

Basic Technology Series

Fundamentals of Car Air Conditioning

2007
Air Conditioning #001

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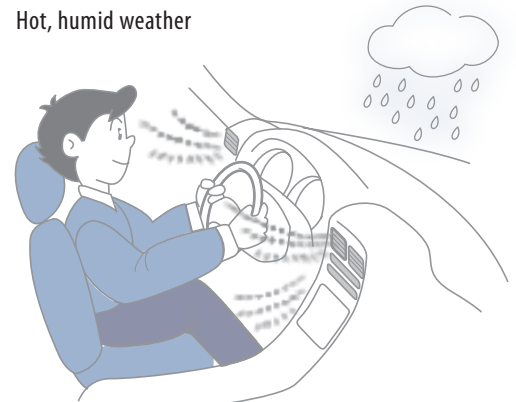
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Fundamentals of Car Air Conditioning

The DENSO car air conditioner was sold from 1957 as the "DENSO CAR COOLER." With the remarkable development of motorization, a new engineering revolution occurred with the car cooler, car air conditioner and auto air conditioner for the sake of a more comfortable environment. This "Basic Technology Introduction" will be presented together with the introduction of the latest technology.

Hot, humid weather



Cooling & Dehumidifying

Functions of Car Air Conditioners

Car air conditioners are designed to cool and dehumidify the air inside the passenger compartment in order to maintain comfort. They have extraordinarily superior functions not only for summer, but also for the late spring and autumn rainy seasons. For example, when you drive on hot and muggy days, the air is cooled and dehumidified by the cooling unit and heated to the appropriate temperature with the heater unit, so the air from the blow out port has low humidity and is quite refreshing.

