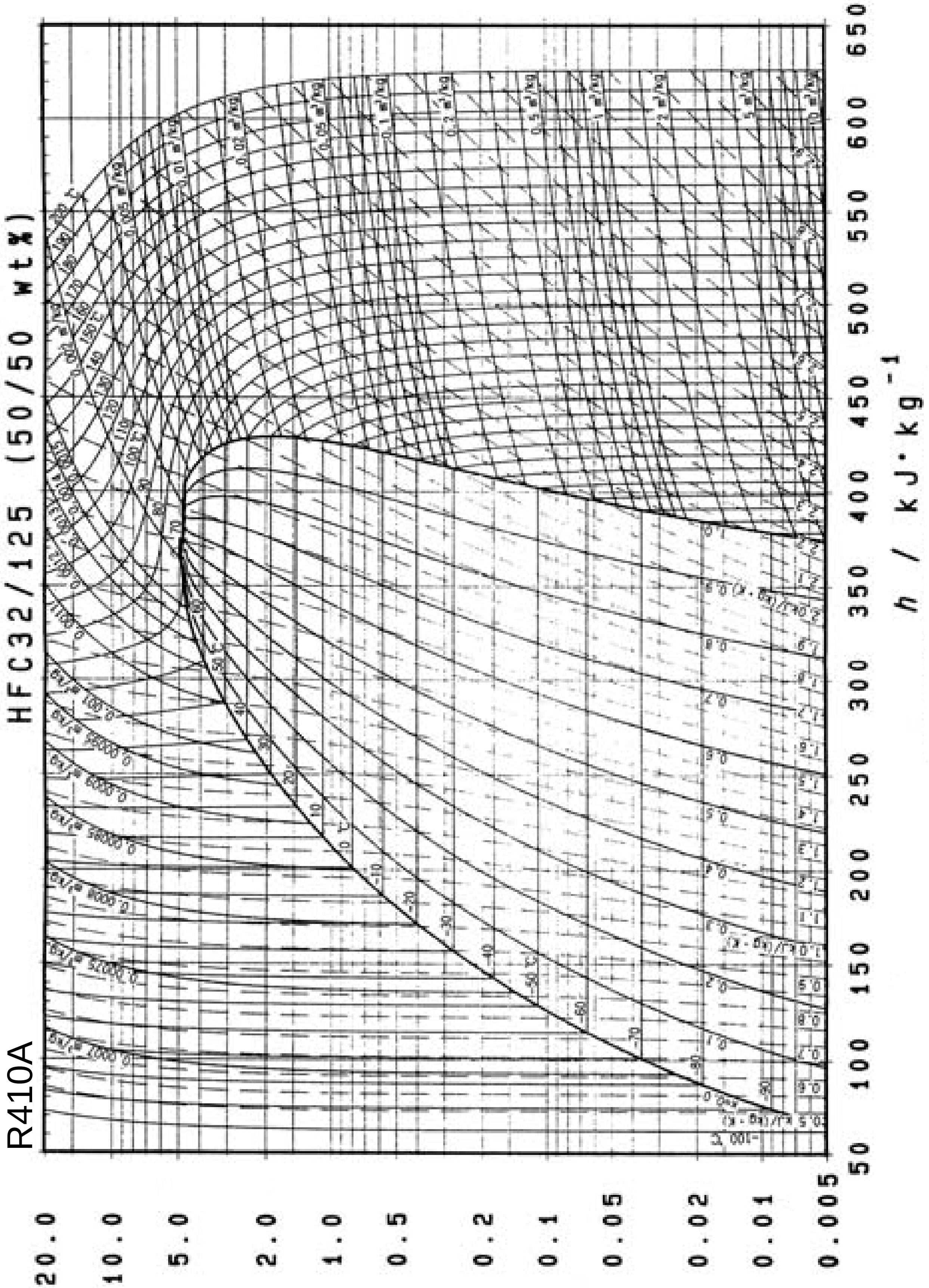
Press. MpaG	Temp °C	Press. MpaG	Temp °C	Press. MpaG	Temp °C
0	-51.58	0.9	7	3.49	57
0.06	-42	0.93	8	3.57	58
0.07	-41	0.97	9	3.65	59
0.08	-40	1	10	3.73	60
0.085	-39	1.03	11	3.82	61
0.09	-38	1.06	12	3.9	62
0.1	-37	1.09	13	3.99	63
0.11	-36	1.12	14	4.08	64
0.12	-35	1.16	15		
0.13	-34	1.2	16		
0.14	-33	1.24	17		
0.15	-32	1.27	18		
0.16	-31	1.31	19		
0.17	-30	1.35	20		
0.18	-29	1.39	21		
0.19	-28	1.43	22		
0.21	-27	1.48	23		
0.22	-26	1.52	24		
0.23	-25	1.56	25		
0.24	-24	1.6	26		
0.26	-23	1.65	27		
0.27	-22	1.7	28		
0.29	-21	1.75	29		
0.3	-20	1.79	30		
0.32	-19	1.84	31		
0.33	-18	1.89	32		
0.35	-17	1.92	33		
0.36	-16	1.94	34		
0.38	-15	2.02	35		
0.4	-14	2.1	36		
0.42	-13	2.16	37		
0.43	-12	2.21	38		
0.45	-11	2.27	39		
0.47	-10	2.33	40		
0.49	-9	2.39	41		
0.51	-8	2.45	42		
0.54	-7	2.51	43		
0.56	-6	2.57	44		
0.58	-5	2.64	45		
0.6	-4	2.7	46		
0.63	-3	2.77	47		
0.65	-2	2.83	48		
0.68	-1	2.9	49		
0.7	0	2.97	50		
0.73	1	3.04	51		
0.75	2	3.11	52		
0.78	3	3.19	53		
0.81	4	3.26	54		
0.84	5	3.34	55		
0.87	6	3.41	56		

14.2.4 Thermodynamic characteristics of R410A

DAIREP ver2.0

Temperature (C)	Steam pressure (kPa)		Density (kg/m³)		Specific heat at constant pressure (kj/kgK)		Specific enthalpy (kj/kg)		Specific entropy (kj/kgK)	
	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor	Liquid	Vapor
-70	36.13	36.11	1410.7	1.582	1.372	0.695	100.8	390.6	0.649	2.074
-68	40.83	40.80	1404.7	1.774	1.374	0.700	103.6	391.8	0.663	2.066
-66	46.02	45.98	1398.6	1.984	1.375	0.705	106.3	393.0	0.676	2.058
-64	51.73	51.68	1392.5	2.213	1.377	0.710	109.1	394.1	0.689	2.051
-62	58.00	57.94	1386.4	2.463	1.378	0.715	111.9	395.3	0.702	2.044
-60	64.87	64.80	1380.2	2.734	1.379	0.720	114.6	396.4	0.715	2.037
-58	72.38	72.29	1374.0	3.030	1.380	0.726	117.4	397.6	0.728	2.030
-56	80.57	80.46	1367.8	3.350	1.382	0.732	120.1	398.7	0.741	2.023
-54	89.49	89.36	1361.6	3.696	1.384	0.737	122.9	399.8	0.754	2.017
-52	99.18	99.03	1355.3	4.071	1.386	0.744	125.7	400.9	0.766	2.010
-51.58	101.32	101.17	1354.0	4.153	1.386	0.745	126.3	401.1	0.769	2.009
-50	109.69	109.51	1349.0	4.474	1.388	0.750	128.5	402.0	0.779	2.004
-48	121.07	120.85	1342.7	4.909	1.391	0.756	131.2	403.1	0.791	1.998
-46	133.36	133.11	1336.3	5.377	1.394	0.763	134.0	404.1	0.803	1.992
-44	146.61	146.32	1330.0	5.880	1.397	0.770	136.8	405.2	0.816	1.987
-42	160.89	160.55	1323.5	6.419	1.401	0.777	139.6	406.2	0.828	1.981
-40	176.24	175.85	1317.0	6.996	1.405	0.785	142.4	407.3	0.840	1.976
-38	192.71	192.27	1310.5	7.614	1.409	0.792	145.3	408.3	0.852	1.970
-36	210.37	209.86	1304.0	8.275	1.414	0.800	148.1	409.3	0.864	1.965
-34	229.26	228.69	1297.3	8.980	1.419	0.809	150.9	410.2	0.875	1.960
-32	249.46	248.81	1290.6	9.732	1.424	0.817	153.8	411.2	0.887	1.955
-30	271.01	270.28	1283.9	10.53	1.430	0.826	156.6	412.1	0.899	1.950
-28	293.99	293.16	1277.1	11.39	1.436	0.835	159.5	413.1	0.911	1.946
-26	318.44	317.52	1270.2	12.29	1.442	0.844	162.4	414.0	0.922	1.941
-24	344.44	343.41	1263.3	13.26	1.448	0.854	165.3	414.9	0.934	1.936
-22	372.05	370.90	1256.3	14.28	1.455	0.864	168.2	415.7	0.945	1.932
-20	401.34	400.06	1249.2	15.37	1.461	0.875	171.1	416.6	0.957	1.927
-18	432.36	430.95	1242.0	16.52	1.468	0.886	174.1	417.4	0.968	1.923
-16	465.20	463.64	1234.8	17.74	1.476	0.897	177.0	418.2	0.980	1.919
-14	499.91	498.20	1227.5	19.04	1.483	0.909	180.0	419.0	0.991	1.914
-12	536.58	534.69	1220.0	20.41	1.491	0.921	182.9	419.8	1.003	1.910
-10	575.26	573.20	1212.5	21.86	1.499	0.933	185.9	420.5	1.014	1.906
-8	616.03	613.78	1204.9	23.39	1.507	0.947	189.0	421.2	1.025	1.902
-6	658.97	656.52	1197.2	25.01	1.516	0.960	192.0	421.9	1.036	1.898
-4	704.15	701.49	1189.4	26.72	1.524	0.975	195.0	422.6	1.048	1.894
-2	751.64	748.76	1181.4	28.53	1.533	0.990	198.1	423.2	1.059	1.890
0	801.52	798.41	1173.4	30.44	1.543	1.005	201.2	423.8	1.070	1.886
2	853.87	850.52	1165.3	32.46	1.552	1.022	204.3	424.4	1.081	1.882
4	908.77	905.16	1157.0	34.59	1.563	1.039	207.4	424.9	1.092	1.878
6	966.29	962.42	1148.6	36.83	1.573	1.057	210.5	425.5	1.103	1.874
8	1026.5	1022.4	1140.0	39.21	1.584	1.076	213.7	425.9	1.114	1.870
10	1089.5	1085.1	1131.3	41.71	1.596	1.096	216.8	426.4	1.125	1.866
12	1155.4	1150.7	1122.5	44.35	1.608	1.117	220.0	426.8	1.136	1.862
14	1224.3	1219.2	1113.5	47.14	1.621	1.139	223.2	427.2	1.147	1.859
16	1296.2	1290.8	1104.4	50.09	1.635	1.163	226.5	427.5	1.158	1.855
18	1371.2	1365.5	1095.1	53.20	1.650	1.188	229.7	427.8	1.169	1.851
20	1449.4	1443.4	1085.6	56.48	1.666	1.215	233.0	428.1	1.180	1.847
22	1530.9	1524.6	1075.9	59.96	1.683	1.243	236.4	428.3	1.191	1.843
24	1615.8	1609.2	1066.0	63.63	1.701	1.273	239.7	428.4	1.202	1.839
26	1704.2	1697.2	1055.9	67.51	1.721	1.306	243.1	428.6	1.214	1.834
28	1796.2	1788.9	1045.5	71.62	1.743	1.341	246.5	428.6	1.225	1.830
30	1891.9	1884.2	1034.9	75.97	1.767	1.379	249.9	428.6	1.236	1.826
32	1991.3	1983.2	1024.1	80.58	1.793	1.420	253.4	428.6	1.247	1.822
34	2094.5	2086.2	1012.9	85.48	1.822	1.465	256.9	428.4	1.258	1.817
36	2201.7	2193.1	1001.4	90.68	1.855	1.514	260.5	428.3	1.269	1.813
38	2313.0	2304.0	989.5	96.22	1.891	1.569	264.1	428.0	1.281	1.808
40	2428.4	2419.2	977.3	102.1	1.932	1.629	267.8	427.7	1.292	1.803
42	2548.1	2538.6	964.6	108.4	1.979	1.696	271.5	427.2	1.303	1.798
44	2672.2	2662.4	951.4	115.2	2.033	1.771	275.3	426.7	1.315	1.793
46	2800.7	2790.7	937.7	122.4	2.095	1.857	279.2	426.1	1.327	1.788
48	2933.7	2923.6	923.3	130.2	2.168	1.955	283.2	425.4	1.339	1.782
50	3071.5	3061.2	908.2	138.6	2.256	2.069	287.3	424.5	1.351	1.776
52	3214.0	3203.6	892.2	147.7	2.362	2.203	291.5	423.5	1.363	1.770
54	3361.4	3351.0	875.1	157.6	2.493	2.363	295.8	422.4	1.376	1.764
56	3513.8	3503.5	856.8	168.4	2.661	2.557	300.3	421.0	1.389	1.757
58	3671.3	3661.2	836.9	180.4	2.883	2.799	305.0	419.4	1.403	1.749
60	3834.1	3824.2	814.9	193.7	3.191	3.106	310.0	417.6	1.417	1.741
62	4002.1	3992.7	790.1	208.6	3.650	3.511	315.3	415.5	1.433	1.732
64	4175.7	4166.8	761.0	225.6	4.415	4.064	321.2	413.0	1.450	1.722

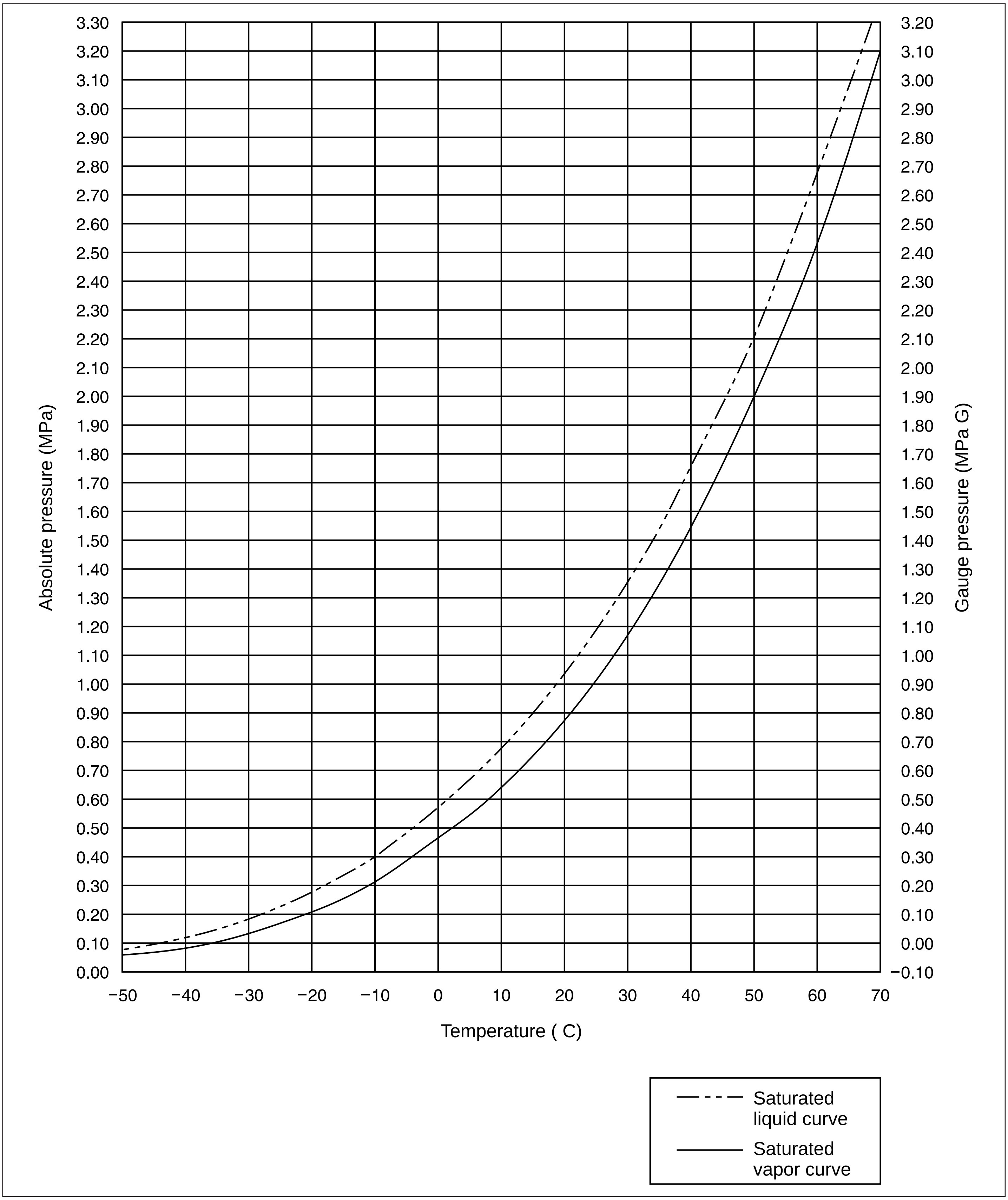
(Z0168)



Pressure-enthalpy curves of HFC32/125 (50 / 50 wt%)

(Z0169)