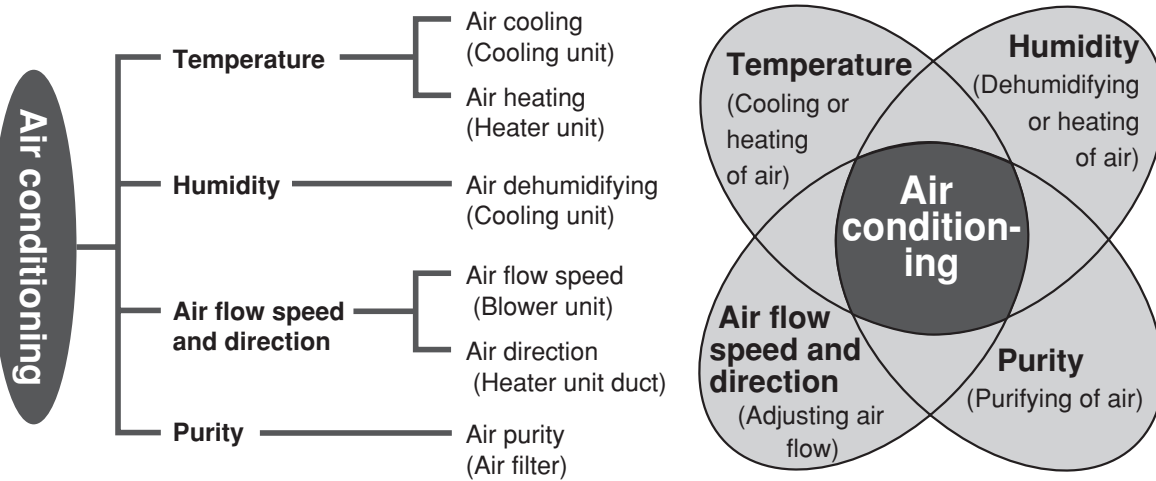
Hot, dry weather



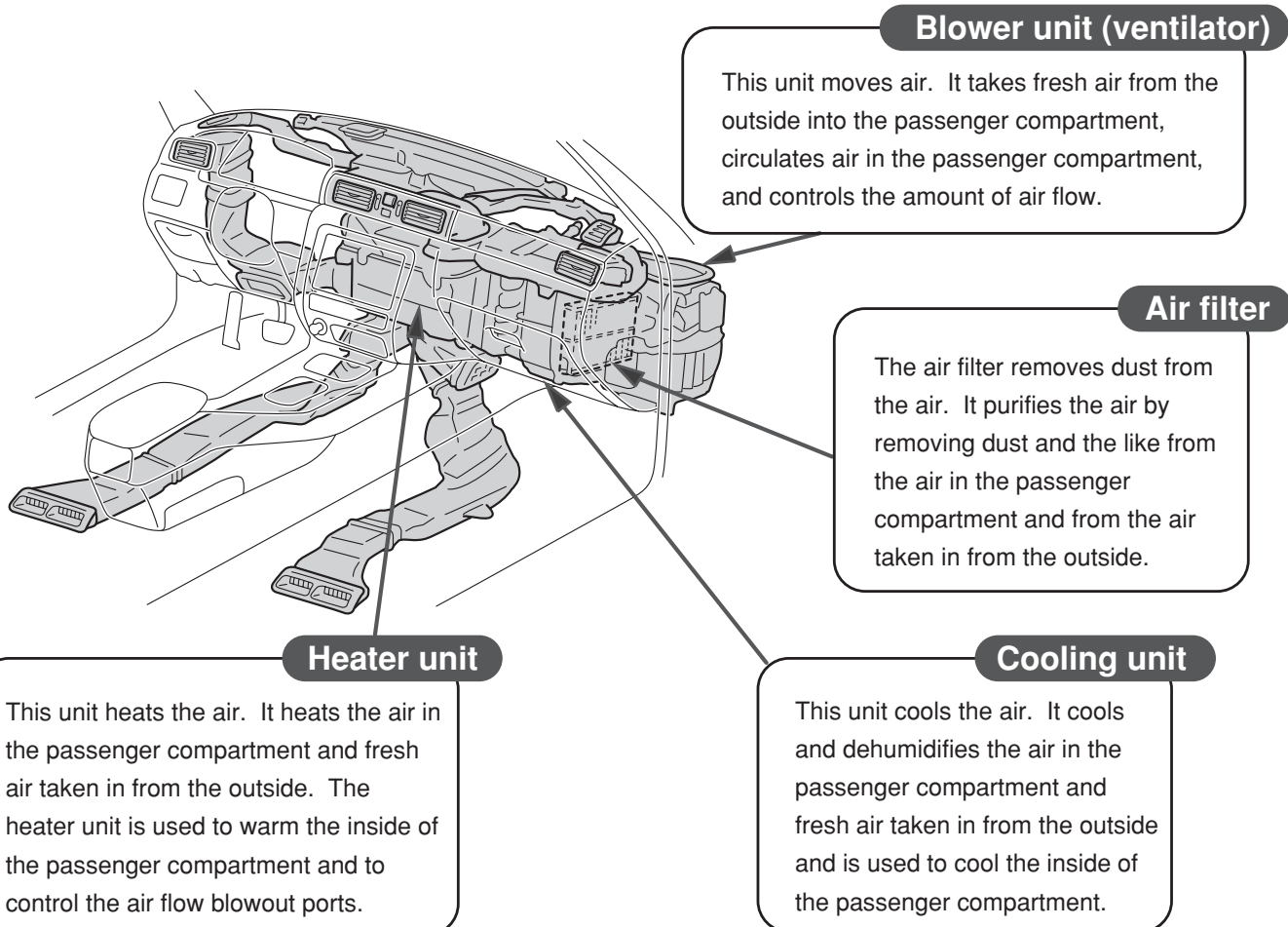
Cooling

Air conditioning

Air conditioning adjusts the temperature, humidity, air flow, and air purity for the air in the passenger compartment according to the usage objective and maintains a uniform state. In order to create an environment in which the passengers can feel comfortable, car air conditioning adjusts the temperature, humidity, air flow, and air purity within the passenger compartment either all together or each separately.



The equipment for air conditioning mounted in cars includes the following.



Types of car air conditioners

Car air conditioners can be classified as follows by their mounting location and control type.

Car air conditioners

Mounting location

1. Front air conditioners
2. Rear air conditioners (coolers)
3. Overhead air conditioners (coolers)

Control type

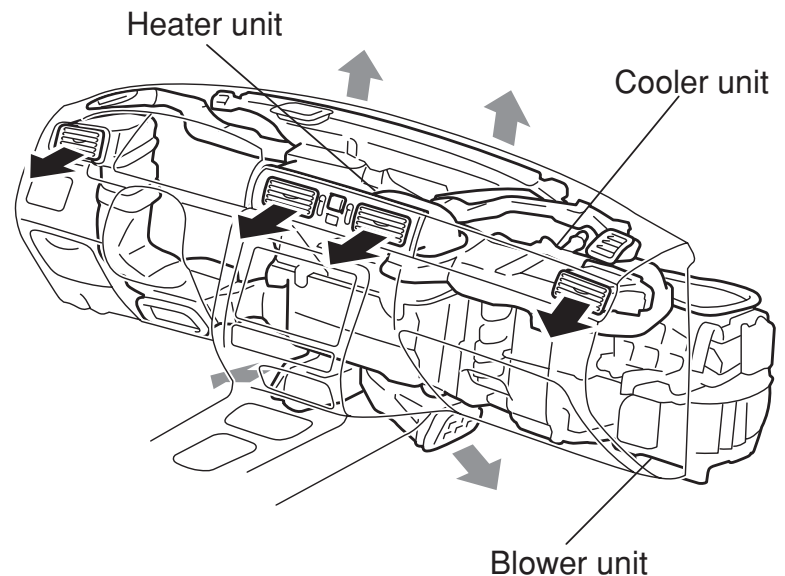
4. Manual air conditioners
5. Automatic air conditioners

A Brief Note

In the classification by mounting location, an air conditioner that combines a front air conditioner and a rear cooler is called a dual air conditioner and an air conditioner that combines a front air conditioner and an overhead air conditioner is called an overhead dual air conditioner.

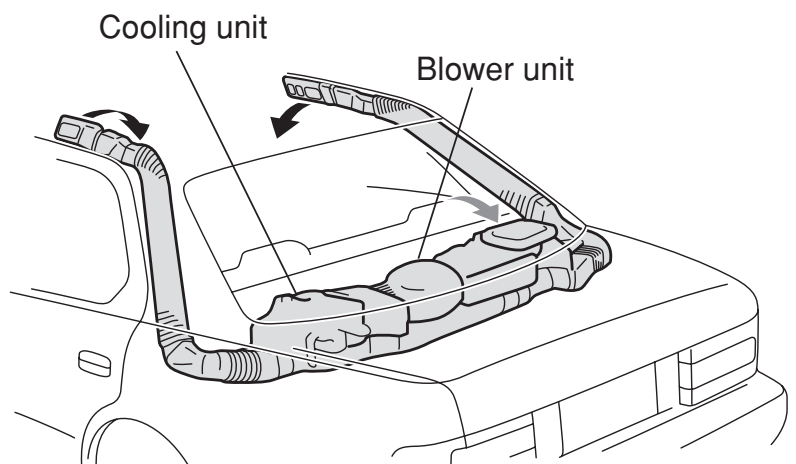
■ FRONT AIR CONDITIONER

This is a basic type car air conditioner. The cooling unit is installed behind the dash panel and is connected to the heater unit. The blower unit takes in outside air or inside air and sends out this air. The cool air blowout ports are in the center and at the driver side and passenger side. On the other hand, hot air is blown out at the feet. There are also defroster blowout ports to defog the windshield.



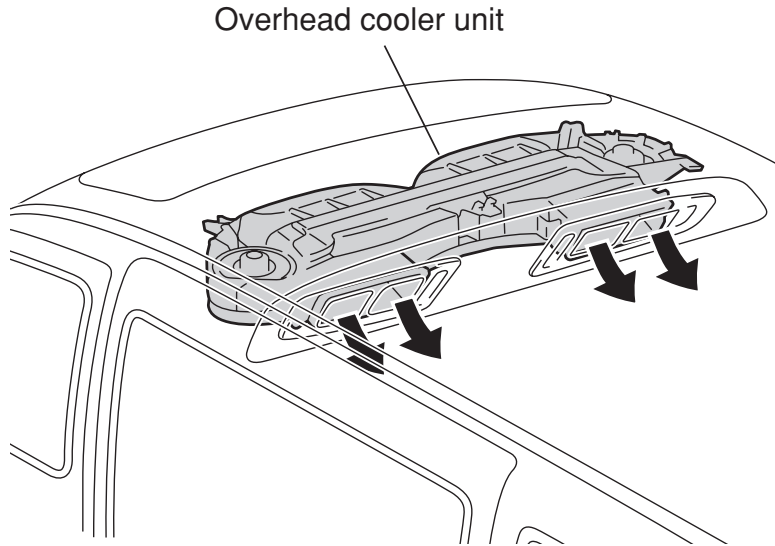
■ REAR COOLER

A rear cooler has the cooling unit and blowing unit in the trunk. The cool air is blown out from the rear of the passenger compartment. Combining a rear cooler with a front air conditioner is extremely effective for cooling down the passenger compartment and can provide a comfortable environment with a uniform temperature distribution within the passenger compartment.



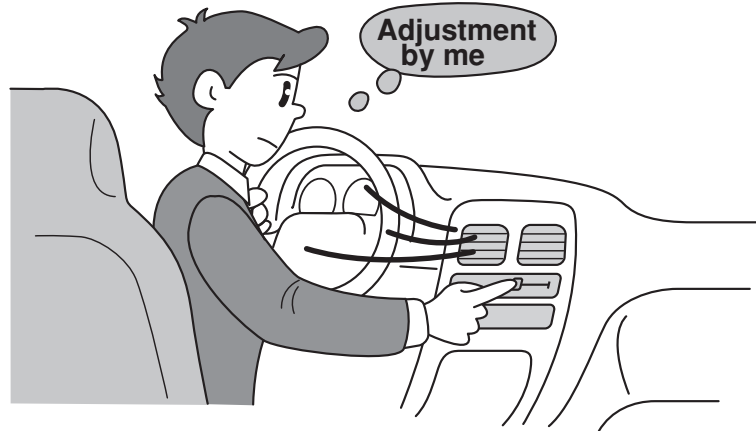
OVERHEAD COOLER

This is the optimum cooler for station wagons and the like. This type of unit has the rear cooler on the ceiling. When such a unit is used in a set combined with a front air conditioner at the front of the passenger compartment, the cool down characteristic and temperature distribution are extremely good, and a cooling effect appropriate for station wagons is obtained.



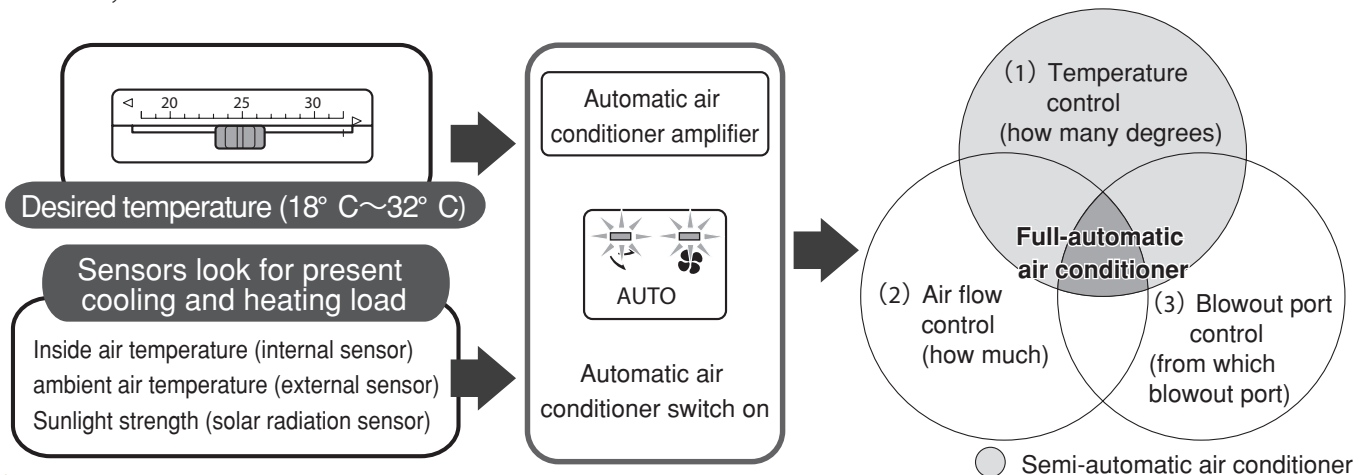
MANUAL AIR CONDITIONER

This is the general manual control type and allows the passengers themselves to adjust the air conditioning as they like. The blowout port temperature is controlled with the temperature adjustment lever. This method also controls the air flow, blowout port selection, inside/outside air selection, etc., with their own levers (or switches).



AUTOMATIC AIR CONDITIONER

This is the automatic control type that automatically maintains the passenger compartment temperature at the desired preset temperature by compensating the influences caused by the changes of room temperature, ambient air temperature and the effect of sunlight. The automatic air conditioner control functions are (1) temperature control, (2) air flow control, and (3) blowout port control. An air conditioner with all these functions is called a fully automatic air conditioner and is distinguished from a semi-automatic air conditioner, in which either (2) or (3), or both, are fixed manually.



Cooling in the Natural World

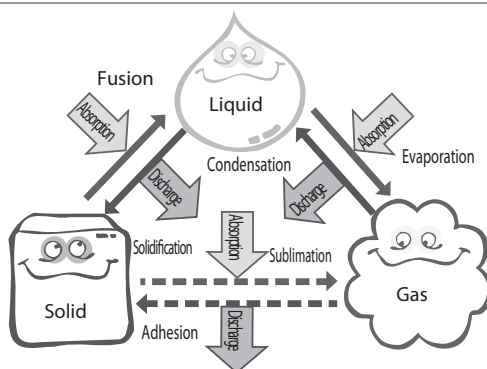
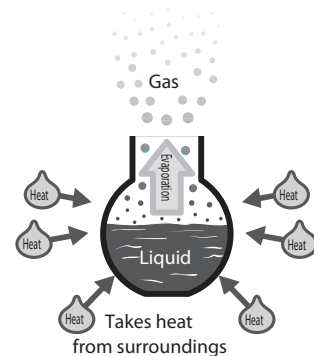
Natural phenomena include a variety of principles of cooling. Cooling principles which you experience firsthand include the cold feeling of the alcohol when applied to your skin. Likewise, if you spray water in your garden in the summer you feel cool and refreshed. How does this happen? When the alcohol or water evaporate in the air, they take heat from the surroundings (known as latent heat). In other words, for a liquid (such as alcohol or water) to change into a gas (alcohol vapor or water vapor, for example), heat is required (heat of evaporation). The side from which the heat is taken (the section contacting the liquid) is then cooled. These natural phenomena clearly show this principle of cooling. Cooling draws on this natural phenomenon to obtain coolness and freshness.



To give another example, if you insert ice water in a glass and leave it in the air, water droplets will warm on the outside of the glass. This is because the water vapor in the air (resulting when water becomes a gas) has its heat absorbed by the ice water in the glass so that it becomes a liquid. The ice water, on the other hand, is warmed by the heat of condensation.

If heat is applied to or taken away from an object, the temperature of the object changes or the state of the object changes.

The heat accompanying this change in the object is known as latent heat because heat is either discharged or absorbed in accordance with the change.