14.2.5 Refrigerant R407C saturation curve



14.2.6 R407C Saturation pressure (gauge pressure) chart

Press.	Temp ℃		Press.	Temp ℃		Press.	Temp ℃	
MPaG	Liquid	Gas	MPaG	Liquid	Gas	MPaG	Liquid	Gas
0	-44	-36	0.61	6.8	13	2.56	58	62
0.007	-43	-35	0.63	8	14	2.63	59	63
0.014	-41	-34	0.66	9	15	2.69	60	64
0.02	-40	-33	0.68	10	16	2.76	62	65
0.026	-39	-32	0.7	11	17	2.82	63	66
0.032	-38	-31	0.72	12	18	2.89	64	67
0.038	-37	-30	0.75	13	19	2.96	65	68
0.045	-36	-29	0.78	14	20	3.03	66	69
0.051	-35	-28	0.81	15	21	3.1	67	70
0.058	-34	-27	0.83	16	22			
0.065	-33	-26	0.86	17	23			
0.073	-32	-25	0.89	18	24			
0.08	-31	-24	0.92	19.5	25			
0.085	-30	-23	0.95	21	26			
0.09	-29	-22	0.98	22	27			
0.1	-28	-21	1.01	23	28			
0.11	-27	-20	1.04	23.5	29			
0.12	-26	-19	1.07	24	30			
0.13	-25	-18	1.1	25.5	31			
0.14	-24	-17	1.14	27	32			
0.15	-23	-16	1.17	28	33			
0.16	-22	-15	1.21	29	34			
0.17	-21	-14	1.25	30	35			
0.18	-20	-13	1.29	31	36			
0.19	-19	-12	1.32	32	37			
0.2	-18	-11	1.36	33	38			
0.22	-17	-10	1.4	34	39			
0.23	-16	-9	1.44	35	40			
0.24	-15	-8	1.49	36	41			
0.26	-13	-7	1.53	37	42			
0.27	-11	-6	1.57	38	43			
0.29	-11	-5	1.61	39	44			
0.3	-10	-4	1.65	40	45			
0.32	-9	-3	1.7	41	46			
0.33	-8	-2	1.75	42	47			
0.35	-7	-1	1.8	43	48			
0.36	-6	0	1.85	44	49			
0.38	-5.5	1	1.89	45	50			
0.39	-5	2	1.95	46.5	51			
0.41	-3.5	3	1.99	48	52			
0.43	-2	4	2.05	49	53			
0.45	-1.3	5	2.1	50	54			
0.46	-0.5	6	2.16	51	55			
0.48	0.5	7	2.21	52	56			
0.5	1.5	8	2.27	53	57			
0.52	2.5	9	2.32	54	58			
0.54	3.5	10	2.38	55	59			
0.56	4.5	11	2.44	56	60			
0.58	5.5	12	2.5	57	61			

14.2.7 Thermodynamic characteristics of R407C

DAIREP ver2.0

Temperature (C)	Steam pressure (kPa) Liquid	Steam pressure (kPa) Vapor	Density (kg/m^3) Liquid	Density (kg/m^3) Vapor	Specific heat at constant pressure (kj/kgK) Liquid	Specific heat at constant pressure (kj/kgK) Vapor	Specific enthalpy (kj/kg) Liquid	Specific enthalpy (kj/kg) Vapor	Specific entropy (kj/kgK) Liquid	Specific entropy (kj/kgK) Vapor
-70	23.54	14.46	1456.2	0.745	1.306	0.671	101.7	370.7	0.690	2.208
-68	26.69	16.59	1450.4	0.848	1.309	0.676	104.3	371.9	0.703	2.021
-66	30.17	18.98	1444.7	0.962	1.312	0.680	106.9	373.2	0.716	2.014
-64	34.03	21.64	1438.8	1.088	1.314	0.685	109.6	374.4	0.728	2.008
-62	38.27	24.61	1433.0	1.227	1.315	0.690	112.2	375.6	0.741	2.001
-60	42.94	27.91	1427.1	1.380	1.316	0.694	114.8	376.9	0.753	1.995
-58	48.05	31.56	1421.2	1.548	1.316	0.699	117.5	378.1	0.766	1.989
-56	53.65	35.59	1415.2	1.733	1.316	0.704	120.1	379.3	0.778	1.983
-54	59.76	40.03	1409.3	1.934	1.316	0.710	122.7	380.5	0.790	1.978
-52	66.42	44.91	1403.3	2.155	1.316	0.715	125.4	381.8	0.802	1.973
-50	73.67	50.27	1397.4	2.395	1.317	0.720	128.0	383.0	0.814	1.967
-48	81.53	56.13	1391.4	2.656	1.318	0.726	130.6	384.2	0.825	1.962
-46	90.06	62.53	1385.4	2.939	1.319	0.732	133.3	385.4	0.837	1.958
-44	99.26	69.52	1379.4	3.246	1.321	0.737	135.9	386.6	0.849	1.953
-43.57	101.32	71.09	1378.1	3.315	1.321	0.739	136.5	386.8	0.851	1.952
-42	109.21	77.11	1373.3	3.579	1.323	0.743	138.6	387.8	0.860	1.948
-40	119.93	85.36	1367.2	3.937	1.325	0.749	141.2	389.0	0.871	1.944
-38	131.47	94.30	1361.1	4.324	1.328	0.756	143.9	390.1	0.883	1.940
-36	143.86	103.97	1355.0	4.741	1.331	0.762	146.5	391.3	0.894	1.936
-34	157.15	114.41	1348.9	5.189	1.335	0.769	149.2	392.5	0.905	1.932
-32	171.39	125.68	1342.7	5.670	1.339	0.775	151.9	393.6	0.916	1.928
-30	186.63	137.80	1336.4	6.186	1.343	0.782	154.6	394.8	0.927	1.924
-28	202.90	150.84	1330.1	6.739	1.348	0.789	157.3	395.9	0.938	1.921
-26	220.25	164.83	1323.8	7.331	1.353	0.797	160.0	397.0	0.949	1.917
-24	238.73	179.82	1317.4	7.963	1.359	0.804	162.7	398.1	0.960	1.914
-22	258.40	195.87	1311.0	8.638	1.364	0.812	165.4	399.2	0.971	1.910
-20	279.30	213.02	1304.5	9.357	1.370	0.820	168.2	400.3	0.982	1.907
-18	301.48	231.33	1297.9	10.12	1.377	0.828	170.9	401.4	0.993	1.904
-16	325.00	250.85	1291.3	10.94	1.383	0.836	173.7	402.5	1.003	1.901
-14	349.90	271.63	1284.7	11.81	1.390	0.845	176.5	403.5	1.014	1.898
-12	376.25	293.73	1277.9	12.73	1.396	0.854	179.3	404.6	1.025	1.895
-10	404.08	317.21	1271.1	13.71	1.403	0.863	182.1	405.6	1.035	1.892
-8	433.47	342.11	1264.2	14.75	1.411	0.872	184.9	406.6	1.046	1.889
-6	464.46	368.51	1257.2	15.85	1.418	0.882	187.7	407.6	1.056	1.887
-4	497.11	396.47	1250.1	17.02	1.425	0.892	190.6	408.6	1.067	1.884
-2	531.47	426.03	1243.0	18.26	1.433	0.903	193.4	409.5	1.077	1.881
0	567.61	457.27	1235.8	19.57	1.441	0.913	196.3	410.5	1.088	1.879
2	605.59	490.26	1228.4	20.95	1.449	0.924	199.2	411.4	1.098	1.876
4	645.45	525.04	1221.0	22.42	1.457	0.936	202.1	412.3	1.109	1.874
6	687.27	561.70	1213.5	23.97	1.465	0.948	205.0	413.2	1.119	1.871
8	731.09	600.30	1205.9	25.60	1.473	0.960	208.0	414.1	1.130	1.869
10	776.99	640.90	1198.2	27.33	1.482	0.973	210.9	414.9	1.140	1.866
12	825.02	683.58	1190.3	29.16	1.490	0.987	213.9	415.8	1.150	1.864
14	875.24	728.41	1182.4	31.08	1.499	1.001	216.9	416.6	1.161	1.861
16	927.72	775.46	1174.3	33.12	1.508	1.015	219.9	417.4	1.171	1.859
18	982.52	824.81	1166.2	35.26	1.518	1.030	222.9	418.1	1.181	1.857
20	1039.7	876.52	1157.9	37.53	1.527	1.046	226.0	418.8	1.191	1.854
22	1099.3	930.69	1149.4	39.92	1.538	1.063	229.0	419.5	1.202	1.852
24	1161.5	987.38	1140.9	42.44	1.548	1.081	232.1	420.2	1.212	1.850
26	1226.2	1046.7	1132.2	45.10	1.559	1.099	235.2	420.9	1.222	1.847
28	1293.5	1108.7	1123.3	47.91	1.571	1.118	238.3	421.5	1.232	1.845
30	1363.6	1173.4	1114.3	50.87	1.583	1.139	241.4	422.1	1.242	1.842
32	1436.4	1241.0	1105.1	54.00	1.596	1.161	244.6	422.6	1.252	1.840
34	1512.1	1311.6	1095.8	57.31	1.610	1.184	247.8	423.1	1.263	1.838
36	1590.7	1385.2	1086.3	60.80	1.625	1.208	251.0	423.6	1.273	1.835
38	1672.2	1461.9	1076.6	64.49	1.641	1.234	254.2	424.0	1.283	1.833
40	1756.7	1541.9	1066.6	68.40	1.658	1.263	257.5	424.4	1.293	1.830
42	1844.4	1625.1	1056.5	72.54	1.677	1.293	260.7	424.8	1.303	1.827
44	1935.2	1711.8	1046.1	76.93	1.698	1.325	264.1	425.1	1.313	1.825
46	2029.3	1802.0	1035.5	81.58	1.720	1.361	267.4	425.3	1.324	1.822
48	2126.6	1895.8	1024.6	86.52	1.745	1.399	270.8	425.5	1.334	1.819
50	2227.3	1993.4	1013.5	91.78	1.773	1.442	274.2	425.6	1.344	1.816
52	2331.4	2094.8	1001.9	97.38	1.804	1.488	277.7	425.7	1.355	1.813
54	2439.0	2200.2	990.1	103.4	1.838	1.540	281.2	425.7	1.365	1.809
56	2550.2	2309.7	977.8	109.8	1.878	1.598	284.7	425.6	1.376	1.806
58	2664.9	2423.3	965.1	116.6	1.922	1.664	288.3	425.4	1.386	1.802
60	2783.2	2541.4	951.9	124.0	1.973	1.739	292.0	425.1	1.397	1.799
62	2905.3	2664.0	938.2	132.0	2.033	1.826	295.7	424.7	1.408	1.794
64	3031.0	2791.2	923.8	140.7	2.103	1.928	299.6	424.2	1.419	1.790
66	3160.5	2923.3	908.6	150.1	2.186	2.049	303.5	423.5	1.430	1.785
68	3293.8	3060.4	892.6	160.5	2.288	2.197	307.5	422.6	1.441	1.780
70	3430.8	3202.7	875.5	172.0	2.413	2.387	311.7	421.5	1.453	1.775

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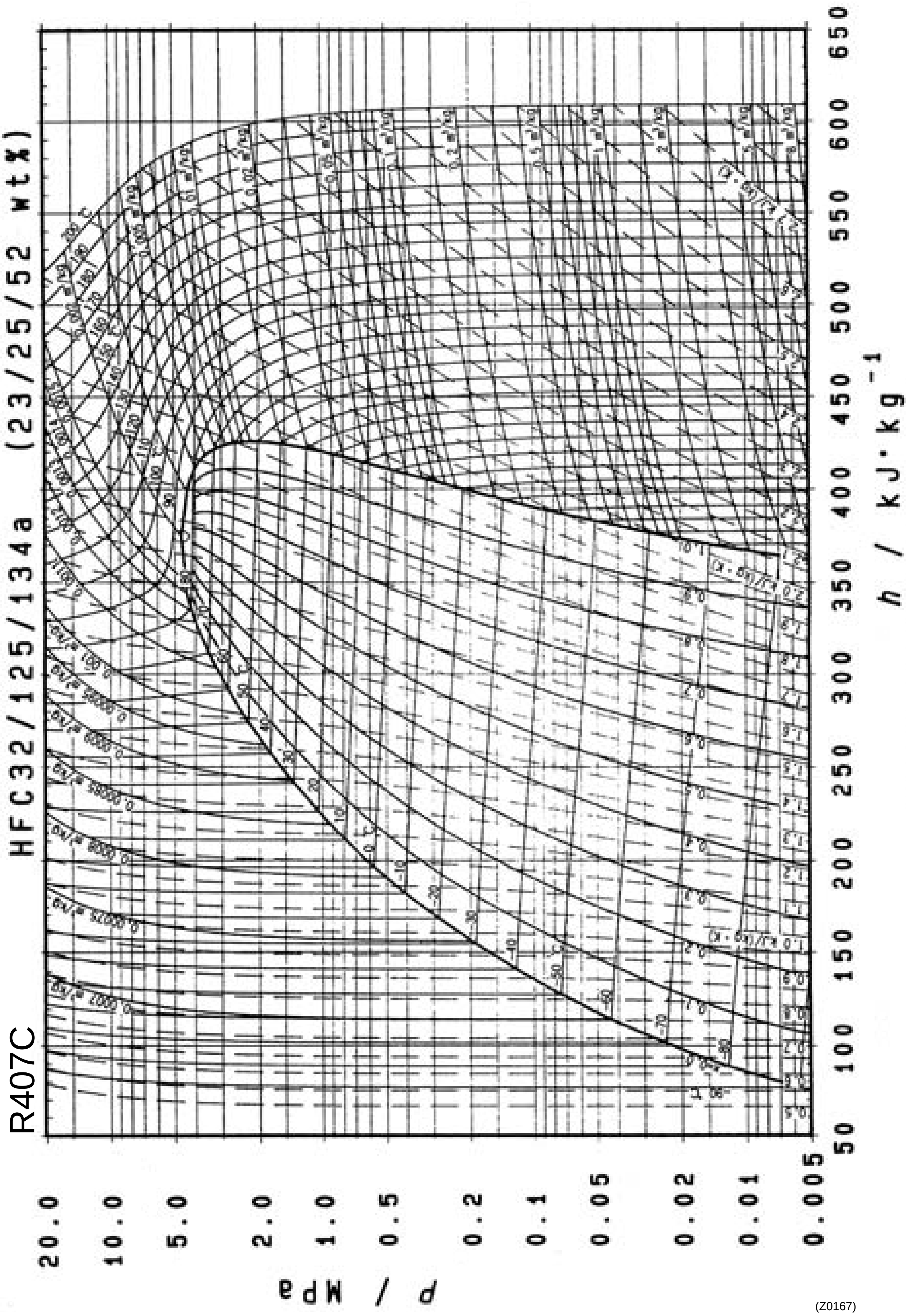

Pressure-enthalpy curves of HFC-32/125/134a (23/25/52 wt%)

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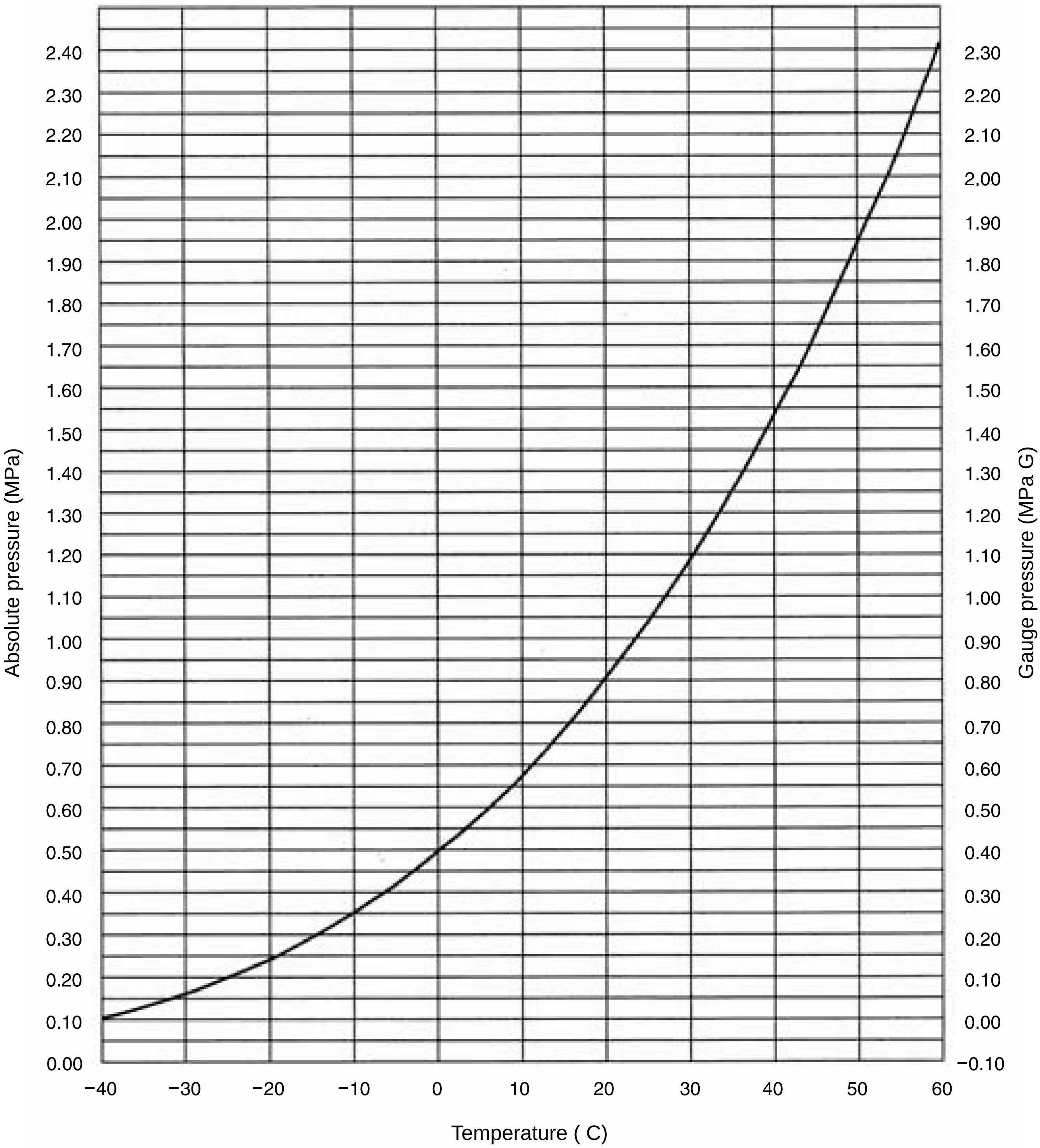
14.2.8 R-22 Refrigerant saturation curve