DISCHARGE OF HEAT:

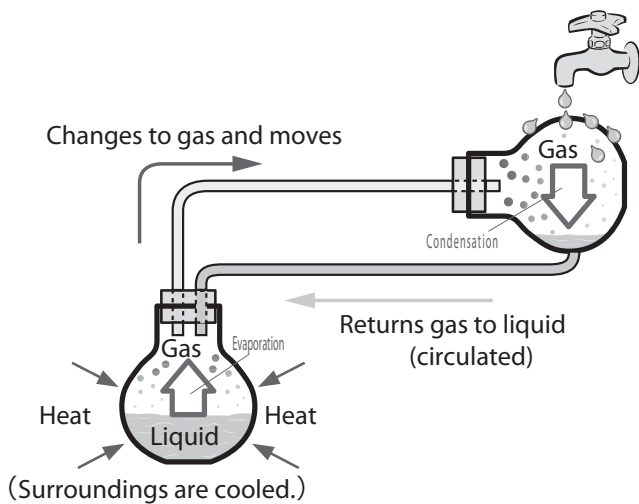
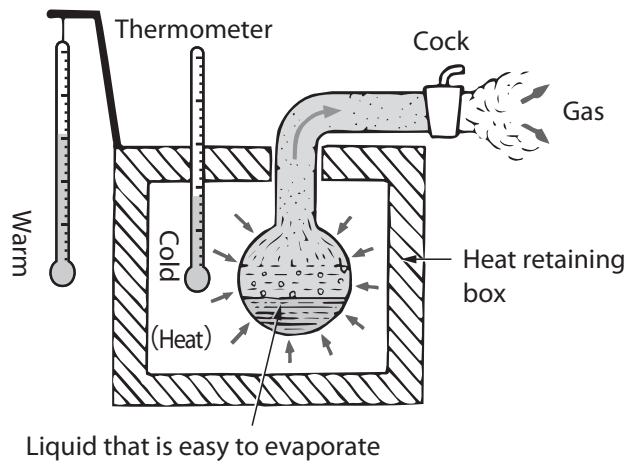
Heat of condensation, heat of solidification, heat of adhesion. (Warms the surroundings).

ABSORPTION OF HEAT:

Heat of evaporation, heat of fusion, heat of sublimation. (Cools the surroundings).

Principle of Cooling

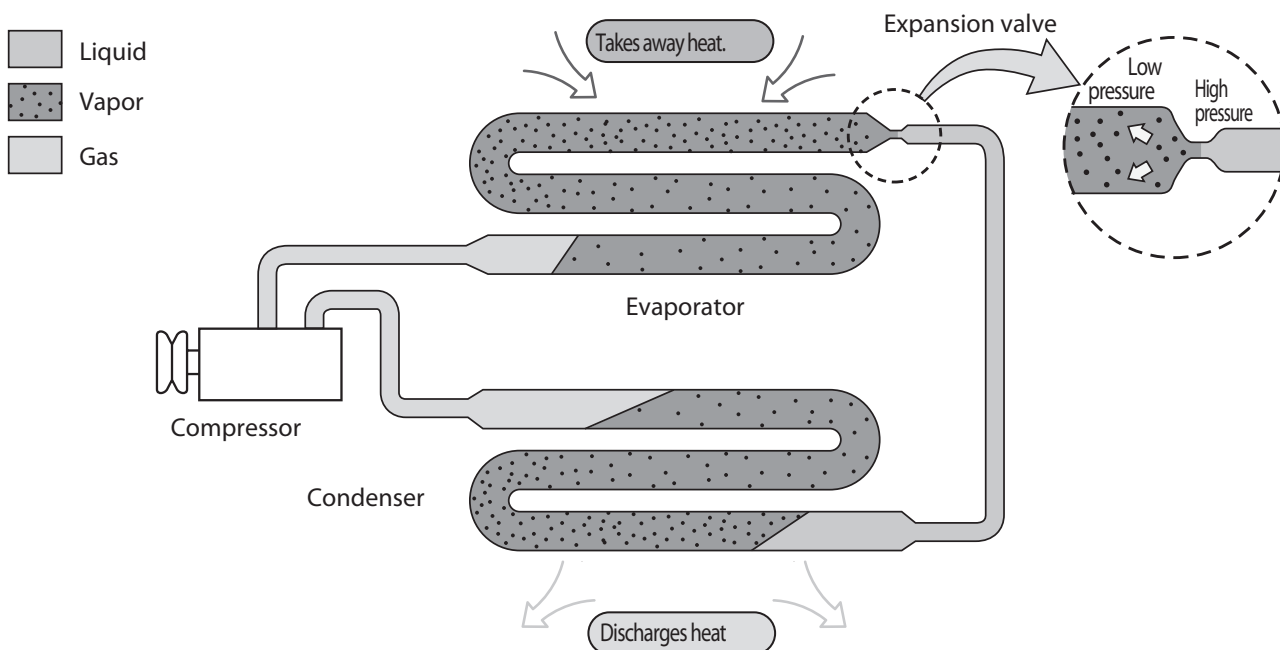
In causing evaporation of a liquid so that heat is taken from the surroundings to cool a room, if the water vapor is simply discharged into the atmosphere it is necessary to constantly replenish the liquid. This is not very effective. Instead, the gas which has been evaporated is cooled to return it to a liquid state in a cycle. Liquefying a gas requires removing the heat in the gas. At the same time, however, if the gas is compressed to increase its pressure, it is relatively easy to turn it into a liquid. An actual cooling device requires a compressor to add pressure to the gas and a condenser to take away the heat from the gas.



Conditions of a Cooling Device

Generally speaking, a cooling device involves sealing a liquid (known as the refrigerant) that readily evaporates inside the device and connecting the individual elements by pipes to cause circulation of the liquid while repeating a process of evaporation, condensation and evaporation through the device. A car air conditioner adopts the vapor compression refrigerating system to carry out cooling.

Conditions for a cooling device that cools properly include the following. First of all, there should be evaporation at the lowest temperature possible and use of a refrigerant having the property of easy liquefaction. In addition, the refrigerant should change efficiently into a gas inside the evaporator.



Structure of a Car Air Conditioner

In examining a cooling device (freezing cycle: passageway through which the refrigerant circulates) and the state of the refrigerant in that device we can describe the following sections:

■ EVAPORATOR: (INSIDE THE COOLING UNIT)

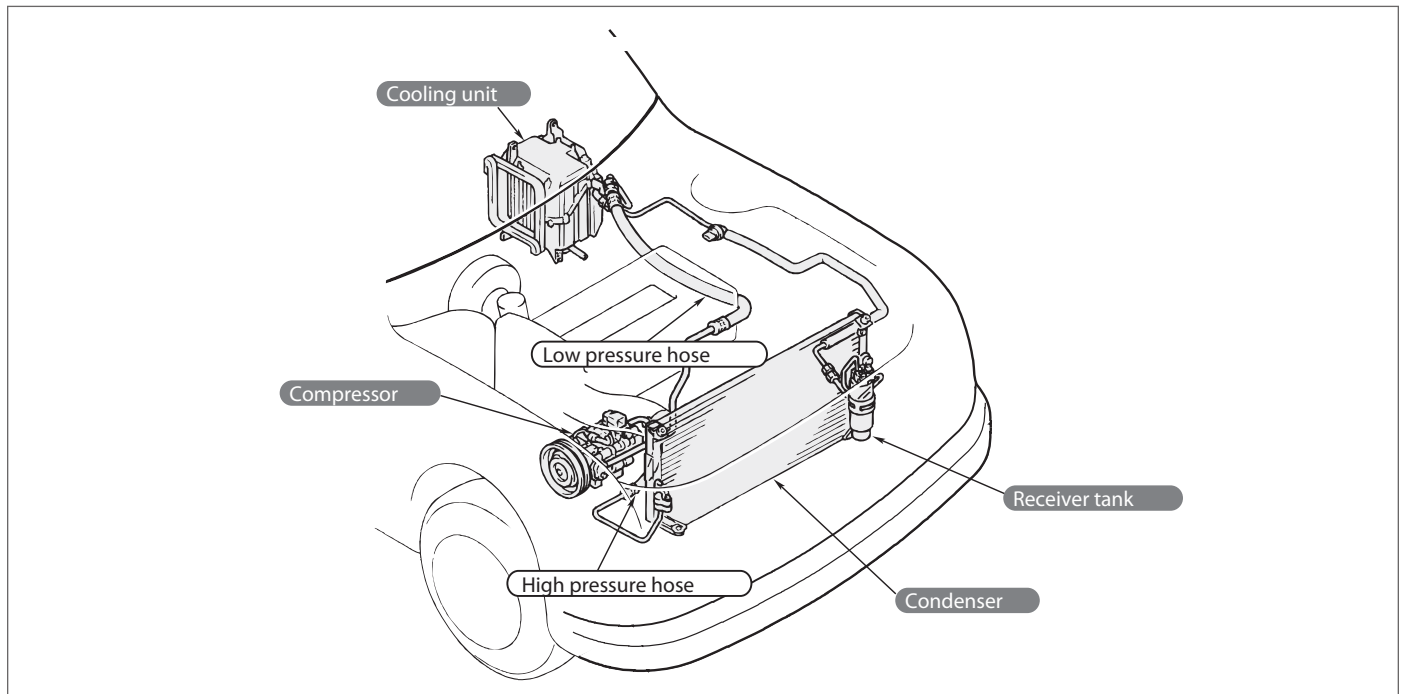
This is the section where the refrigerant evaporates, taking heat from the area around the pipe and cooling the surroundings (interior). Inside the evaporator, the refrigerant, in the form of a mist, takes away heat in the car interior while suddenly evaporating. The area near the exit is a refrigerant in a total gas state.

■ COMPRESSOR

The refrigerant gas which is evaporated in the evaporator is absorbed and condensed as pressure is added with the condenser to cause ready condensation. The refrigerant compressed in the compressor becomes a high temperature, high pressure gas.

■ CONDENSER

The refrigerant that was compressed in the compressor to form a high-temperature/high-pressure gas is then cooled to return it to a liquid state. As the refrigerant enters and passes through the condenser, it is cooled and changes from a gas to a refrigerant in the form of a liquid. At this time it is necessary that it changes into a liquid at the exit of the condenser. If cooling with the condenser is insufficient at this time, there will be a residue of refrigerant in a gas state which will decrease the cooling capacity.



■ RECEIVER TANK

The receiver tank is a receptacle for temporary storage of excess refrigerant. In a car air conditioner the compressor is driven with the car engine. This means the rotation may fluctuate considerably. In addition, the car interior is heavily influenced by the outside temperature. In particular, the temperature of the car interior can become very high during summer or when the car is parked in the hot sun. Because the compressor rotational frequency and the exterior temperature fluctuate in this way, the amount of refrigerant circulating in the cycle also fluctuates considerably. The receiver tank thus also has the function of regulating this fluctuation.

■ EXPANSION VALVE (INSIDE THE COOLING UNIT)

The refrigerant that was compressed in the compressor to form a high-temperature/high-pressure gas is then cooled to return it to a liquid state. As the refrigerant enters and passes through the condenser, it is cooled and changes from a gas to a refrigerant in the form of a liquid. At this time it is necessary that it changes into a liquid at the exit of the condenser. If cooling with the condenser is insufficient at this time, there will be a residue of refrigerant in a gas state which will decrease the cooling capacity.

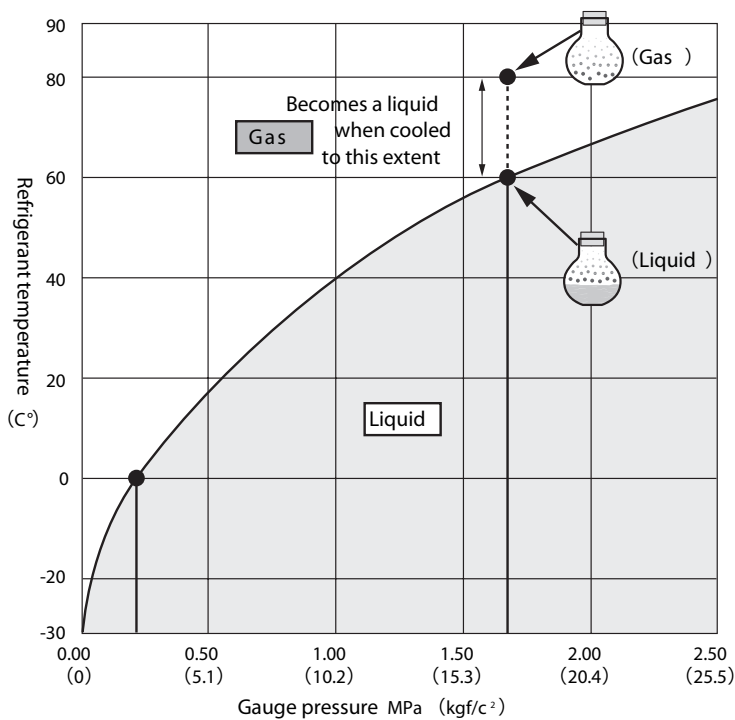
Car Air Conditioner Refrigerant

One major difference between a car air conditioner and other room coolers is the distribution of the refrigerant with rubber hoses to absorb the vibration of the compressor attached to the car engine. As a result, there is use of HFC-134a to prevent deterioration of the rubber. There are the following additional reasons for use of HFC-134a:

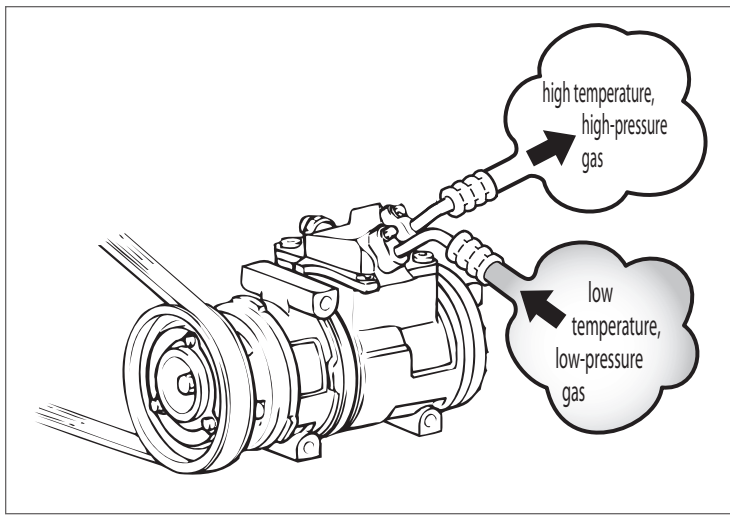
- It does not harm the ozone layer in terms of environmental protection.
- There is a large volume of latent heat of evaporation, making it easier to achieve liquefaction.
- There is no danger of burning or explosion.
- It is non-poisonous, non-corrosive and not harmful to food products or clothing.
- It is easily obtainable.

Features of HFC-134a	
Chemical formula	CH ₂ FCF ₃
Boiling point (1 atm)	-26.07 degrees C
Latent heat of evaporation (0 degrees C)	198.7 kJ/kg

Features of the Refrigerant



The graph shows the characteristics of HFC-134a which is used as a car air conditioner refrigerant. As the curved line shows, if the refrigerant is strongly compressed it remains a liquid up to a considerably high temperature. At low pressure, however, it can evaporate and become a gas at a temperature of 0 degrees Centigrade or -10 degrees Centigrade. For example, this means that, in a state of gasification at 0 degrees C the evaporator is also in a state of 0 degrees C. As a result, the air passing through the evaporator becomes cooler. If the pressure is lowered to a state where it gasifies at -5 degrees C, the evaporator is also maintained at 5 degrees C. This causes the so-called frost state, resulting in poor air circulation and no cooling. Next, the gasified refrigerant must be turned into a liquid. However, considering the environment in mid-summer for a condenser in a car, it is impossible to maintain this at a low temperature of 40 degrees C. If we now consider it possible at a temperature of about 60 degrees C, the HFC-134a will become a liquid at 60 degrees C under conditions of about 1.7 MPa (approximately 17 kgf/cm²G) or higher. Likewise, if the refrigerant in a gas state is compressed up to 1.7 MPa (role of compressor), the temperature of that gas will rise to about 80 degrees C. In other words, the temperature of the gas at the entrance to the condenser becomes about 80 degrees C. If it is cooled about 20 degrees C, it will become a liquid refrigerant with a temperature of about 60 degrees C at the exit of the condenser, as is shown by the curved line.



The Role of the Compressor

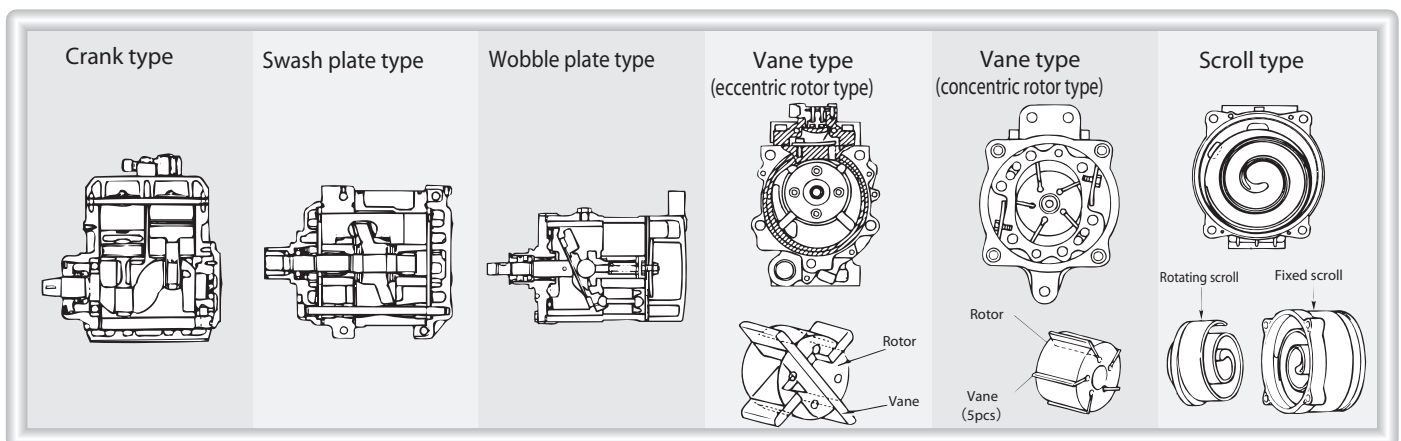
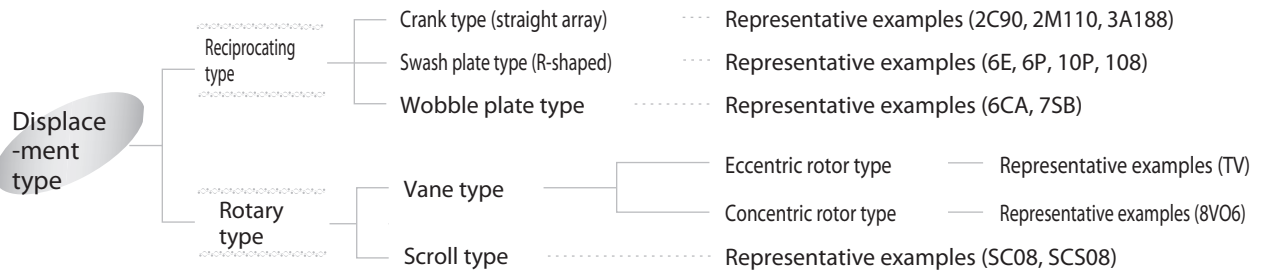
The car air-conditioning compressor is driven by the engine via a belt and magnetic clutch. The liquid refrigerant in the evaporator removes heat inside the car, and changes to low-temperature, low-pressure refrigerant gas. This refrigerant gas is absorbed and compressed by the compressor, and changed to high-temperature, high-pressure gas. This gas is then sent to the condenser.

Types of Compressors

Compressors are classified into displacement type and turbo type (gas dynamics type). All compressors used for car air-conditioning systems are the displacement type. The compressors can be classified according to the compression method and structure as follows;

Although the swash plate type is mainstream, the use of vane-type and scroll-type has been increased in response to market needs for smaller, quieter units.