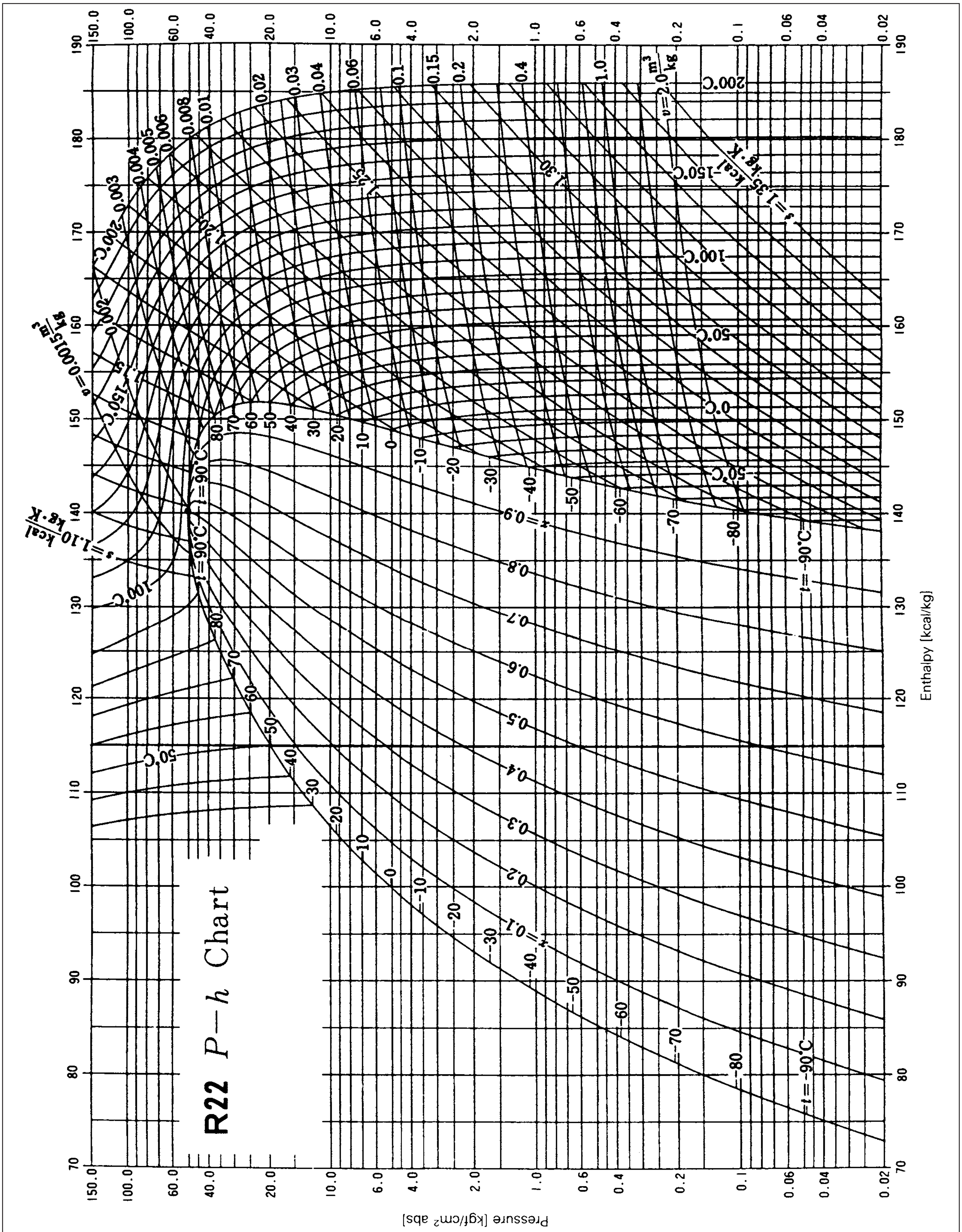


14.2.9 R-22 Saturation pressure (gauge pressure) chart

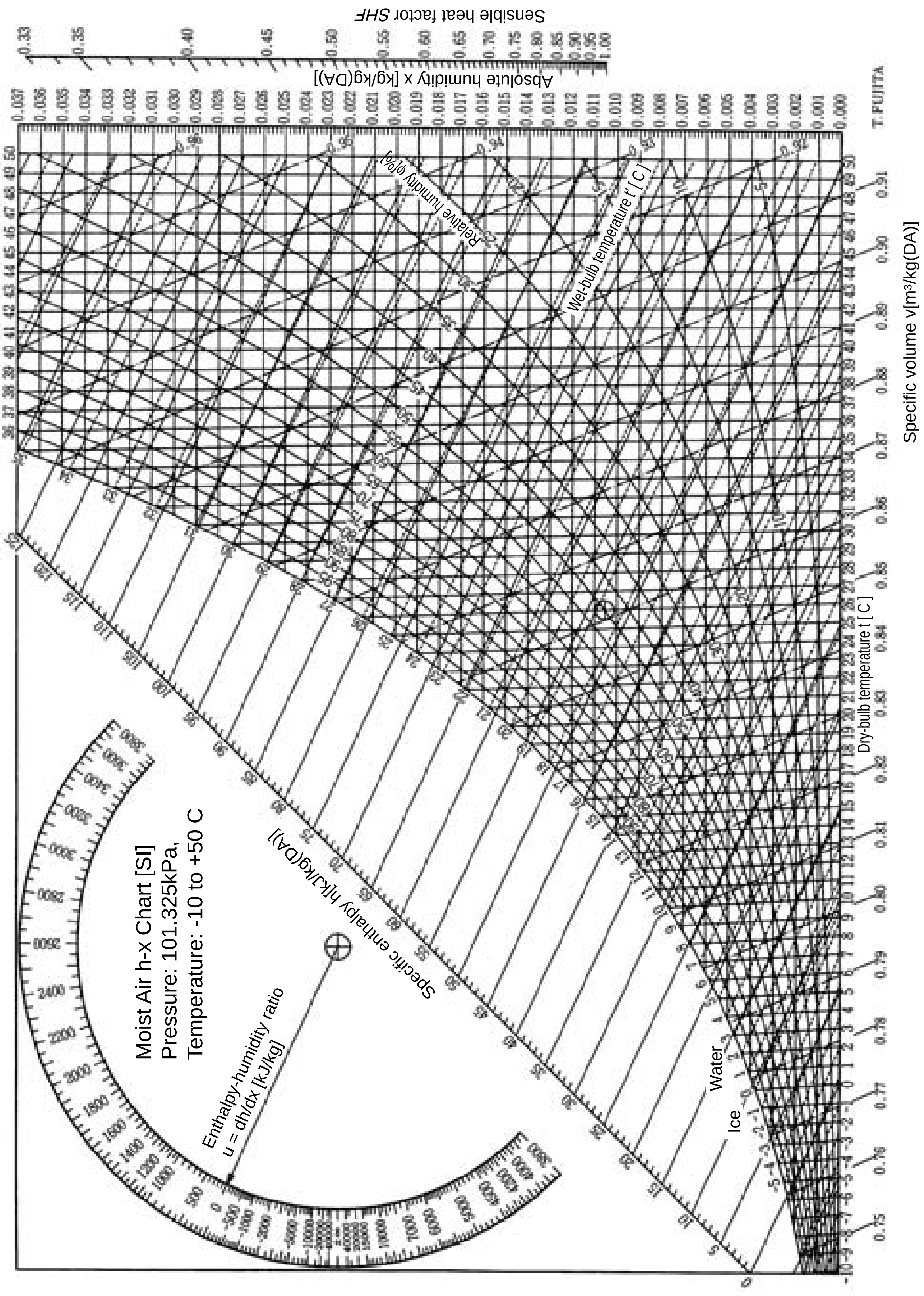
Press. kgf/cm²G	Press. MPaG	Temp. °C	Press. kgf/cm²G	Press. MPaG	Temp. °C	Press. kgf/cm²G	Press. MPaG	Temp. °C
0	0.000	-40.8	5.0	0.490	5.4	10.0	0.981	26.3
0.1	0.010	-38.8	5.1	0.500	5.9	10.1	0.990	26.7
0.2	0.020	-37.0	5.2	0.510	6.5	10.2	1.000	27.0
0.3	0.029	-35.2	5.3	0.520	7.0	10.3	1.010	27.3
0.4	0.039	-33.6	5.4	0.530	7.5	10.4	1.020	27.7
0.5	0.049	-32.0	5.5	0.539	8.0	10.5	1.030	28.0
0.6	0.059	-30.6	5.6	0.549	8.5	10.6	1.040	28.3
0.7	0.069	-29.1	5.7	0.559	9.0	10.7	1.049	28.6
0.8	0.078	-27.8	5.8	0.569	9.5	10.8	1.059	29.0
0.9	0.088	-26.5	5.9	0.579	9.9	10.9	1.069	29.3
1.0	0.098	-25.3	6.0	0.588	10.4	11.0	1.079	29.6
1.1	0.108	-24.1	6.1	0.598	10.9	11.1	1.089	29.9
1.2	0.118	-22.9	6.2	0.608	11.4	11.2	1.098	30.2
1.3	0.127	-21.8	6.3	0.618	11.8	11.3	1.108	30.6
1.4	0.137	-20.7	6.4	0.628	12.3	11.4	1.118	30.9
1.5	0.147	-19.7	6.5	0.637	12.7	11.5	1.128	31.2
1.6	0.157	-18.7	6.6	0.647	13.2	11.6	1.138	31.5
1.7	0.167	-17.7	6.7	0.657	13.6	11.7	1.147	31.8
1.8	0.177	-16.7	6.8	0.667	14.1	11.8	1.157	32.1
1.9	0.186	-15.8	6.9	0.677	14.5	11.9	1.167	32.4
2.0	0.196	-14.9	7.0	0.686	14.9	12.0	1.177	32.7
2.1	0.206	-14.0	7.1	0.696	15.4	12.1	1.187	33.0
2.2	0.216	-13.1	7.2	0.706	15.8	12.2	1.196	33.3
2.3	0.226	-12.3	7.3	0.716	16.2	12.3	1.206	33.6
2.4	0.235	-11.5	7.4	0.726	16.6	12.4	1.216	33.9
2.5	0.245	-10.7	7.5	0.735	17.0	12.5	1.226	34.2
2.6	0.255	-9.9	7.6	0.745	17.4	12.6	1.236	34.5
2.7	0.265	-9.1	7.7	0.755	17.8	12.7	1.245	34.8
2.8	0.275	-8.3	7.8	0.765	18.2	12.8	1.255	35.0
2.9	0.284	-7.6	7.9	0.775	18.6	12.9	1.265	35.3
3.0	0.294	-6.9	8.0	0.785	19.0	13.0	1.275	35.6
3.1	0.304	-6.2	8.1	0.794	19.4	13.1	1.285	35.9
3.2	0.314	-5.5	8.2	0.804	19.8	13.2	1.294	36.2
3.3	0.324	-4.8	8.3	0.814	20.2	13.3	1.304	36.5
3.4	0.333	-4.1	8.4	0.824	20.6	13.4	1.314	36.7
3.5	0.343	-3.4	8.5	0.834	21.0	13.5	1.324	37.0
3.6	0.353	-2.8	8.6	0.843	21.3	13.6	1.334	37.3
3.7	0.363	-2.1	8.7	0.853	21.7	13.7	1.344	37.6
3.8	0.373	-1.5	8.8	0.863	22.1	13.8	1.353	37.8
3.9	0.382	-0.9	8.9	0.873	22.5	13.9	1.363	38.1
4.0	0.392	-0.3	9.0	0.883	22.8	14.0	1.373	38.4
4.1	0.402	0.3	9.1	0.892	23.2	14.1	1.383	38.6
4.2	0.412	0.9	9.2	0.902	23.5	14.2	1.393	38.9
4.3	0.422	1.5	9.3	0.912	23.9	14.3	1.402	39.2
4.4	0.431	2.1	9.4	0.922	24.3	14.4	1.412	39.4
4.5	0.441	2.7	9.5	0.932	24.6	14.5	1.422	39.7
4.6	0.451	3.2	9.6	0.941	25.0	14.6	1.432	40.0
4.7	0.461	3.8	9.7	0.951	25.3	14.7	1.442	40.2
4.8	0.471	4.3	9.8	0.961	25.6	14.8	1.451	40.5
4.9	0.481	4.9	9.9	0.971	26.0	14.9	1.461	40.8

Press. kgf/㎠G	Press. MPaG	Temp. ℃	Press. kgf/㎠G	Press. MPaG	Temp. ℃	Press. kgf/㎠G	Press. MPaG	Temp. ℃
15.0	1.471	41.0	20.0	1.961	52.6	25.0	2.452	62.3
15.1	1.481	41.3	20.1	1.971	52.8	25.1	2.461	62.5
15.2	1.491	41.5	20.2	1.981	53.0	25.2	2.471	62.7
15.3	1.500	41.8	20.3	1.991	53.2	25.3	2.481	62.9
15.4	1.510	42.0	20.4	2.001	53.5	25.4	2.491	63.0
15.5	1.520	42.3	20.5	2.010	53.7	25.5	2.501	63.2
15.6	1.530	42.5	20.6	2.020	53.9	25.6	2.511	63.4
15.7	1.540	42.8	20.7	2.030	54.1	25.7	2.520	63.6
15.8	1.549	43.0	20.8	2.040	54.3	25.8	2.530	63.8
15.9	1.559	43.3	20.9	2.050	54.5	25.9	2.540	63.9
16.0	1.569	43.5	21.0	2.059	54.7	26.0	2.550	64.1
16.1	1.579	43.8	21.1	2.069	54.9	26.1	2.560	64.3
16.2	1.589	44.0	21.2	2.079	55.1	26.2	2.569	64.5
16.3	1.598	44.3	21.3	2.089	55.3	26.3	2.579	64.6
16.4	1.608	44.5	21.4	2.099	55.5	26.4	2.589	64.8
16.5	1.618	44.7	21.5	2.108	55.7	26.5	2.599	65.0
16.6	1.628	45.0	21.6	2.118	55.9	26.6	2.609	65.1
16.7	1.638	45.2	21.7	2.128	56.1	26.7	2.618	65.3
16.8	1.648	45.5	21.8	2.138	56.3	26.8	2.628	65.5
16.9	1.657	45.7	21.9	2.148	56.5	26.9	2.638	65.7
17.0	1.667	45.9	22.0	2.157	56.7	27.0	2.648	65.8
17.1	1.677	46.2	22.1	2.167	56.9	27.1	2.658	66.0
17.2	1.687	46.4	22.2	2.177	57.1	27.2	2.667	66.2
17.3	1.697	46.6	22.3	2.187	57.3	27.3	2.677	66.3
17.4	1.706	46.9	22.4	2.197	57.5	27.4	2.687	66.5
17.5	1.716	47.1	22.5	2.206	57.7	27.5	2.697	66.7
17.6	1.726	47.3	22.6	2.216	57.9	27.6	2.707	66.8
17.7	1.736	47.6	22.7	2.226	58.1	27.7	2.716	67.0
17.8	1.746	47.8	22.8	2.236	58.2	27.8	2.726	67.2
17.9	1.755	48.0	22.9	2.246	58.4	27.9	2.736	67.3
18.0	1.765	48.3	23.0	2.256	58.6	28.0	2.746	67.5
18.1	1.775	48.5	23.1	2.265	58.8	28.1	2.756	67.7
18.2	1.785	48.7	23.2	2.275	59.0	28.2	2.765	67.8
18.3	1.795	48.9	23.3	2.285	59.2	28.3	2.775	68.0
18.4	1.804	49.2	23.4	2.295	59.4	28.4	2.785	68.2
18.5	1.814	49.4	23.5	2.305	59.6	28.5	2.795	68.3
18.6	1.824	49.6	23.6	2.314	59.8	28.6	2.805	68.5
18.7	1.834	49.8	23.7	2.324	59.9	28.7	2.815	68.7
18.8	1.844	50.0	23.8	2.334	60.1	28.8	2.824	68.8
18.9	1.853	50.3	23.9	2.344	60.3	28.9	2.834	69.0
19.0	1.863	50.5	24.0	2.354	60.5	29.0	2.844	69.1
19.1	1.873	50.7	24.1	2.363	60.7	29.1	2.854	69.3
19.2	1.883	50.9	24.2	2.373	60.9	29.2	2.864	69.5
19.3	1.893	51.1	24.3	2.383	61.1	29.3	2.873	69.6
19.4	1.902	51.3	24.4	2.393	61.2	29.4	2.883	69.8
19.5	1.912	51.6	24.5	2.403	61.4	29.5	2.893	70.0
19.6	1.922	51.8	24.6	2.412	61.6	29.6	2.903	70.1
19.7	1.932	52.0	24.7	2.422	61.8	29.7	2.913	70.3
19.8	1.942	52.2	24.8	2.432	62.0	29.8	2.922	70.4
19.9	1.952	52.4	24.9	2.442	62.2	29.9	2.932	70.6

14.2.10 Mollier chart of R-22



14.3 Psychrometric chart



14.4 Water quality control

In recent years, as air conditioning technology develops, miniaturization and weight saving of the equipments have made rapid progress, too.
This means that in the condenser or the other where the heat exchanging for water is done, the efficiency has been raised, too. But, upper the efficiency is raised, more easily is affected by the scale or the other. When newly installed, it is the most important to preliminarily investigate and see through the water quality come into use, and to change the source of water supply or to do water treatment, if necessary. This is the best way to prevent the troubles originated in water quality.
Especially, when ground water is used as make-up water of the cooling tower, troubles occur frequently.
Therefore, as make-up water, tap water should be used.
In case of established equipments too, it is important to investigate the water periodically to control the water quality.