Time Period	1960	1970	1980	1990	2000
Market Needs	• Cooling capacity • Lighter versions • Compact versions with lower noise • Low motive force and superior comfort				
Compresses Responding To Needs	• Crank type • Swash plate type • Vane type • Scroll type				

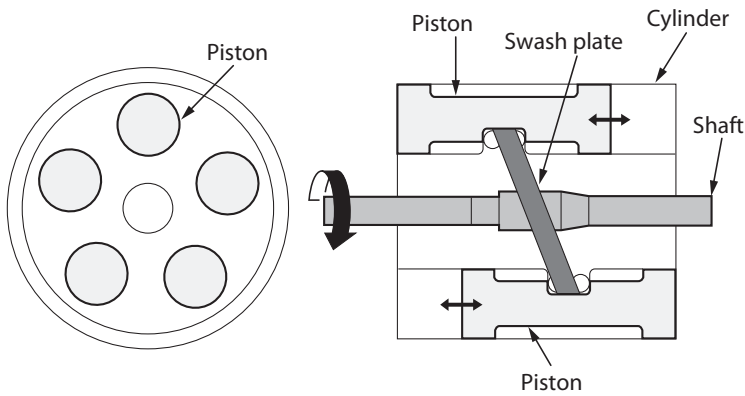
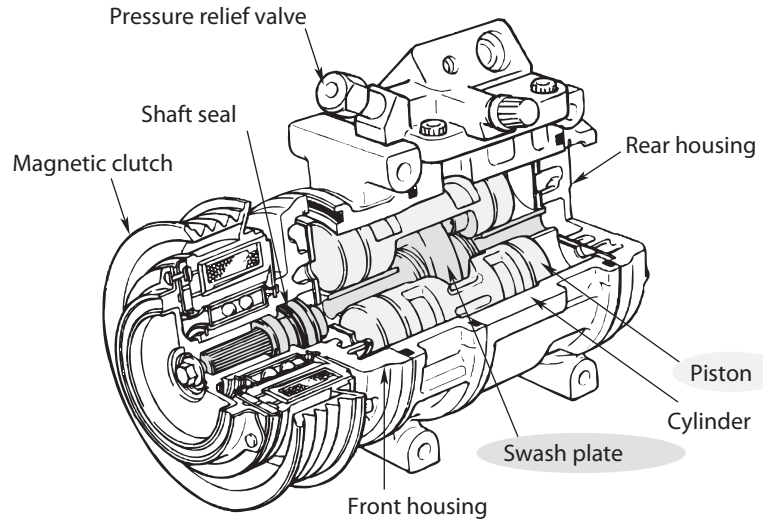


Structure and Operation of Swash Plate Compressor

The DENSO Compressor includes 10 varieties classified according to differences in model and capacity. The following is a description of the swash plate type compressor and scroll-type compressor which are now being produced as the mainstream of production.

■ STRUCTURE

One feature of the swash plate compressor is how the swash plate is fixed at a slant to the shaft. Five pairs of pistons (10 cylinders) are set on the swash plate. When the shaft rotates, the swash plate causes the pistons to carry out reciprocal motion in the same direction as the shaft.

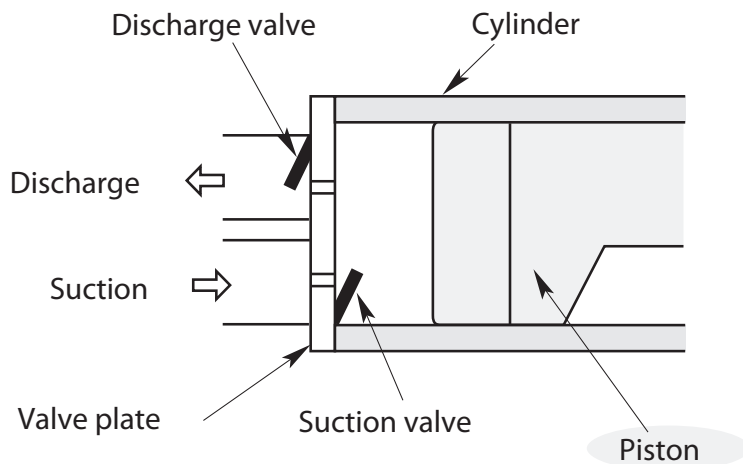


Five pairs of pistons are put inside the cylinder. When one side is moved in the compression process, the other side is moved in the suction process. As a result, when the shaft rotates one time, 10 cylinders carry out suction and compression. This smooths out torque fluctuation and discharge pressure to reduce noise.

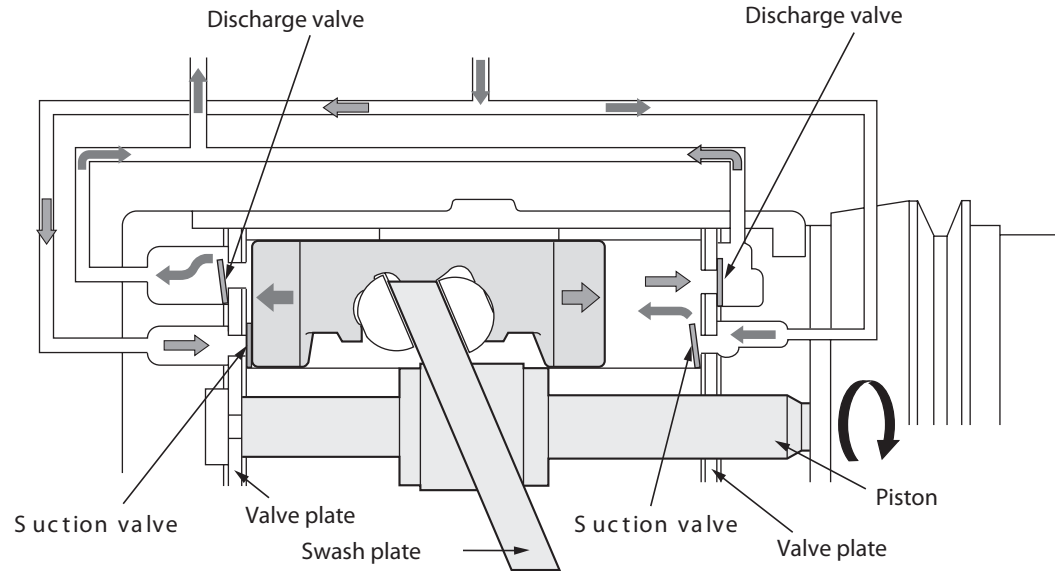
Piston array (10 cylinders)

Swash plate principle

The valve plates on both ends of the cylinder include suction holes and discharge holes. Attached to these are a suction valve and discharge valve. The compressor interior is lubricated by the compressor oil contained in the refrigerant gas and the swash plate splashing oil. On some types (large displacement type and special type for freezers), an oil pump is used to force-feed the compressor oil to the system.



Note: Both valves are closed when the compressor is stopped.

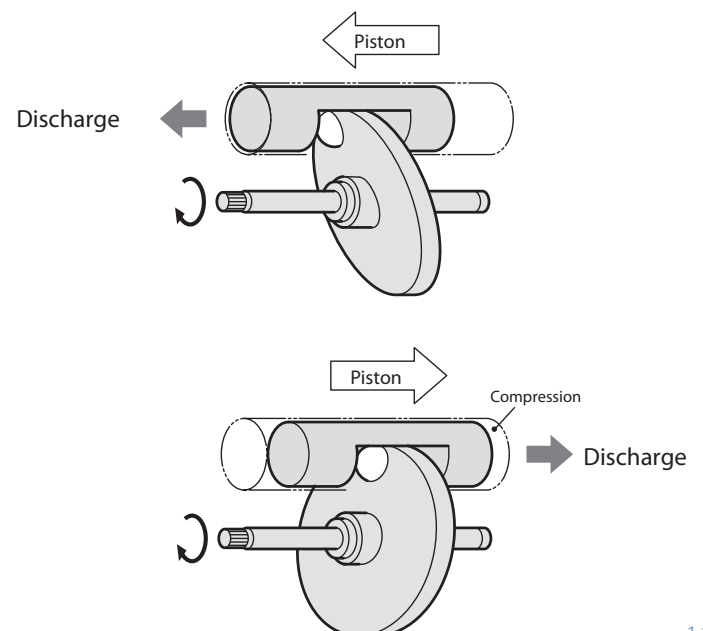


■ Suction Stroke

The rotation of the swash plate causes the piston to move away from the valve plate so that the cylinder internal volume increases and the pressure inside the cylinder becomes lower than the low pressure side of the refrigerant cycle. This opens the suction valve so that the refrigerant gas can enter the cylinder. In this case, the discharge valve is pressed against the valve plate due to the pressure on the high pressure side. The discharge holes on the valve plate are closed so that there is no reverse flow from the high pressure side to the inside of the cylinder.

■ Compression Stroke

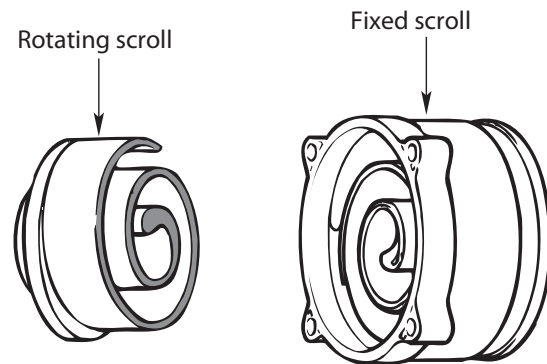
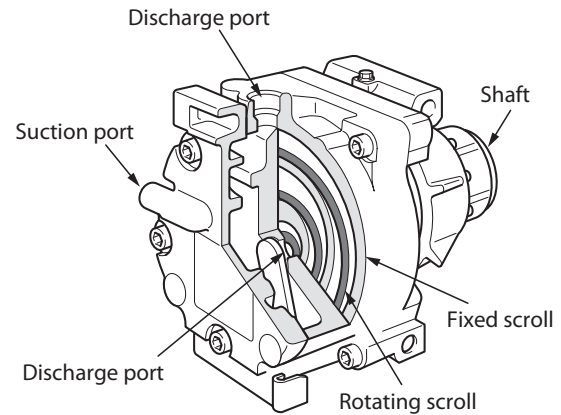
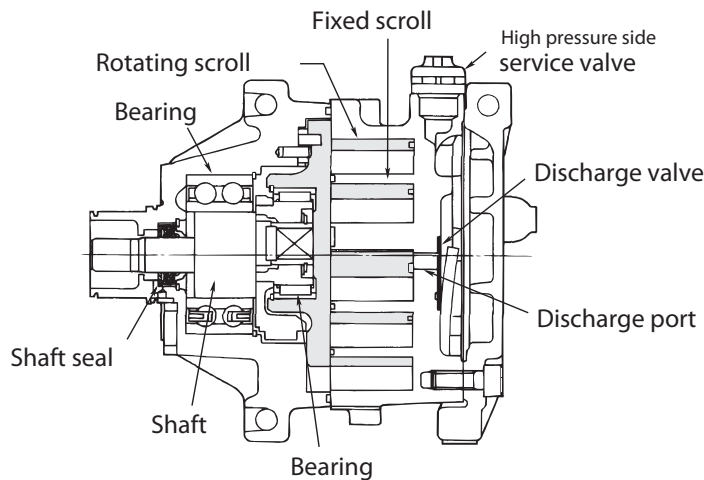
The rotation of the swash plate causes the piston to move toward the valve plate so that the cylinder internal volume decreases and the pressure inside the cylinder becomes higher than the high pressure side of the refrigerant cycle. As a result, the discharge valve opens and the high-temperature, high-pressure refrigerant gas is sent to the condenser. At this time, the suction valve is pressed against the valve plate due to the pressure inside the cylinder. This closes the suction holes on the valve plate so that the refrigerant gas does not flow back to the suction side (low pressure side).



Structure and Operation of Scroll-Type Compressor

■ STRUCTURE

The scroll-type compressor is composed of two scrolls: a fixed scroll and a rotating scroll, which together, create a spiral configuration. The fixed scroll forms a single unit with the housing. The rotating scroll carries out circular motion due to the rotation of the shaft (while maintaining the same position). As a result, the volume of space separated by the two scrolls varies, causing suction and compression of the gas refrigerant.



■ OPERATION

■ Suction, Compression

When the volume between the fixed scroll and rotating scroll changes together with the circular motion of the rotating scroll, the refrigerant is sucked in from the suction port and compressed.

■ Discharge

When the refrigerant pressure rises, the discharge valve is pushed open and the refrigerant gas is discharged from the discharge port. In this method, the refrigerant gas is discharged once every shaft rotation.

■ Cautions

❑ The rotating scroll does not rotate

The rotating scroll does not rotate. Instead it moves in an oval path.

❑ The scroll has 1 cylinder (compression every 360 degrees)

Examine the figure again. On the outside of the compression chamber, a new compression chamber starts to form after advancing 360 degrees. In other words, every 360 degrees (i.e., every rotation) a new compression chamber is created and there is one discharge every 360 degrees. This means the scroll is a one-cylinder compressor.