14.4.1 Points of sample taking for water quality analysis

Sample taking

(1) In case of circulating system such as cooling tower or the other, two types of water namely make-up water (headwater) and circulating water should be taken. Even though only circulating water is investigated, it cannot be judged that the head water is originally inferior or gradually becomes worse during the circulation.
(2) The sample should be taken under the ordinal using. If it is taken just after the all replacement of the water, a pertinent judgement will be impossible.
(3) Each volume of the water should be 200cc or more. Containers hard to be broken such as polyethylene containers should be used. (In case of special trouble, sometimes the water of 500cc or more is required.)
(4) A field survey before the fact is required.

- Has the water treatment been done yet?
- When it has been done, how is the way? What is the chemicals name?
- Has it done over blow? How is the volume?
- How is the past cleaning?
- How is the past trouble?
- How is the water system?
- Is there anything else referred to?

14.4.2 Troubles in water system

There are many troubles relating to the water system for air conditioning such as firstly heat exchanger.
Generally, the representative troubles are following three corrosion trouble, scale trouble and slime trouble.
These troubles occur sometimes separately, but in many cases, several troubles do in piles.

1. Corrosion trouble

There are two phenomena, namely acid corrosion and neutral zone corrosion in the water system corrosions produced by the water using for air conditioning. Acid corrosion in many cases, arises from dissolution of sulfurous acid gas in the air, when a cooling tower is used. On the other hand, the neutral zone corrosion is regarded as an electrochemical corrosion, and the presence of oxygen speeds up this reaction. In the water system for air conditioning, water and air usually contact each other, therefore it should be careful that the oxygen is fully supplied.

2. Scale trouble

Scale trouble that is scale formation means that substances dissolved or suspended in the water are separated or deposited at the inside face of the material such as firstly heat exchanger in the water system.
Among them, hardness components, especially calcium scale and silica scale comparatively much exist. When they are formed, heat transfer at the heat exchanger may deteriorate, besides, the water-course area of heat transfer tubes or other piping decreases. For this reason, various troubles such as the rise of high pressure in the condenser, the drop in cooling capacity or the increase in operation power would be brought about.
Sometimes, on the surface of metal of the under surface scale, pitting-corrosion phenomenon may occur mainly by the formation of oxygen concentration-batteries.
Recently, when ground water (well water) is used as make-up water of the cooling tower, trouble that the scale adheres to the condenser occurs frequently. Care should be taken.

3. Slime trouble

Slime is a mixture of bacteria, algae, dust in the air, etc. It adheres to the inside face of tubes in the condenser or the inside face of the cooling tower to check the heat transfer or the water passage. More, like the case of scale, sometimes, pitting corrosion is produced on the surface of metal under the slime adhesion.
Usually, the cooling water in the condenser presents good conditions for growth of microorganisms, and sometimes their propagating power is displayed. Pay attention to this state.

4. Relation between how to use water for air conditioning and troubles of water system can be summarized as following table.

Troubles by how to use

How to use		Major examples in use	Major head water	Major causes of troubles	Types of troubles
Circulation system	Open type	• Heat-dissipation to atmosphere by cooling tower	Tap water Neutralized water Industrial water	• Influence by air pollution (SO_2) • Dissolution of soot and smoke and exhaust • Inclusion of dirt and dust, earth and sand or insect • Concentration of dissolved salts	Scale trouble Slime trouble Corrosion trouble
	Semi closed type	• Heat storage tank in an office building and the other • Cooling of industrial process	Ditto	• Dissolution of oxygen by inclusion of air • Inflow of other drainage • Lye from concrete wall • Invasion of spring water • Propagating of bacteria	
	Closed type	• Water chilling unit • Fan coil unit system	Ditto	• There are a small pollution factors, and the number of cases of troubles is the fewest.	
Transient system		• After drawing water from a well and using it as a water cooled (heat pump) type, discharge it.	Ground water	• Adhesion of hard scale such as silica, ingredients of hard water ,etc. • Corrosion by bubbles	

14.4.3 Control of water quality

1. Reference level for water quality

The quality of water which is used for cooling water and chilled or hot water system of refrigerating and air conditioning equipments is decided as follows.

Reference level for water quality

	Items		*1 Cooling water		Chilled or hot water		Tendency to	
			Cooling water in transient or circulation system	Make-up water to cooling tower	Chilled or hot water in circulation system	Make-up water	Corrosion	Formation of scale
Reference level	PH	(25˚C)	*2 6.5 to 8.0	*2 6.0 to 8.0	*2 6.5 to 8.0	*2 6.5 to 8.0	○	○
	Conductivity	(25˚C µS / cm)	800 and below	200 and below	500 and below	200 and below	○	
	M Alkalinity	(PPM)	100 and below	50 and below	100 and below	50 and below		○
	Total hardness	(PPM)	200 and below	50 and below	100 and below	50 and below		○
	Chlorine ion	(PPM)	200 and below	50 and below	100 and below	50 and below	○	
	Sulfuric acid ion	(PPM)	200 and below	50 and below	100 and below	50 and below	○	
	Total iron	(PPM)	1.0 and below	0.3 and below	1.0 and below	0.3 and below	○	
	Sulfur ion	(PPM)	Undetectable	Undetectable	Undetectable	Undetectable	○	
	Ammonium ion	(PPM)	1.0 and below	0.2 and below	0.5 and below	0.2 and below	○	
	Silica	(PPM)	50 and below	30 and below	50 and below	30 and below		○
	Free carbonic acid	(PPM)	*3	*3	10 and below	10 and below	○	

(Note1)*1 Reference levels for cooling water and for make-up water to cooling tower agree with the JRA Standard revision proposal. (JRA is short of the JRAIA that is The Japan Refrigeration and Air Conditioning Industry Association.)

*2 The pH value of only make-up water is 6.0 to 8.0.The reason is that, in the case of ground water or the other, even the pH value drops temporally because of the dissolution of carbon dioxide, it will rise in the use of the water, circulating through the cooling tower.

*3 In the JRA Standard the following view is described. Free carbonic acid, manganese, residual chlorine and the others are not included in the items of the reference level, because their quantitatively allowed values related with accident are not clear, but it is clear that they act as corrosion factors.

(Note2)Each item of the reference levels is strongly relevant to the corrosion or scale troubles. Although only one item of them is against the rule, the water is regarded as following a tendency to generate corrosion or scale. Therefore, these items should be controlled periodically.

(Note3)The water-quality range which is able to use after water treatment differs according to the chemical fed to the water. Then, it is not printed in this table. Under the guidance of a water-treatment specialist you may establish the proper level for the water-quality and control it periodically.

2. Water quality control in case of using cooling tower for cooling water

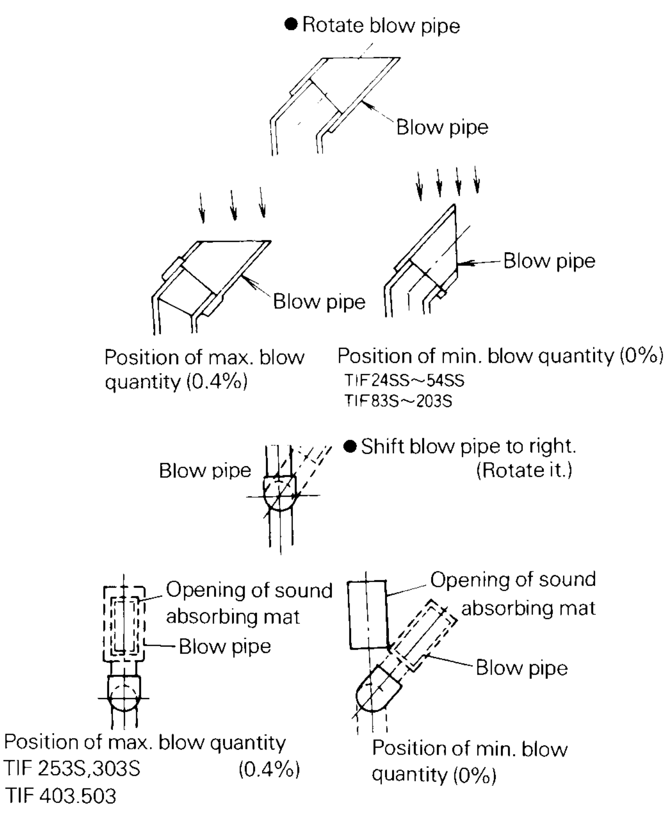
■ Summary

At an open circulation system cooling tower, about 1% of circulating water quantity evaporates, and the water temperature itself is lowered by the latent heat of this evaporation to use as cooling water.
Therefore, make-up water is required at all times. And the components of water quality brought by the make-up water shall be concentrated more and more.
Furthermore, sulfurous acid gas, nitrogen oxides, ammonia gas, hydrogen sulfide gas or the other is brought from fresh air and water quality will be concentrated to become worse rapidly.
There are many instances of this sort.
Care should be taken.
The cooling towers produced by our company, adopt, in all types, forced blow device so that the water can be replaced automatically.
It is so contrived that a part of circulating water is continuously discharged. By adjustment, the blow quantity of 0 to 0.4% can be secured. Therefore, when a cooling tower of which the forced blow is impossible is used, it is necessary to replace the whole circulating water periodically.

■ How to adjust forced blow

How to adjust blow pipe varies more or less with the types of cooling towers.
Do it as follows.

Fig.14-1



14.4.4 Corrosion or puncture-accident measures

■ Prior practice of water analysis

First analyze the quality of the make-up water supplied to the cooling tower to check the propriety of using the water.
The reference level of the quality of the make-up water should be conformed to the column of 'make-up water to cooling tower' in the table above.

■ When the water quality is judged to be unsuitable as a result of the water analysis, choose either of the following two and execute it.

- Adopt the tap water of the best quality as the make-up water.
- When the water other than tap water is adopted, discuss the matter with the nearest Daikin dealer or a specialist in water treatment.

■ Water quality control of circulating water

Although the tap water is adopted as make-up water, there are various water qualities in various parts of the country, more, there are variously wide differences in the figures in date. For this reason, analyze the quality of make-up water and calculate, in every item, how many concentration multiple will be possible to reach the reference level for the quality of the circulating cooling water. Finally, the smallest value is set as a possible concentration multiple. The blow rates according to the concentration multiples are set as follows.

Concentration multiple	Blow rate (%)	Blow water quality (in case of 10 tons cooling tower)
2.0	0.8	0.96/1.04 l/min
2.5	1.5	0.6 /0.65 l/min
3.0	0.35	0.42/0.46 l/min
3.5	0.26	0.31/0.34 l/min
4.0	0.2	0.24/0.24 l/min

(Note)
Concentration multiple (N) is calculated by the following expression.

$$N = \frac{E + B + W}{B + W}$$

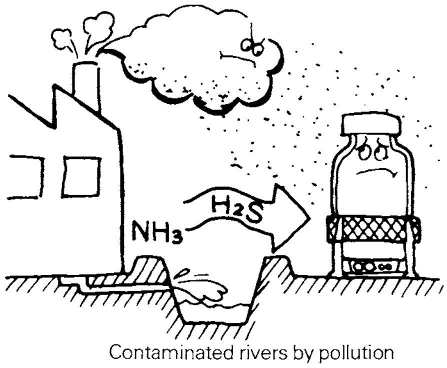
Provide,
E : Rate of evaporating-loss water-volume to circulating water-volume (usually 0.9%)
B : Rate of forced-blow water-volume to circulating water-volume (0 to 0.4% adjustable)
W : Rate of scattering-loss water-volume to circulating water-volume (usually 0.1%)

■ When the water quality is judged to be suitable as a result of the water analysis, also in this case, be careful of the following items.

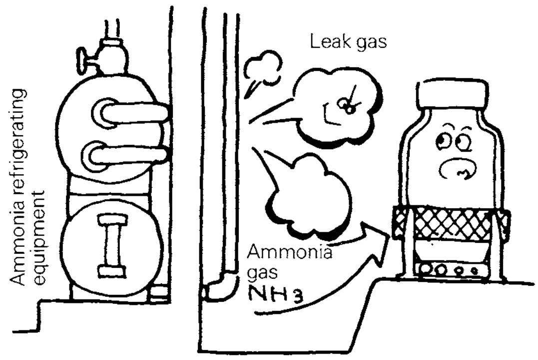
- Periodical inspection of the circulating water
  The quality inspection of the circulating water of cooling tower should be executed once or twice a month.
  Inspect two items as follow.
  pH (concentration of hydrogen ion)
  Conductivity

1. Water quality

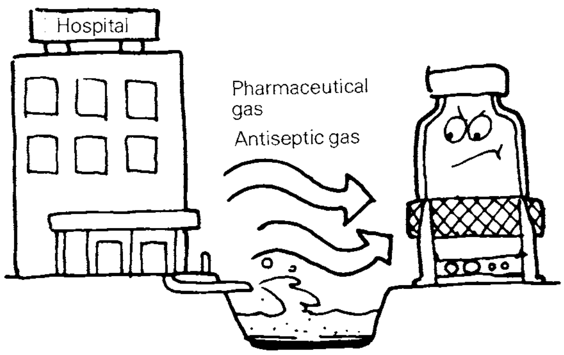
Water passing through a heat exchanger, a cooling tower or a water pipe is needed to conform to the reference level for water quality. Even though the water is transparent and clean at first glance, or there is no problem of drinking, sometimes it is unsuitable for refrigerating or air conditioning equipment. Therefore, it is necessary to grasp the water quality rightly by water analysis and ascertain whether it conforms to the reference level or not.



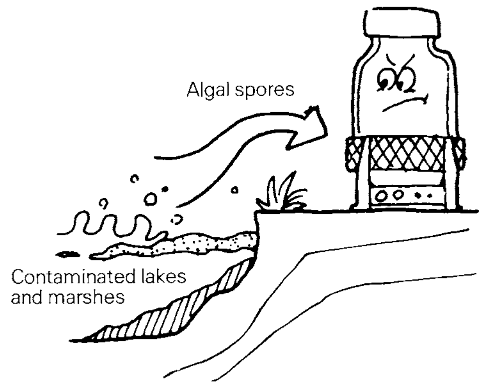
Contaminated rivers



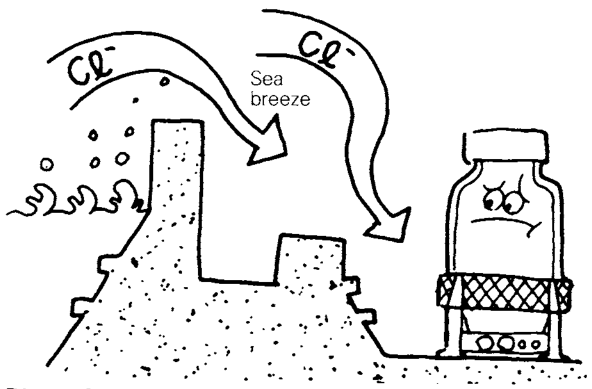
Leak gas from ammonia refrigerating machine



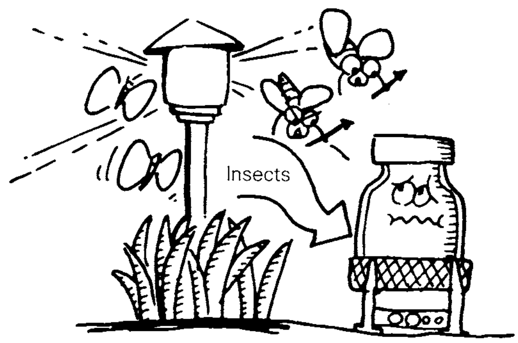
Exhaust gas from operating or medicine room of hospital



Inflow of algal spores of lakes and marshes



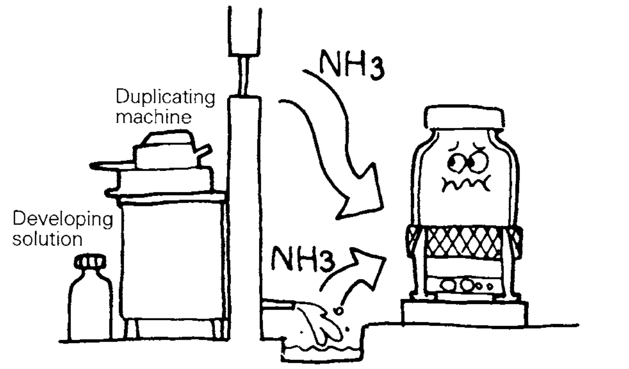
Blow of sea breeze



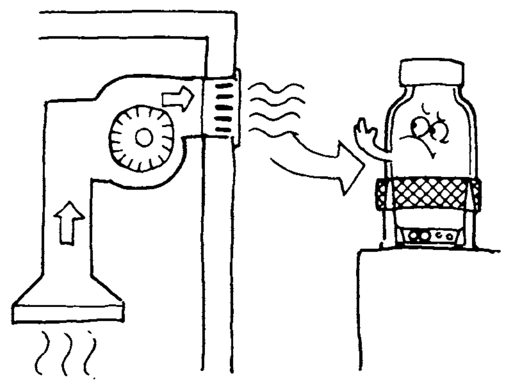
Mixing of insects

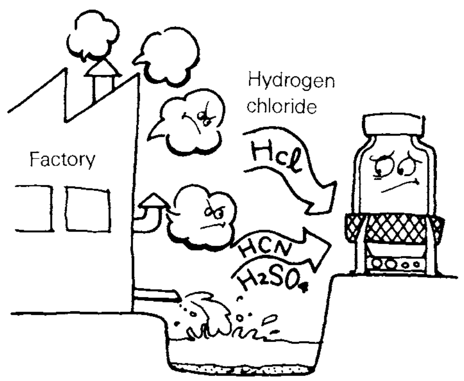
- Cooling tower water

When a cooling tower is used for the circulating of water, it is necessary to care about the air contamination and the concentration of mixture components.
At the places as shown below, installation of the cooling tower is unsuitable.
More, when the concentration multiple of the cooling tower water is not treated yet, it is necessary to blow constantly by force 0.2 to 0.4% of the circulation water quantity so that the multiple will not exceed three or four times.

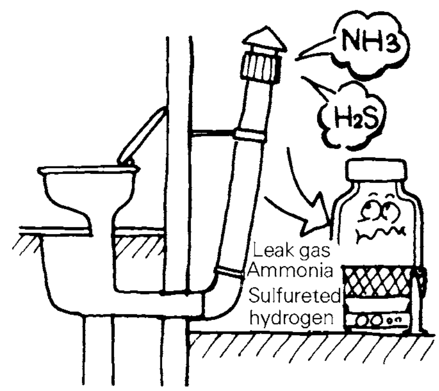


Exhaust gas from developing solution of duplicated machine of blueprint

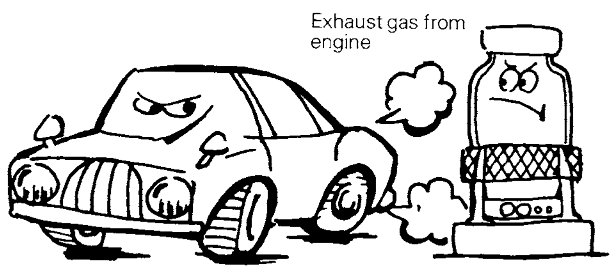

Exhaust gas from kitchen or food factory



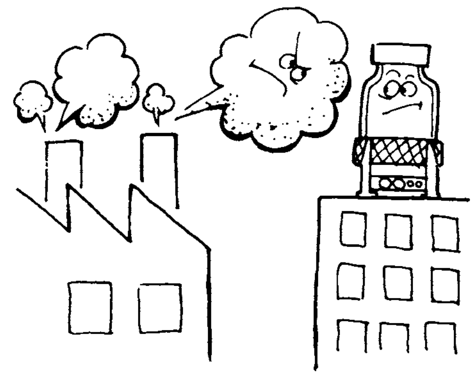
Exhaust gas from factory



Exhaust gas from toilet

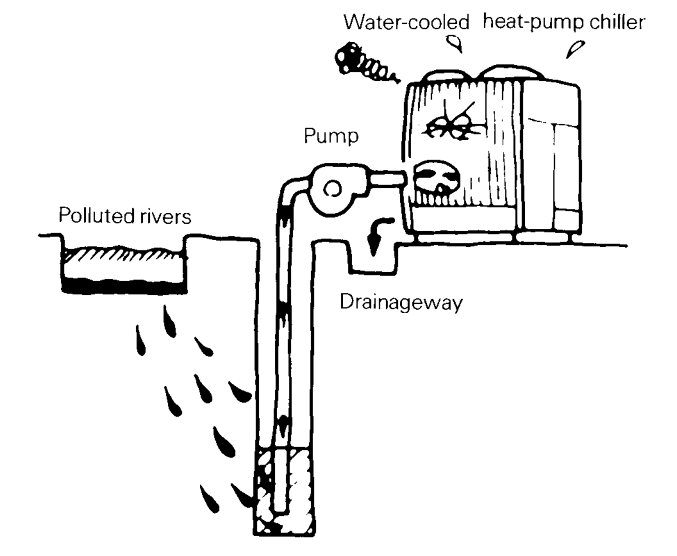


Place fronting the street and taking a large quantity of automobile exhaust-gas


Smoke of chimney

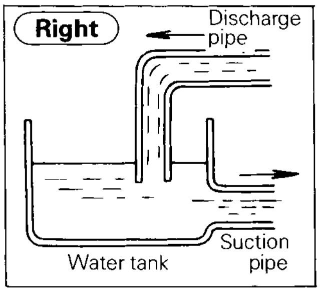
● Ground water
When the source of water supply is ground water, as sometimes the water changes in quality, care should be taken sufficiently.
● Water in a heat storage tank or other storage tank
When a heat or other storage tank is used, sometimes unexpected pollutant water flows in the storage tank or other water circulation system. Examples caused troubles are as follows.

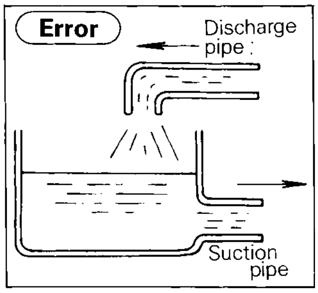
Fig.14-2



- There is no roofing nor covering on the water tank. For this reason, dirt and dust in the air flow in, and the water quality becomes worse.
- As there is no suitable drainageway, rainwater, muddy water or waste water to overflow enter in the water tank or circulating water system.
- River water or dirty water (mixed with agricultural chemicals or the other) enters the system from the crack of the concrete water-tank.
- As the treatment of the concrete water-tank is insufficient, 'lye' (alkalinity) of concrete oozes out.
- The polluted component soaked into the concrete gradually oozes out in the long term.
- Sometimes a water tank becomes the best breeding place for bacteria or various germs. In this case, using a germicidal agent or a measures such us excluding the sunlight is required.
- Rust on the metal surface I the water system dissolves in water to become red water, and separates out on the surface of the heat exchanger pipe to become deposit, thus local corrosion is produced.
- Water in the pipes of the water system of high-rise building has flowed in the storage tank underground, every time the air conditioner stops. And every time it restarts, it causes water hammer to corrode the pipes.

■ When the water is aerated on halfway in the circulating water system as shown below, dissolves oxygen increases or pollutant matter in the air is concentrated in the water to become corrosive water quality.





Discharge outlet of discharge pipe should be installed below the surface of water in tank.

■ After chemical cleaning inside the water system, it should be taken care whether some liquid medicines remain or not.
■ About the brine such as ethylene glycol or propylene glycol, the brand of antirust additives for metal should be used.

2. Influence of sand dust

When sand, dust or the other is mixed in the water system, mental materials are mechanically eroded. Therefore, prepare the guard so that they do not proper place to remove the sand, dust or the pieces of rust which have invaded in the water system.

3. Cavitation

Take care of the flow rate in the water system, the installation position of the expansion tank, the position of the air vent on halfway of the piping or the other so that cavitation will not be produced.

Cavitation: This means that on halfway of the piping, the pressure of fluid locally drops less than the saturated-vapor pressure at that time, and the neighborhood becomes vacuum (evaporation). Actually, when the flow rate is high and in the following cases, it occurs frequently.

- When closing the stop valve, at the back of the stop value.
- At the back of sharp bend of the pipe.
- When the suction head of the pump is high, at the inside of the impeller or the other of the pump.

4. Flow rate of water

The corrosion of the pipe is fairly different depending on the flow rate of the water. It is necessary to use the water in the neighborhood of the rated water volume of the product.
Generally, it is said that the limit should be set as follows.
1 m/sec to 3 m/sec (In case of large diameter pipe:4 m/sec and less)
To secure such desirable flow rate, pay attentions as follow.

- Combine with a proper capacity pump.
- Let the rated water volume flow in, while regulating the water volume by the stop valve set upon the discharge side of the pump. In many cases, the flow meter is not set up in the water piping system. So, close the stop valve and check up the performance curve of the pump with watching the pressure gauge set up between the water pump and the stop valve.
- When one pump supplies water to two equipments or more, sufficient care should be taken about the resistance and the drift in the water piping system. And according to the opening and closing state, or ON-OFF state of the stop valve of other equipment, sometimes the water volume of the remaining equipment steeply changes or becomes abnormal head. So, be careful.
- A solenoid valve should not be installed in water piping system. When let the water flow rapidly while leaving the closed solenoid valve, or conversely when changing rapidly the opened state into closed state, water hammer will happen to vibrate the pipes and contribute the troubles.
- Usually thermometers are installed at the entrance and exit of the heat exchanger. By using it, you can check the contamination of the tubes or set the flow rate of the water.

5. Electrolytic corrosion

Because of preventing the electrolytic corrosion, do not ground the wire of another electric installation to the pipe. When the pipes are laid under the ground, sufficient care should be taken for antirust measures.

6. Freezing puncture

When the outdoor temperature falls to 0˚C or less, freezing puncture may happen.
By installing a drain down equipment at the lowest part of the water piping system, it is necessary to draw out the water in the system or to take other measure in advance.

14.4.5 Prevention measures of adhesion of scale and slime

1. Water quality

- As for water-quality control, it is important to follow the reference level above-mentioned. Generally, 'corrosion' and 'separation-aptness' are in the relative connection. It seems more desirable that the water quality should be controlled in a little tendency to scale separation (water quality on the alkalinity side), but not in a tendency to corrosion (water quality on the acidity side).
  The reason is that the separated scale checks the growth of corrosion on the metal surface. For this, PH control, flow control of cooling tower, addition of inhibitor for scale separation, softening treatment by ion-exchange resin, etc. are effective.
- For inhibition of slime separation by bacteria or algae, addition of slime inhibitor or interception of sunlight is effective.
- When a polyvinyl chloride pipe or a internal coating pipe is used, it is effective for inhibition of red waterization of the circulating water, but the problem of strength or the waterization may arise.

2. Make up water

Use potable water for the make up water of cooling tower. Groundwater (well water) generally shows more tendency of scale adhesion, so do not use it for make up water of the cooling tower.

3. Flow rate of water

Extremely rapid water current is not preferable in respect to the corrosion, and extremely low speed water current also is not preferable in respect to the scale adhesion or deposit formation.

Object	Limit flow rate	Note
Cooling pipe	0.6 to 3m / s or the less	
Pipe	1 to 4m / s or the less	

14.4.6 Scale cleaning

1. Outline

It is necessary to clean regularly (once a one season) or practice the anti-corrosion treatment, for facilitating the circulation of water system or preventing the gathering of scales of deposit and the corrosion.

2. Main points

For the cleaning, there are generally two ways cleaning using agent and using brush. The cleaning using agent is called chemical purification, in case of need. Each of these ways has its own merits and demerits. Among them, by examining a kind of scale, the conditions of the workshop, the type of objective equipment, service cost, etc., the way of cleaning should be selected.
According to the form of heat exchanger, there is no more than this chemical way.

Merits and demerits of cleaning using chemical

- There is selectiveness of scales, but almost all scales can be removed, if the chemical is selected precisely. On the other hand, if the mistake is made in the selection, the scale cannot be removed, and more, in some cases, abnormal corrosion is brought about.
- In some cases, neutralization-treatment of drain is required, after cleaning.
- Even the cleaning of large-capacity is possible in a short time.
- Even the complicated water circuit can be cleaned.
- Take care of metal corrosion by the cleaning chemicals.
- Generally, this way is too expensive.

Merits and demerits of cleaning using brush

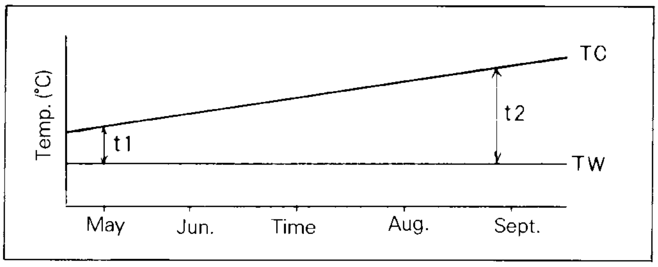
- There is selectiveness of scales comparatively a little. And very hard scales cannot be removed.
- This is almost physical work, so personnel expenses are too high.
- In case of complicated or closed-type water circuit, a brush cannot be inserted, that is the cleaning is impossible.
- As the chemicals is not used, there is no fear of the drain pollution.
- Generally, this way can be cheap.
- Effect of cleaning can be confirmed visually in the working.

3. Is cleaning necessary or unnecessary?

There are various ways to judge of the scale coating, but it is general and certain way to judge be the degree of fall of the heat exchange efficiency.
That is, when full load operating of the cooling (refrigerating) system, 'the outlet temperature of the cooling water flowing in the condenser' is compared with 'the condensation temperature of the refrigerant'. And then this difference is compared with the value at the clean time of the cooling pipe.
Finally, it is judged by how much the former has increased.

Condensation temp. Of refrigerant: This is found by conversion to the saturation temperature of the refrigerant from the indicating pressure of the high-side pressure gauge.

The strong point of this way is that the both temperature differences are almost constant, even though the volume of cooling water changes more or less. So, there are few cases of misjudgement.



Provided,
TC : Condensation temperature
TW : Cooling water temp. at condenser outlet.
t1 :Temp. difference when cooling pipe is clean.
t2 :Temp. difference when scale adheres.

Do not be confused by the sudden stop of the operating cooling (refrigerating) equipment, even though the high pressure switch does not get to the function.
For this, it is necessary to examine the increasing rate of "t2 — t1" and clean the scale in advance. Generally when "t2 — t1" becomes over 3 to 5˚C, cleaning is necessary.

4. Judgement after cleaning

The simplest and the most certain way is to confirm visually the state of coming off the scale.
But, in some cases the visual confirmation is impossible because the recent heat exchanger in a cooling (refrigerating) equipment has hermetic or other complicated structure. For this, it is important to compare the before and after cleaning, using the ways mentioned above in the clause 3. when you neglect this (confirmation of cleaning effect), even though the high pressure is cut by other reasons than scale, sometimes it may be judged that the cleaning made a mistake. More, the way of judgement of the state of scale adhesion only by high pressure is not proper, because the state changes depending on the temperature or the volume of cooling water.

5. How to select chemicals for cleaning

An important factor in the chemical cleaning is to select the proper chemicals depending on the type of scales. As a matter of fact, analysis of composite scales should be consulted our Daikin S.S. or the specialist of water treatment.

14.5 Tools and instruments for installation and services

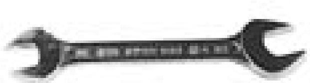
14.5.1 Tools

No.	Names	Specifications
1	Screwdrivers	Phillips (+) No.1 No.2 No.3
2	Screwdrivers	Flat ( ) No.1 No.2 No3
3	Open ended wrenches (spanners)	10, 14, 17, 19, 21, 23, 27, 30 mm
4	Adjustable angle wrenches	150, 200, 300 mm
5	Cutting nipper	
6	Cutting plier	
7	Allen setscrew wrench	1 set
8	Tape measure	
9	Flaring tool	
10	Tube cutter	
11	Copper tubing reamer	
12	Tube benders	1 / 2'', 5 / 8'', 3 / 4"
13	Gas leak detecor	
14	Valve key	

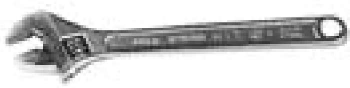
- Tool No.1

- Tool No.2

- Tool No.3



- Tool No.4



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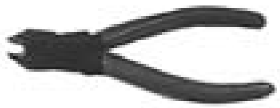

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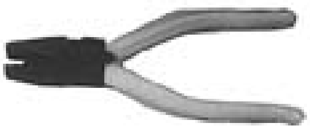
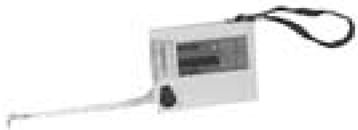


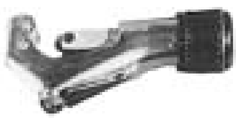
- Tool No.7

- Tool No.8



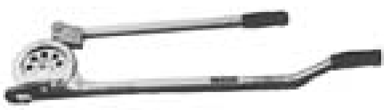
- Tool No.9

- Tool No.10



- Tool No.11

- Tool No.12



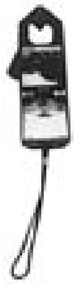
- Tool No.13

- Tool No.14

14.5.2 Instruments

No.	Names	Specifications
1	Ammeter (Clamp meter)	
2	Ohmmeter (Tester)	
3	Insulation resistance tester (Megger tester)	500V
4	Mercury themometer	
5	Gauge manifold kit	
6	Charging cylinder	2 kg (or 4 kg)
7	Weight scale	50 kg
8	Vacuum pump	
9	Surface thermometer	
10	Anemometer	

- No.1



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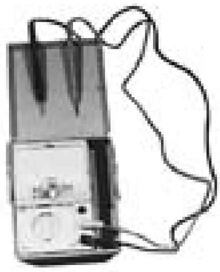

- No.3

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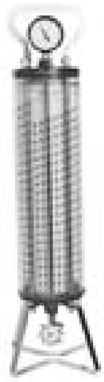

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14.6 About refrigerant oil

1. Features and types of refrigerant oil

The lubricated places in a refrigerating machine are main bearings, cylinder, crankshaft, piston pin etc., in case of reciprocating, and bearing, multiplying gear etc., in case of centrifugal compressors.
Recently, the hermetic compressors are structurally produced so that these places are in contact with the refrigerant. Therefore, the good consolute property of refrigerant oil for these lubrication is an important factor.
Especially for small hermetic refrigerating machines, there will be no exchange of lubricating oil semipermanently. Therefore, of course the good lubrication property, the good consolute property and the heat and chemical stability are required.

■ Conditions for refrigerating machine oil

- Freezing point is low, good liquidity at low temperature.
  —— Solidification in the evaporator.
- The separation of oil from the refrigerant is easy.
- The heat resistance is good
  —— Sometimes the temperature of discharge gas goes up to 100~200˚C
- The oil does not contain water, acid or other impurities.
  —— The insulating property falls, Sludge, Copper plate.
- Viscosity is comparatively high because refrigerant (especially freon gas) and lubrication oil have property of dissolving in each other.
- When using a hermetic compressor, the insulating property must be good.

2. General caution

■ Brand designation

Fill the standard refrigerant oil. In consideration of the maintenance control or the filling work process, use of the oil of other brand is unacceptable.
But, at the time only when the acquisition of standard refrigerant oil is difficult for supplement or exchange in the field (especially in foreign countries), the comparable oil marked with ○ or the equivalent marked with ◎ may be used.

■ Blended oil

When the refrigerant oil is supplemented or exchanged, blending or using of a different kind of brand should not be done as a principle. Because of the difference of crude oil or the existence of additives, an unforeseen accident may happen.
Care should be taken when the oil is exchanged with the one of a different brand. Oil in the tank should be completely discharged. After sufficient cleaning of the interior of the tank, fill the new oil.

- Discharge the oil in the tank
- Fill the new oil operate the machine for about a night and day.
- Discharge the oil.
- Fill the new oil and begin the normal operation.

■ When piping the refrigerating machine in the field

In this case, sometimes the pipes or flanges are assembled with the rust preventive oil or the welding mouth unremoved sufficiently.
Therefore, it is desirable to fill the new oil and then operate after the sufficient cleaning of them.
In the rust preventive oil, a compound which contains fatty acid is used. And it reacts on the refrigerant to form an acid. For this reason, the oil deteriorates and can cause troubles.
When conducting the test run, it is favorable to exchange the oil two or three times for cleaning and removing the cause of oil deterioration.

■ Handing the refrigerant oil in the field

The refrigerant oil on the market is filled in the containers in the state of dehydration of 20 p.p.m. and less. Therefore, when replenishing the oil, a dry day should be selected as much as possible. After the replenishment, seal it speedily so that water or dust or dust should not get mixed in.

14.6.1 SUN OIL refrigerant oil for the compressors

Properties / Types		SUNISO 3GS(VG32)	SUNISO 3GS-DI(VG32)	SUNISO 4GS(VG56)	SUNISO 4GS-DI(VG56)	SUNISO 331	SUNVIS 51
Hue (Union)		1 or less		1 or less		2 or less	2.5 or less
Reaction (Neutralization value)		0.05 or less		0.05 or less		0.05 or less	0.05 or less
Flash point	COC˚F	330 or more (166˚C or more)		340 or more (171˚C or more)		430 or more (221˚C or more)	475 or more (246˚C or more)
Ignition point	COC˚F	370 or more (187.5˚C or more)		390 or more (199˚C or more)		490 or more (254˚C or more)	535 or more (279.5˚C or more)
Viscosity SUS/1000˚F (328˚C)		150 to 160		280 to 300		300 to 315	500 to530
Dynamic viscosity CSt	100˚F (37.8˚C)	33.1		62.5			
	210˚F (98.9˚C)	4.43		5.94			
Pour point	˚F	-40 or less (-40˚C or less)		-35 or less (-37˚C or less)		0 or less (-17.8˚C or less)	0 or less (-17.8˚C or less)
Floc point	˚F	-60 or less (-51˚C or less)		-50 or less (-45.5˚C or less)		-30 or less (-34.5˚C or less)	
Corrosion of copper plate	212˚F3hr	1 or less		1 or less			
	100˚F3hr						
Specific gravity	60˚F (15.6˚C)	22 to 24 (0.921 to 0.910)		20.5 to 23 (0.930 to 0.915)		29 to 31 (0.882 to 0.870)	28.5 to 30.5 (0.884 to 0.873)
	API-15/4˚C						
Dielectric breakdown voltage	KV	25 or more		25 or more		25 or more	25 or more
A trace of water	P.P.M.	30 or less		30 or less		30 or less	30 or less
Additives		Unused	Refractory	Unused	Refractory	Unused	Unused

14.6.2 List of refrigerant oil suppliers

	Guidelines of temperature of evaporation (Te)	
	Te≥-30˚C	Te<-30˚C
SUN OIL NIPPON SUN OIL		SUNISOGS (VG32)
		SUNISOGS-D1 (VG32)
	SUNISO3GS (VG56)	
	SUNISO4GS-D1 (VG56)	
	SUNVIS 51	
	SUNSIO 331	
DAIKYO OIL		PIOREFROIL 32
	PIOREFROIL 56	
MOBILE OIL		GARGOIL ARCTIC 155
	GARGOIL ARCTIC 300	
	DOTE HEAVY MEDIUM	
GENERAL OIL		POLAROIL SUPER 32
	POLAROIL SUPER 68	
BRITISH PETOROLEUM		BP ENERGOL LPT32
	BP ENERGOL LPT 68	
SHOWA OIL		SHOSEKI R-M22S
	SHOSEKIR-M46S	

14.6.3 List of refrigerant oil all kinds of machines

	Reciprocating compressor								Rotary comp.		Turbo comp.	Screw comp.	
	Hermetic, semi-hermetic single-stage		Semi-herm, two-stage	For container	For cab cooler and bus cooler	Open-type single-stage		Open-type two-stage					
	Te≥-30°C	Te<-30°C				Te≥-30°C	Te<-30°C		Te≥-30°C	Te<-30°C		Te≥-30°C	Te<-30°C
SUNISO3GS (VG32)		◎	◎				◎	◎					◎
SUNISO3GS-D1 (VG32)		○	○	◎			○	○		◎			
SUNISO4GS (VG56)	◎					⊙							
SUNISO4GS-D1 (VG56)	○								◎			◎	
SUNVIS 51					◎								
SUNSIO331											◎		
PIOREFROIL 32		⊙	⊙				⊙	⊙					
PIOREFROIL 56	⊙					⊙							
GARGOIL ARCTIC 155		⊙	⊙				⊙	⊙					
GARGOIL ARCTIC 300	⊙					⊙							
DOTE HEAVY MEDIUM											○		
POLAROIL SUPER 32		⊙	⊙				⊙	⊙					
POLAROIL SUPER 68	⊙					⊙							
BP ENERGOL LPT 32		⊙	⊙				⊙	⊙					
BP ENERGOL LPT 68	⊙					⊙							
SHOSEKI R-M22S													
SHOSEKI R-M46S						◎							

Note) ◎…… Refrigerant oil used as standard.
⊙…… The equivalent of standard refrigerant. (Rebrand of SUNSIO 3GS or 4GS)
○…… Comparable goods of the standard refrigerant oil.

14.7 Glossary

Automatic reset
On pressure switches for the high/low pressure shut-off use, temperature switches, and others, this means that the switches are activated when reaching a given set value and automatically return to the previous state when the cause of the actuation is removed even though they turn into the open state.
⇨ Refer to information on "Manual reset".

Blow down
The "blow down" means a process to discharge internal water from the boiler, water piping system, and others.

Bypass factor
Part of air passing through the evaporator passes through it without touching it. The bypass factor means the ratio of this air to the total airflow rate.

Carry-over
This means water consumption due to splashes of water drips on cooling towers and evaporative condensers. On the cooling towers, some surplus water is consumed due to other reasons than evaporation due to the splashes of water drips during the fan ventilation.

Coefficient of Performance
This is a ratio of the power (input) consumed through the refrigeration cycle to the refrigerating capacity (heating capacity), that is, Refrigerating capacity kW/Input kW.

Cold shock
This means discomfort that one feels when suddenly entering a room having a low temperature, which results in a physical disorder. It is significantly influenced by the difference in temperature between indoor air and outdoor air in cooling operation.
⇨ Refer to information on "Heat shock".

Comfort zone
This means the range of effective temperature at which most of the adults feel comfortable.

Compound gauge
The compound gauge is a kind of the Bourdon tube pressure gauge, which is a pressure-vacuum gauge enabling the measurement up to over or below atmospheric pressure.

COP
This is the abbreviation of Coefficient of Performance.
⇨ Refer to information on "Coefficient of Performance".

Copper plating
Fluorocarbon compressors use copper alloy for the refrigerant path, which is solved while the refrigerant comes in contact with oil, thus resulting in the adhesion to other metallic surface. This phenomenon is referred to as copper plating. It is said that oil and moisture contained in the oil accelerate the phenomenon, resulting in degradation in the accuracy of bearing surface, discharge valve, suction valve, and others.

Counter-flow
This means that liquid on the higher temperature side and one on the lower temperature side flows in the opposite direction on heat exchangers and cooling towers.

Defrost
When air is cooled down to 0˚C or less through the evaporator of refrigeration unit, the moisture contained in air condenses on the evaporator surface to freeze up while gradually increasing the frozen thickness, thus inhibiting the heat exchange. Defrost means the removal of the frozen layer.
The methods of defrosting, such as hot water spraying, electric heating, and heating with hot gas discharged from the compressor, are available.

Defrosting
⇨ Refer to information on "Defrost".

Dew condensation
Moist air comes in contact with an object having a low surface temperature. The contact point is cooled down to the dew-point temperature or less, thus resulting in moisture condensation, dew condensation, or wet state. This phenomenon is referred to as dew condensation.

Differential
This term means operating amplitude from the set value of controllers such as thermostat.

Discomfort index
This index represents the level of discomfort due to the temperature and relative humidity of air.
Discomfort index = (Dry bulb temperature + Wet bulb temperature) × 0.72 + 40.6

Discomfort index	Level of discomfort
86	Discomfort, to which everyone is unbearable
80	Discomfort, which everyone feels
75	Discomfort, which half or more of people feels
70	Discomfort, which people starts feeling
68	Comfortable

Distributor
This is a distribution unit of liquid, which minimizes resistance to the flow of the liquid and performs the uniform distribution of the liquid. When the distribution unit is used on the refrigeration unit, it is installed at the outlet of the expansion valve to distribute the refrigerant to numbers of cooling tubes.

Draft
In general, draft means a flow of air caused by the pressure difference, producing a flow of air or gas in hot air pipes, chimneys, heating units, indoor spaces, and others.

Drain trap
The drain tap means a water sealing unit installed somewhere in the drain pipe of component, by which stems the back-flow of air all the way through the drain pipe, thus preventing the occurrence of foul smell.

Dry compression
This means dry saturated compression. In the refrigeration cycle, the refrigerant immediately before it is sucked in the compressor is not in the wet state (i.e., incompletely evaporated liquid refrigerant remains) and not the superheated state (i.e., the temperature has risen far beyond the saturated temperature), but in the state having a temperature appropriately higher than that in the saturated state. The dry compression is one that is initiated from this state as the starting point.
⇨ Refer to information on wet compression.

Dry coil
Since the moisture mixed in air is very small in the amount and low in the relative humidity, the air does not reach the dew point even though it is cooled. Therefore, the dry coil means cooling coil that produces no dew condensation (i.e., drain) on the surface of the cooling coil.

Electronic expansion valve
The electronic expansion valve is a part to achieve a maximum of the compressor capacity by controlling the expansion mechanism through the microcomputer operation. The control input signal is the discharge pipe temperature. Referring to the indoor and outdoor temperatures as well as the respective temperatures of evaporation and condensation, open or close the valve through the pulse motor driving so that the discharge pipe temperature can be optimized. Thus, this valve achieves various effects and functions such as the reduction in compressor ON/OFF frequencies and power consumption, improvement in defrosting efficiency in winter, frosting prevention of evaporator in summer, and extension of allowable length of refrigerant piping.

Elevated water tank
This means a water tank, which is installed on a tower or on the rooftop of a high-rise building, or on a height utilizing the landform when city water pressure is insufficient or well water is fed. This type of tanks is frequently used for feed water.

Energy efficiency ratio (EER)
Referred to as energy effective ratio (kcal/Wh), which means the ratio of the cooling capacity of refrigeration cycle to the input.

Flash gas
Halfway in the liquid piping of refrigeration unit, part of the liquid evaporates due to significant drop in pressure or penetration of heat, thus producing air bubbles in the liquid. The production of air bubbles is referred to as flash gas, resulting in marked degradation in the performance of the expansion valve.

Freon
The Freon is the trade name of fluorocarbon gas from Du Pont, U.S.A.

Heat pump
The heat pump means a pump to collect heat from a place having a low temperature and transfer the heat to another place having a high temperature. (This pump has the same concept as that of water pump used to transfer water from a place at low level to another place at high level.)

Heat shock
The heat shock is referred to as temperature shock as well, which means a shock or substantial discomfort given to human body when coming in or out of the air-conditioned room under the condition having marked difference between the indoor air temperature and the outdoor air temperature in cooling operation. *The heat shock is classified into cold shock in cooling operation and hot shock in heating operation.

Hot shock, thermal shock
This is discomfort perceived when abruptly entering a room having a high temperature, which yields a large influence over the indoor temperature conditions in heating operation.
⇨ Refer to information on "Heat shock".

Hunting
The hunting means a phenomenon that surplus and insufficient refrigerant feed rate to the evaporator repeat by turns due to the wrong choice of expansion valve and faulty adjustment.

Liquid compression
When oil or liquid refrigerant is sucked in the compressor, the liquid having non-compression property causes a large pressure, thus resulting in the destruction of the compressor with an intense shock sound and vibration involved. This phenomenon is called liquid compression.

Manual reset
When any of controllers mainly used for safety device, such as the pressure switches for the high/low pressure shut-off use or hydraulic pressure protection switch, is actuated due to the occurrence of malfunction, the controller can be reset manually without setting it back into the previous state even though the malfunction is released. This sequence is referred to as manual reset.
⇨ Refer to information on "Automatic reset".

Manual reset
When any of the safety devices (e.g. pressure switch and freeze-up protection temperature switch) is actuated, this mode disables functions due to re-activated contacts unless the system is reset manually.
⇨ Refer to information on "Automatic reset".

Non-condensable gas
The non-condensable gas means a gas that does not condense at the temperature and pressure of refrigeration unit. When this gas gets mixed in the condenser, it produces its unique pressure, thus giving adverse influences such as higher pressure in the refrigeration cycle or degraded volumetric efficiency due to increased discharge pressure and discharge temperature from the compressor.

Oil foaming
Refrigerant is facilitated to melt in oil at a low temperature. If a large quantity of refrigerant melts in lubricant in the crankcase of the compressor, when the compressor starts, the pressure in the crankcase sharply drops to produce a sudden evaporation of the refrigerant in the lubricant, thus resulting in foaming phenomenon which means oil foaming. The occurrence of this phenomenon causes faulty lubrication. Therefore, provide a crankcase heater to heat the lubricant for the evaporation of the solved refrigerant.

Outdoor air intake
This means the amount of fresh air to be taken in from the outside in order to prevent air contamination due to smoking, foul smell, or generation of carbon dioxide in air-conditioned rooms. The reference amount has been determined according to the size and objective of the building.

Over charge
This means that refrigerant is charged with refrigeration units in addition to the proper refrigerant charging amount. If the unit operates in this state, the liquid level of the condenser rises, resulting in increased condensing pressure or locked compressor.

Overflow
This means that, if the liquid level in the tank exceeds a given level, the amount exceeded is discharged from the tank. It is referred to as over-spill or spill stream.

Pull down
The "pull down" means a process to cool down the room temperature from that prior to operation to a desired set temperature while running the refrigeration unit and the air conditioners.

Rate of air circulation
This means the number of the replacement times of air (e.g. outdoor air and circulation air) supplied to a given space (e.g. room) per unit hour, which is usually indicated by times/h.

Scale
The components of calcium, magnesium, silica, or else solved in water precipitate to firmly adhere to the heat exchange surface. This adherence is referred to as scale, which substantially degrades the heat exchanging performance.

Scale factor
On heat exchangers, scale adheres to the heat exchange surface and turns into heat resistance, thus inhibiting overall heat transfer. The inhibiting ratio is referred to as scale factor. The practical unit is g· h· ˚C/kJ.

Sludge
Sludge is decomposition product of oil and others due to impurities, moisture, or chemical changes. The generation is accelerated through heating.

Temperature and relative humidity conditions
This term means the conditions of the temperature and the humidity of indoor air and outdoor air to be determined as the design parameters for air conditioning.

Thermal equivalent of work
Heat and work can be converted each other as the energy. The conversion is represented by the following equation in the conventional units.

$$Q \text{ (heat)} = AW \text{ (work)},\ A = \frac{1}{427} \text{ kcal / kgm}$$

This A is referred to as thermal equivalent of work.
The inverse number of A, that is J, is referred to as equivalent work of heat.

$$J = \frac{1}{A} = 427 \text{ kgm / kcal}$$

Unloader
The unloader is a device to disable the compression by the compressor, which reduces the load of the motor at the startup and controls the compressor capacity while in operation.

Ventilation
In order to keep the cleanliness in the air-conditioned room or minimize the variation in the room temperature, outdoor air is taken in, thus making the smoking, foul smell, or carbon dioxide subtle.
A variety of references are provided for the ventilation amount.

Wet compression
Gas compression, by which suction gas of the compressor of refrigeration unit turns into wet state. ◊ Refer to information on "Dry compression".

Zoning
The heat loads in large buildings per room or zone substantially vary with differences in the direction of external wall or internal heat generated. Therefore, since it is inconvenient to control these loads with a single air conditioning system, the space is to be divided into several air conditioning zones having the heat loads with the same characteristics. That is referred to as zoning.

Chapter 15 Supplementary explanations

Chapter 15 Supplementary explanations

15.1 How to select V-belt or motor pulley for fan

When a motor pulley for fan is changed, the length of V-belt can be found as follows. (Because the position of the motor holder is adjustable, the length of the V-belt is permissible to the degree of calculated value ±1 inch.)

1. Determination of number of fan revolutions

By plotting the point where the required air volume and the external static pressure (air volume-total static pressure on the performance curves) cross, the number of fan revolution can be read.

2. Determination of fan motor pulley

As fan pulley is already determined and recorded in the fan performance characteristics, a motor pulley is determined by the number of fan revolution, the number of motor revolution (when 50Hz, 1,450rpm, and when 60 Hz, 1,725rpm) and the fan pulley pitch diameter.

Motor pulley pitch

$$= \frac{\text{Number of fan revolution} \times \text{Fan pulley pitch diameter}}{\text{Number of motor revolution}}$$

Note)

(1) The pulley diameter is indicated in outside diameter, therefore, the pitch diameter must be deducted as shown on the right table.

(2) As to the motor pulleys on the market, refer to the table below.

Classified by form	Deducted measure
A	9mm
B	11mm
C	14mm

3. Determination of V-belt

Using the distance between the shafts of fan and fan motor at the time of shipment as a guide, the length of V-belt is determined.

The length of V-belt can be found, using following formula, when the center distance is found.

$$L = 2C + 1.57\,(D + d) + \frac{(D - d)^2}{4C}$$

L : Length of belt (mm)

C : Center distance (mm)

D : Large pulley pitch diameter (mm)

d : Small pulley pitch diameter (mm)

Note) V-belt is indicated by inch.

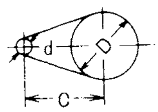
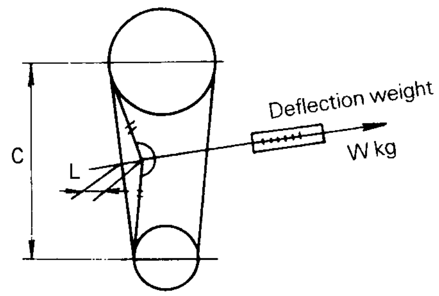


Fig.15-1 Size list of motor pulley (goods on the market) (Unit mm)

Belt form	A		B		C	
Number of belt	1 to 3 are common		1 to 5 are common		3 to 6 are common	
	O.D (outside diameter)	P.D (pitch diameter)	O.D (outside diameter)	P.D (pitch diameter)	O.D (outside diameter)	P.D (pitch diameter)
Pulley size	Minimum pulley diameter		Minimum pulley diameter		Minimum pulley diameter	
	84	75	136	125	214	200
	89	80	143	132	226	212
	94	85	151	140	238	224
	99	90	161	150	250	236
	104	95	171	160	264	250
	109	100	181	170	279	265
	115	106	191	180	294	280
	121	112			314	300
	127	118	211	200	329	315
	134	125			369	355
	141	132	235	224	414	400
	149	140			464	450
	159	150	261	250	514	500
	169	160	291	280	574	560
	189	180	311	300	644	630
			326	315	724	710
	209	200	366	355		
	233	224	411	400		
	259	250	461	450		
	The rest is omitted.		511	500		
			571	560		

4. **Proper tension of V-belt**
For the tension per one V-belt, the following deflection weight (W) must be satisfied. Calculate the value of proper deflection load (L) by following formula, and confirm that the deflection weigh (W) at that time is in the following range. If it is out of the range, adjust it, because the motor base is adjustable.

Type of V-belt	Deflection weight (W) kg
A type	1.4 to 2.1
B type	2.3 to 3.5
C type	4.0 to 6.0
D type	8.0 to 12.0

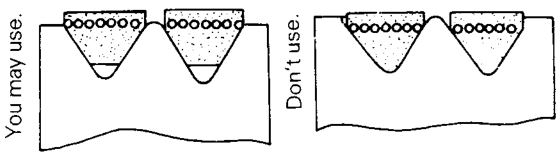


L = 0.016 × C
C : Distance between the shafts of pulley (mm)

Note)
- Adjust it to the proper tension after it got to fit well with the pulley. (After 24 to 48 hours operation)
- Or, in case of new belt, adjust it to 1.3 times of maximum of the deflection weight (W).

5. **Guide for timing of V-belt replacement**
When the V-belt becomes the state as shown below, you must estimate that the belt reaches a limit of the use, and replace it with a new one.
- When the belt wears to adhere to the bottom of the pulley groove.
- When the slippage is large and the output rotation slows down even though the normal adjustment is carried out.

Use-limit of V-belt



15.2 Installation of air conditioner in the place where much of soot such as cutting oil smoke is drawn in

When an air conditioner is installed in the place where cutting oil (for lathe, screw cutting lathe, etc.)is used, the following problems may occur:
- A hole is produced on the drain pan made of expanded polystyrene, and it raises a leakage of water.
- The inlet grille or the outlet grille made of resin is soaked with water.
- Insulation material of coil of the fan motor or the other is soaked with water to raise poor insulation of the motor.

The problems are probably caused by the following process.

⬇

Chlorine and sulfur are annexed to the water-soluble cutting oil.

⬇

The oil decomposes and gasifies by the heat at the time of cutting.

⬇

The gas adheres to the cooler, drain pan, inlet grille, outlet grille and fan motor.

⬇

The gas or deposits dissolve in the water to become chlorine or sulfuric acid.

⬇

These solutions dissolve the resin or expanded polystyrene.

* Especially, when room air conditioner (all types) or ceiling suspended air conditioner of which the drain pan made of expanded polystyrene is used, a hole is produced on the drain pan by drawing the vapor of cutting oil water leaks from there.

15.3 Noise from air conditioner and the measure

The noise on TV and radio affected by air conditioner is mainly caused by discharge of high-tension electricity, by discharge of contact or the other at the breaking time. We will discuss noise prevention, product care, and trouble-shooting.

1. Classification of main electric noises and sources

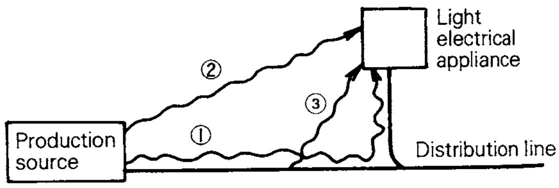
- Natural noise
  - ● Atmospheric noise ······ The earth, water vapor, ionosphere (thermal noise); Lightning discharge (atmospheric noise); Raindrop, dust storm, snowstorm (deposition noise)
  - ● The solar system and space noise
- Man-made noise
  - ● Due to spark discharge ······ Spark high-frequency-utilized equipment; Spark plug of internal-combustion engine (car, motorcycle, airplane); Thermostat, vibrator; Deteriorated glass of transmission or distribution line
  - ● Due to spark discharge and impulse contact ······ Tram; Small-sized series-motor used in electric drill, dentist's engine, electric motor, vacuum cleaner or the other
  - ● Due to glow discharge ······ Fluorescent lamp, neon sign, mercury-arc rectifier
  - ● Due to corona discharge ······ Extra-high voltage (275 kV) transmission line, ozanizer
  - ● Due to continuous oscillation ······ High-frequency-utilized (high-frequency sewing machine, medical appliances)

2. Production of trouble-wave and the propagation

The trouble by high frequency is produced in the connected electric-circuit due to the discharge, oscillation or a sudden change or voltage (current). The propagation path is as follows.

- Trouble-wave current travels power supply wiring to make trouble (Fig.15-2 ①).
- Trouble wave becomes electric wave and reflects to make trouble (Fig 15-2 ②).
- Composite propagation of ① and ②.
- It becomes electric wave from power supply wiring to radiate (Fig.15-2 ③).

Fig.15-2



3. How to consider noise prevention

Most of man-made noise can be stopped by taking a measure on the source of trouble-wave. It is effective and inexpensive way to solve the problem.

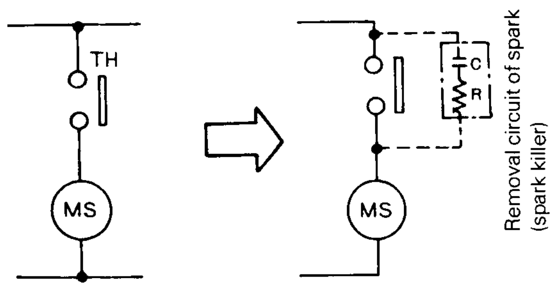
Examples:

- Eliminate the noise → get rid of the spark or corona.
- Obstruct the propagation of the noise.
- when the source of the noise cannot be eliminated due to the operation of equipment (for example: high-frequency-utilized equipment), obstructing the propagation of the noise can stop the damage. The propagation from the power supply → put a power filter in.
  The propagation turned into the electric wave and radiated → shield electrically.

4. Concrete measures of noise prevention

■ Removal of spark

This applies to the removal of electric spark caused by the thermostat.



● Contrivance of spark
When the current is sending, the energy stored in the magnet switch is discharged at the time of thermostat OFF and sparks fly at the contact.

The capacities of C and R in the removal circuit of spark can be found by calculation. However, it will be more effective that extra types of C and R should be prepared to make combinations of the various types of C and R when problem occurs.

■ Types of C and R needed at the work site

The spot C (capacitor) 0.1 µF with resisting pressure is $\sqrt{2}$ times or more of working voltage, mica type
The spot C (capacitor) 0.05 µF with resisting pressure is $\sqrt{2}$ times or more of working voltage, mica type
The spot C (capacitor) 0.01 µF with resisting pressure is $\sqrt{2}$ times or more of working voltage, mica type
R (resistance) 100Ω 1/4W type or larger
R (resistance) 200Ω 1/4W type or larger
R (resistance) 300Ω 1/4W type or larger

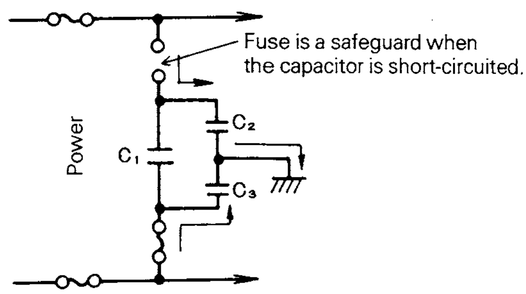
By combining the various types of above C and R, the most effective combination should be determined.

[For reference]
The most effective combination of C and R through the up to date experimental value is
C = 0.05µF
R = 300Ω

■ Setting a power filter

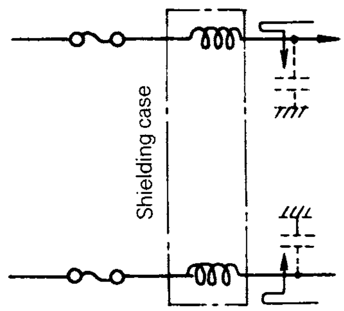
Obstruct the propagation from the wire by using C and R (coil).

Fig.15-3 C type (circuit structure)



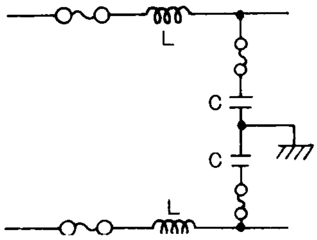
(Operation principle)
The higher the frequency rises, the lower the resistance (impedance) drops. By using this property of the capacitor, the resistance becomes high against the commercial frequency and the resistance becomes low against the noise frequency. Thus, only trouble wave is bypass to the ground.

Fig.15-4 L type



(Operation principle)
The propagation to the distribution line is obstructed by using the property of L, as L rises frequency and the resistance (impedance) increases, which is opposite from C.
(Independent use of this circuit is few. F type is used in many cases.)

Fig.15-5 type



(Operation principle)

A substantial effect is expected compares to independent use of C or L. Because this type uses the change of resistance to the high frequency of C and L, then ground the energy that was obstructed at L.

■ Notes for selecting C and R.

- Select as good quality of capacitor as possible for C.(Mica types are recommended.)
- With respect to the machine installed an earth leakage circuit breaker, C and R are selected and installed so that the increase of leak current to the ground is within 1mA.
- Ground the wire completely. (The third kind of ground work, ground resistance is not more than 100Ω.) In addition, ground the wire independently because sharing it with other equipment may result unexpected troubles.
- C and R should be installed at the closest place to trouble-making parts such as thermostat and ignition transformer.

5. In DAIKIN products, part where there is possibility of producing trouble-wave, the production form, attention to products.

Type of machine	*1 Trouble produced place *2 (Place where there is possibility of producing)	Production form	Measure to the product	Countermeasure when trouble is produced
All types of machines (Except air conditioner for computer)	*2 There is high possibility that the trouble is produced by superannuation of the thermostat circuit or the circuit contact correspond to it.	Spark discharge	Does not exist.	Trouble is solved only by installing a spark quenching circuit.
Boiler · Hot air furnace	*1 Electrode high-tension spark (Transformer for ignition)	Spark discharge	Does not exist. during sparking, trouble wave is usually being produced. But, as the can is shielded, the propagation is hard.	① Exchange for magnetic-shield incorporated in ignition-transformer. (A designation of "LOW NOISE TYPE" is written on the transformer.) ② C, L type circuit is incorporated.
Clean heat air conditioner (GFW)	*1 (Delay sparker)	Continuous oscillation	Exists (Built-in C, R type circuit)	
Fan coil (Attached automatic air volume control device)	*1 Automatic air volume control device	Owing to abrupt voltage change	Exists (Built-in C, R type circuit)	
Fan coil (Incorporated electric precipitator)	*2 When electrode board of the dust collector is clogged with dirt, the trouble tends to be produced.	Corona discharge or spark discharge	Does not exist. As the 100-voltage is raised by transformer, there is no production from the high-voltage transformer.	
Air cleaner	*1 High-voltage power unit	Continuous oscillation	Exists (Built in C type circuit)	
Air conditioner for computer room	*2 Control circuit	Spark discharge	Exists (C, R type 2 steps)	

6. Detection method of propagation path (Case of radio or TV)

Remove the antenna of radio receiver or TV receiver, and short-circuit between the antenna terminal and the ground terminal.

↓

Does the trouble appear?

- **NO** → The cause of propagation is that it travels in a moment from the space wave to the antenna or that it travels in a moment in the cable from the antenna to the receiver.
- **Yes** →
  - It becomes slight. → The propagation paths are both space wave and power distribution line.
  - It does not change. → The propagation causes trouble through the power distribution line.

Disposal method

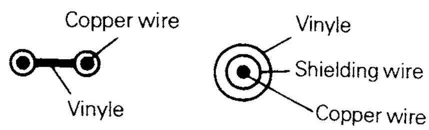
- Dispose as shown on the right.

Steps

- In the case caused by thermostat, use C, R types.
- In the case caused by ignition such as burner, use C type.
- Gain the power from another plug socket.
- In the case of power side of the trouble-producing-origin equipment, C type 2 steps should be installed.
- When a radio or the other is used without antenna, install an antenna of about 1m to 2m length as much as possible.
- In the case of TV, make sure that the antenna and the cable are surely connected.

Steps

- In the case caused by thermostat, use C, R types.
- In the case caused by ignition such as burner, use C type.
- When an old-fashioned cable of TV or the other is used, get it changed to the coaxial cable.



- Check the ground performance of the trouble-producing-origin equipment.

15.4 A very small amount of leakage current by suspended electrostatic capacity

Sometimes, between the casing of air conditioner or chiller and the ground, over 10 voltage is measured, or a very small amount of leakage current can be perceived by human body.
Such phenomena is generated at all electric appliances (especially at the one mounted motor such as electric washer or electric refrigerator), if all conditions become complete, that is to say, this is not abnormal phenomena.

[Preventive measure]
This phenomena can be prevented by ground construction. More, there is no preventive measure except the grounding. Therefore, execute surely the grounding when installing.

■ Judgement of suspended electrostatic capacity and leak

In all cases, more or less, the human body gets an electric shock, but the causes are fundamentally different from each other.

- If sufficient insulation resistance is provided, when measuring insulation resistance, there is no short circuit.
  → Judge it as electricity by suspended electrostatic capacity.
- After the voltage between the part where electricity other than electric circuit is perceived and the earth, is measured by tester, if there are differences among the voltages measured in each range, judge them as electricity by suspended electrostatic capacity.
  Note) There are various ways to judge whether the ground construction is complete or not. As a simple way of judgement, measure the voltage between the ground terminal and the power (in the case of 100V is ⊖) side.
  - When voltage is equal to the power voltage
    —— Earth is good.
  - When voltage is less than the power voltage
    —— Earth is bad.

15.5 "Spray" phenomena of air conditioner in cooling operation

■ Phenomena

Occasionally, in cooling operation, there is a phenomena of spraying from the outlet of air conditioner which is rather new after only several months or one season.

■ Occurrence place

The occurrence place is almost limited to the place where the producing quantity of oil mist and steam are comparatively large, such as Chinese restaurant or roast meat restaurant.

■ Cause

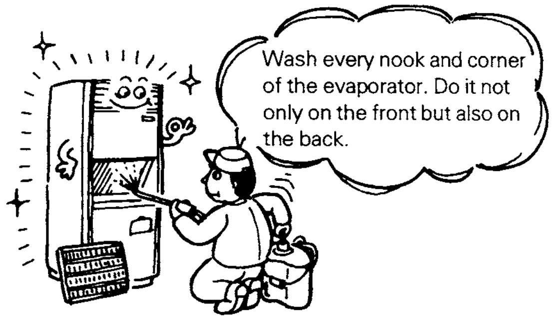
It is supposed that, in an atmosphere where the quantity of oil mist is large, oil coating is formed on the surface of evaporator and drain water on this coating is repelled to become misty state in the process of blowing off with cooled air.

■ Points of disposal

When such a phenomena occurs, wash the evaporator. More, this washing way is effective for trouble such as "from the air conditioner in the barber's shop, beauty parlor, cosmetic store, etc., a foul smell is being given out."
The washing way is shown in the following figure. Spray the evaporator with the washing liquid and sprayer until the oil is sufficiently removed. Use the clean-star F101 diluted to five times with water for the washing liquid. And after spray washing, the hot-water-washing of the evaporator should be done completely. (Tepid water is better.)

Notice

- Avoid the washing in opening time of shops, because chemicals are used.
- The washing liquid (undiluted solution) has dilute alkalinity. Be careful not to touch the undiluted solution. But, there is no need of using rubber gloves. More, this liquid has no smell nor toxicity.



■ Washing liquid

Clean-star F-101
Manufacturer and sales agency: Kurita Industries Ltd.

Case example
Chinese restaurant
Type: UCS3G
- Amount of used washing liquid (undiluted solution): 4 L
- Washing time (including the time necessary for final washing using): about one hour.

15.6 Work procedure using blank plug for cooling pipe in heat exchanger

1. Purpose

When a cooling pipe used in the condenser (CHS) or the evaporator is damaged (opening in the pipes), and when the cooling pipe cannot be exchanged, the condenser or the evaporator can be used holding the damaged pipe idle by putting blank caps into both ends of the pipe. The work procedure in this case is as follows.

But, in the case of corrosion accident of the cooling pipe, begin the work after eddy-current flow detection. And make sure that the cooling pipes except the damaged one are not corroded at all after performing overflow-over-detecting test or the other. Generally, in the case of corrosion accident, almost of all cooling pipes are corroded. Therefore, though the only damaged pipe is plugged with blank caps, the claim will be made again.

2. Applicable heat exchanger

Cooling pipe : Outside diameter ϕ19.1
Inside diameter ϕ16.7

Material { BSTF2
D Cut

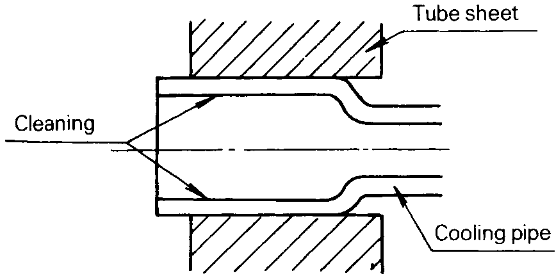
3. Article number of blank cap

Article number : 299601

4. Work procedure

- Clean the inside of cooling pipe. (Installed position of blank caps)
  (Make the inside surface smooth by #600 paper to remove the dirt adhesion.)

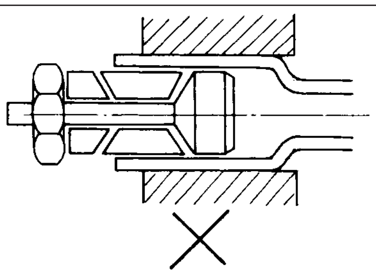
Fig.15-6



■ Installation of the blank cap

- Epoxy adhesives should be used to the inside of the installed position.
  Epoxy adhesive : Cemedine #1302

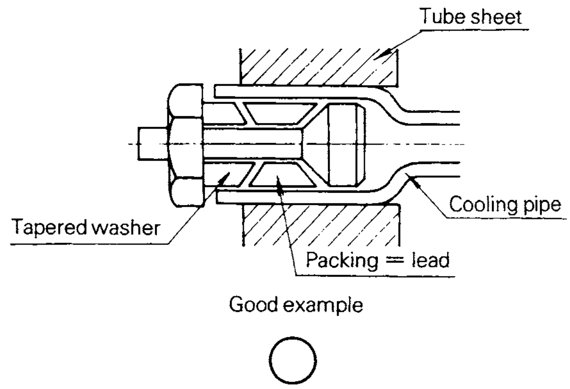
Fig.15-7



Bad example (insufficient insertion of blank plug)

- The tapered washer should be set so that it is surely inserted in the cooling pipe.

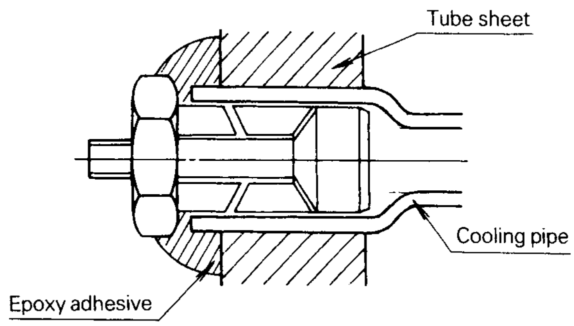
Fig.15-8



Good example

- Tightening of blank cap
  Tightening torque ······ Tighten the cap with torque about 120kg-cm.
  Tighten it with double spanners.
- Swivel stopping
  After tightening, swivel stopping should be carefully done using epoxy adhesive.

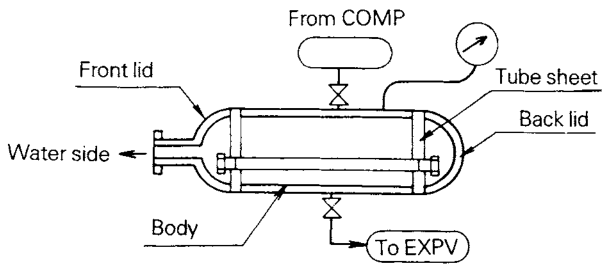
Fig.15-9



- Conduct the above work procedure on the both ends of the cooling pipe.
- Drying of epoxy adhesive
- Drying time → 12 to 24 hours to dry by air-drying.
- Confirmation in the leakage test

	Items	Charged gas	Value of test pressure
1 Body side	R-12	Nitrogen gas + Freon	16.5
	R-22	Nitrogen gas + Freon	20

Fig.15-10



Confirm that there is no gas leakage from the body side or water side by using a halide torch type gas detector.

Note)

- Confirm that the lead packing is used.
- For marine unit, conduct the test under the test pressure specified separately.
- When the number of cooling pipes for which the blank caps are used exceeds 5%, inquiry to our company.

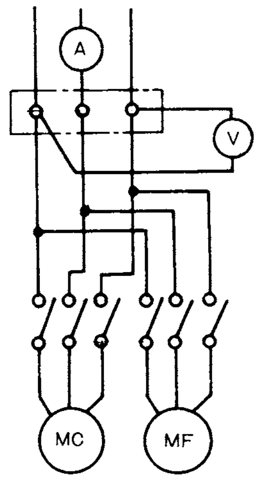
15.7 The way to use the electromagnetic switch

Erroneous usage of electromagnetic switch leads not only to the trouble of itself but also to the trouble or damage of the whole equipment. The electromagnetic switch is important part.
The following is the way to use the electromagnetic switch.

Electromagnetic switch reffered to herein is the one specified in JIS-C8325.

① The operation voltage should be 85% to 110% of the rating.
② The operation coil should not be connected in series.
③ This switch must not be used at the frequency of once or more times per 3 seconds.
④ When there are both a and b auxiliary contacts in the same block and the both contacts are used, they must be connected so that they become in-phase.
⑤ In case of λ-Δ starting, the time lag for changing from λ to Δ must be taken for 0.1 second or more.
⑥ As the rated capacity of contact differs depending on the circuit voltage or the type of load, it must be selected with due regard to the conditions.
⑦ This switch must not be used for the load which exceeds the rated capacity continuously.
⑧ Do not use two or more contactors connected in parallel for switching one load.
⑨ When contacts of one contactor are used in parallel, they must be used after verifying by the test according to the actual state of the load.
⑩ The standard ambient temperature is 40˚C, and the maximum service temperature is 65˚C.
⑪ Care should be taken to oil, dirt, gas, etc.,
⑫ Installed in the vertical direction with the powerside terminal located upward and the load side one, downward.
⑬ A 5mm or more clearance must be allowed between the mutual switches and between the switch and the side board or the upper lid.
⑭ Terminal screw must be tightened surely.
⑮ when replacing a contact, all contacts in the same switch must be replaced at the same time.
⑯ The overcurrent relay must be used if necessary according to the type of load.
⑰ There are two types of the restoration system of the overcurrent relay: automation and manual restoration. Choose the one so that the circuit composion of the whole system becomes manual restoration system (reset system).

Fig.15-11



15.8 Effect of instantaneous voltage drop to electromagnetic contactor

At the time of compressor-starting, several times of current compared with the normal current flows, and because of this, sometimes a comparatively large voltage drop occurs. This is generally called "instantaneous voltage drop".
When an instantaneous voltage drop occurs at the instant of closing the electromagnetic contactor, sometimes the magnet coercive force weakens to cause chattering by repulsion force of the spring for iron-core cushioning.
Chattering of the contact reduces the life of contactor. If the contact repeats ON, OFF continuously, the arc between the contacts continues to reduce the life remarkably, as a result.
When wiring outside the equipment is provided with wires having the size and the distance as described in the "DAIKIN technical data book", a voltage drop which reduces the life of contact remarkably, will not occur. If the wire smaller than the size specified is used, or the wiring exceeding the maximum distance is practiced, sometimes trouble will be produced. When there is a voltage drop which causes remarkably short life of the contact, change the wiring.

[A method of measurement of instantaneous voltage drop in the field]

An instantaneous voltage drop cannot be measured by a general voltmeter or a tester. But, the outline can be found by the following formula.

- When there is a load (fan motor or the other) running before the operation of compressor:

$$V_S = V_O - \left(\frac{I_I + I_S}{I_R}\right)(V_O - V_R)$$

- When the unit consists of only the compressor:

$$V_S = V_O - \left(\frac{I_S}{I_R}\right)(V_O - V_R)$$

I_I :Totalizing current of the load running before the operation of compressor.
I_R :Running current of the refrigerating machine.
V_O :Supply voltage at the dwell point of the refrigerating machine.
V_R :Supply voltage when operating the refrigerating machine.
I_S :Starting current ······ refer to the following table.
V_S :Instantaneously dropped voltage.

1. Operation voltage

- Common use of the coil is impossible between direct current (DC) and alternating current (AC).
- In the case of AC, sometimes the same voltage cannot be used for 50Hz and 60Hz.
  For example, there is a triple rating one (60Hz 200V to 220V 50Hz 200V), Which cannot be used for the power supply of the 50Hz 220V rating.
- The minimum operation voltage varies depending on the size of switch. Generally, if it has at least 80% of the rating, it surely operates.
- It can be used up to 110% of the rating without abnormal rising of the coil temperature.
- If the voltage is too high, generation of heat becomes high with an increase in exciting current.
- If the voltage is too low, beating or BZZ sound is generated with a deficiency of sound absorption, and in an extreme case, it becomes the same state as an air-core coil and it is destroyed by burning out.
- When an instantaneous voltage drop is produced at the same time of closing, chattering is generated to cause a contact weld.

2. Series use of operating coil

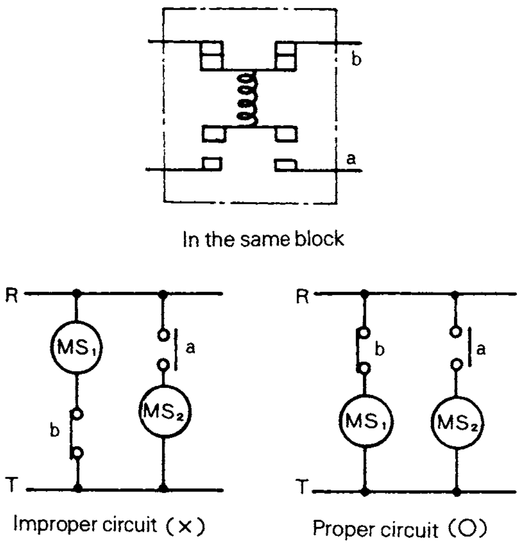
When two 100V coils are used in series in 200V circuit, there occurs a difference between the coil voltages because of the difference between each coil and impedance, and the coil of which the load is heavier is over heated.

3. Frequency of opening and closing of switch

When closing, a large current flows through the coil. Therefore, if it is continuously opened and closed at the frequency of once or more times per 3 seconds, generation of heat becomes large.

4. The way to use "a" and "b" auxiliary contacts in the same block

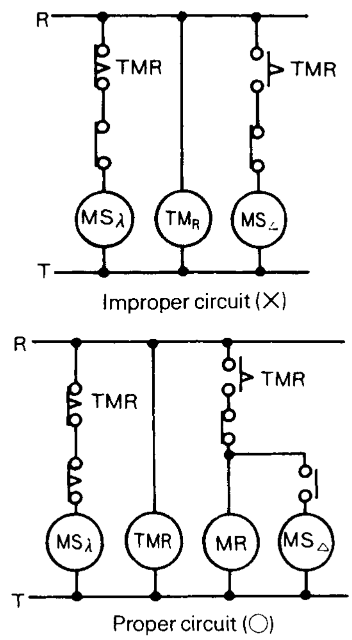
Fig.15-12



The "a" and "b" traveling contacts are connected with a spring, and sometimes, according to the timing, the operation becomes short-circuited.

5. Changing time of λ to Δ

Fig.15-13



When λ operation is shut off and the arc disappearance is insufficient, it is necessary to take the time lag of 0.1 sec. or longer for switching and to prevent to cause the arc short circuit through the contacts.

6. Rated capacity of contacts

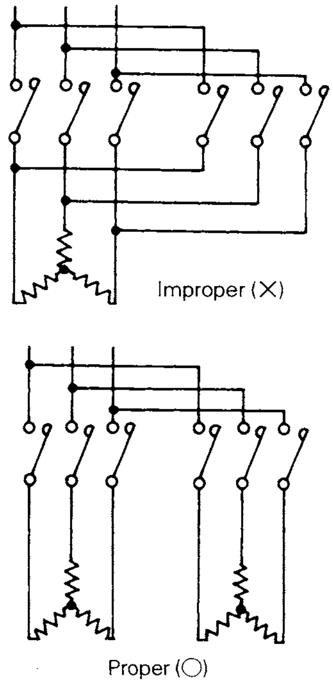
- Rated capacity of the contact is determined from the relations among the breaking capacity (Can the arc be cut off?), the turning-on-electricity capacity (Temperature-rise of the live-part) and the life.
- Even among the same type of contactors, when compared the one attached with overcurrent relay with the one without this attachment, sometimes there is the one of which the rated capacity differs.(Owing to the heat of overcurrent relay, in case of "attached one", the rated capacity is small.)
- There are different rated capacities according to the types of the load. Therefore, select the suitable one referring to the drawings, catalog, etc.,
- Electric life of CLK type is 250,000 times, when 5 times of the current of the rated capacity is loaded at the rate of frequency of opening and closing of 300 times per hour and normal current is cut off. (A-3-2 of JIS8325)
- Locked current of the motor should not be used intermittently, 10times of the current of the rating can be loaded or cut off. But, according to the JIS specifications, CO (closing and opening) is 5 times and C (closing) is 100 times. If the cut off of the large current is repeated, the life will be shortened.
- When chattering is produced, the current is intermittently and continuously cut off, and the arc heat is accumulated and it causes the contact weld.

7. Selection of rated capacity of switch by a kind of loads

- Resistance load: Select this in anticipation of the upper limit of tolerance of the load.
- Motor load:Select the overcurrent relay of which the capacity is more than the set value. (When the overcurrent relay is not used, more than the rated current.)
- Inductive load, electromagnetic-coil load, lamp load: Select the one of which the capacity is more than the rated current.
- Load of only capacitor:The electricity capacity, compared with the general load, is small. Select it by the use of the maker's data book or catalog.
- DC circuit : The same as the above.

8. Parallel use of switches

Fig.15-14



As the rated capacity of one switch is insufficient, two switches connected in parallel to make and break one load is impossible. There are differences in making or breaking speed of the switches. All loads are imposed on the fast making or slow breaking one and it causes the abnormal temperature rising or contacts welding.

9. Parallel use of contacts in one switch

Although conductive capacity is insufficient in case of one pole, it is possible to plan the increase of the conductive capacity by the parallel use of two or three poles.
But, because of imbalance of contact-resistance values, the conductive capacity will not increase double or triple in value. Making or breaking capacity becomes the same value as the case of one-pole using by variations in contact parting times among the each contact. And the frequency of opening and closing should be decreased.
The life will be about one half compared with the case of using one pole.

10. Ambient temperature

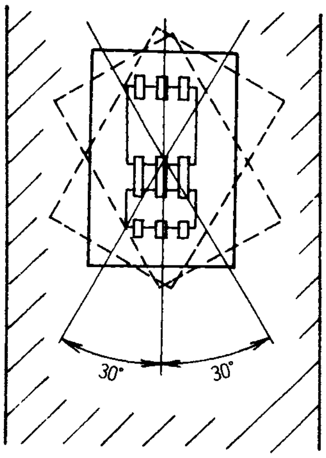
The standard ambient temperature is usually 40˚C, and the maximum service temperature is 65˚C.
When used in high temperature, measure such as raising the insulation rank of reduced coil of applicable load current is required.

11. Influence of oil, dirt or gas

- If oil or dirt adheres to the contact or the iron core, it causes rising of temperature by bad continuity of incomplete contact, or abnormal exhaustion of the contact.
- Sulfur gas, nitrogen gas, ammonia gas etc. invades the silver contact.

12. Installation direction

Fig.15-15



- It must be installed vertically so that the power side terminal is installed upward, and the load side one, downward. But, inclination to 30˚ forward and backward, leftward and /or rightward is tolerable.
- But, if it is installed upward, downward or sideways, it produces an effect on operating voltage, breaking capacity, life, etc.,

13. Terminal-screw tightening

Looseness of terminal-screw contributes to the chattering or burning of resin. Therefore it must be tightened surely.

14. Replacement of contact

When the contact is replaced for its roughness etc., it is necessary to replace the all poles at the same time.

15. Types of overcurrent relay

- When the motors of hermetic and semi-hermetic compressors are compared with the general-purpose ones, the circuit at binding time should be quickly broken.
  Use an overcurrent relay of quickly working type.
  Example
  CLK-25UT-P5
  The one marked with P5 or indicated as "For compressor" on the drawing.
- For general fan, pump etc., use the one of which the properties are shown on the JIS-C8325.
  Example
  CLK-25UT-P4
  The one marked with P4 or not indicated as "For compressor" on the drawing.
- For large-sized propeller fan of which the starting time of 5 seconds or more is required, it is necessary to use a delay operation type.
  Example
  CLK-20UT-P9S3
  UWY80 to 120E for fan, high speed side

16. Restoring system of overcurrent relay

- The one for compressor is not used for both the automatic and the manual.
- Another ones is used for both the automatic and the manual, but the restoring system in the delivering should be indicated.

Daikin Europe N.V. is approved by LRQA for its Quality Management System in accordance with the ISO9001 standard. ISO9001 pertains to quality assurance regarding design, development, manufacturing as well as to services related to the product.

ISO14001 assures an effective environmental management system in order to help protect human health and the environment from the potential impact of our activities, products and services and to assist in maintaining and improving the quality of the environment.

Daikin units comply with the European regulations that guarantee the safety of the product.

Daikin Europe N.V. is participating in the EUROVENT Certification Programme. Products are as listed in the EUROVENT Directory of Certified Products.

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