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Study of Lubrication Mechanism for Horizontal Type Rolling Piston Rotary Compressor

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1. Introduction

In the past decade, rotary compressors were fully enjoying their popularity having widely been utilized as the major key components for air conditioners because of energy efficient advantage and economical merits in comparison to the reciprocating type.

Among those rotary compressors, the vertical type is currently a main stream of their structure; a motor is placed in the upper section of a compressor shell and a pump mechanism is located in the lower section.
However, the configuration of the vertical type rotary compressors is a vertically tall, which was one of the disadvantages when they are built-in the air conditioner where low height in the installed dimensions is requested.

Accordingly, the horizontal type rotaries, in which the motor as well as pump mechanism are horizontally placed, is regarded as more suitable than the vertical type. However, it appears that such a horizontal type rotary compressors need to receive a special consideration to a sufficient lubrication for lubricating the integrated components of the horizontal rotary compressors, specially in the heat pump mode with severe load changes.

In order to meet this requirement, a new oil system to increase and stabilize the oil level in the pump mechanism was developed, having the oil level satisfied, by means of internal pressure differentiation between the two chambers of the rotary compressor.

2. Outline of the New Horizontal Type Rotary Compressor

Figure 1 is a external views covering both types by comparing the new horizontal type rotary compressor, which was used for a heat pump type operation with 750 watts of output with the conventional vertical type rotary compressors.

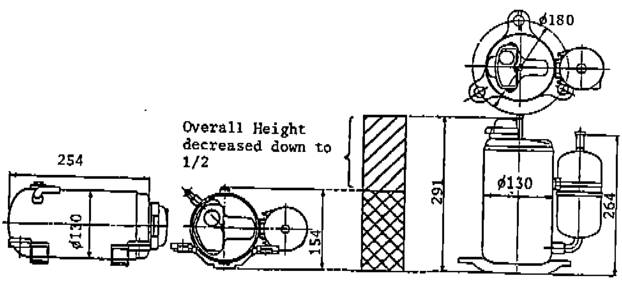


Fig. 1 External View of Rotary Compressor

(a) New Horizontal Type Rotary Compressor
(b) Conventional Vertical Type Rotary Compressor

The horizontal type rotary compressor, including an accumulator as auxiliary equipment, was so designed in a perfectly horizontal configuration, that the overall height was decreased to 154 mm, approximately 1/2 the height of a vertical type rotary compressor with the same output wattage.

3. Structure

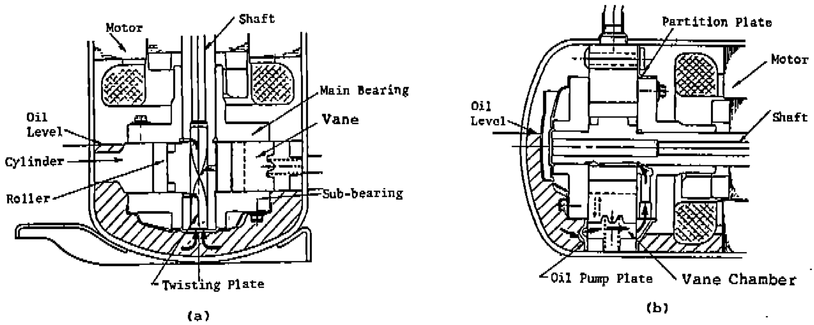
3-1. Pump Mechanism of Vertical Type

The internal pressure inside the shell of a rotary compressor is generally high. This effect was utilized to affect the pressure differentiation in order to supply the oil to the inside of the compression chamber for assuring the lubrication and sealing requirememts.

Additionally, sliding parts such as the shaft and vane would have to be provided with a stable oil supply by means of an oil pump for the purpose of lubrication and cooling.

In the case of a heat pump air conditioner, the refrigerant circuit is switched by means of a four-way valve according to the operation mode, either cooling or heating, so that the refrigerant flow is reversed. Moreover, under the heat pump operation, the load and refrigerant circulation in the system vary remarkably. This change causes the unstable level of lubrication oil charged in the rotary compressor and countermeasures must be taken.

Figure 2 shows the sectional views of both a conventional rotary compressor and the new horizontal type rotary compressor.



The arrow indicates the flow direction of oil.

Fig. 2 Pump Mechanism of Rotary Compressor

(a) Oil Supply Mechanism of Vertical Type Compressor
(b) Horizontal Type Oil Supply Mechanism newly developed

In the vertical type rotary compressor, the motor is located at the upper section of the compressor shell. The pump mechanism is located in the lower section and the lubricant pool being at the bottom of the shell. The lubricant is fed through the oil supply hole of the shaft and is supplied to sliding surfaces such as the internal diameter of the cylinder and the roller surface based on pressure differentiation.
That is, stable oil supply can be performed through the pump mechanism equipped in the lubricant pool. Supposing a vertical type rotary compressor is run in the horizontal position, a new lubrication system is definitely required instead of the conventional style lubrication because the distance from the lubricant pool to the shaft is naturally greater.

Therefore, the following three points are taken into consideration when designing a horizontal type rotary compressor for air conditioning application; development of an oil supply pump with high stability, maintaining the oil lubricant level in the pump mechanism as designated, and how to cool the motor.

3-2. Oil Supply Pump Mechanism (of High Stability)

The following three horizontal oil supply pump systems are discussed.

a) Pressure Differentiation System Utilizing the Difference between the Discharge Pressure and the Suction Pressure
b) Gas Carry System Utilizing the Gas Discharged from the Pump Mechanism into the Compressor Shell
c) Vane Pump System Utilizing the Change of Capacity of the Back Chamber of the Vane

(These are shown in Figure 3.) System a) and b) as illustrated would demonstrate unstable examples for heat pump air conditioners in which refrigerant circulation fluctuates.

To overcome those unstable elements during operation of air conditioner under heat pump mode, vane pump system as referred to system c) is unlikely to affect the aforesaid problems by load changes and refrigerant circulation changes.

The vane pump system functions as if the vane is piston, while vane guide being cylinder when vane repeats the reciprocating motion produced by the rotation of the shaft and compress the oil in the back of the vane to pump up the oil into the shaft.

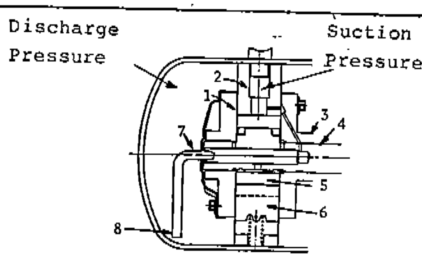
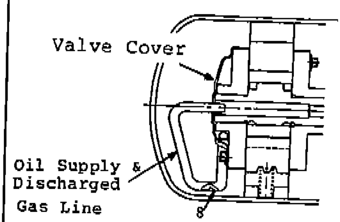
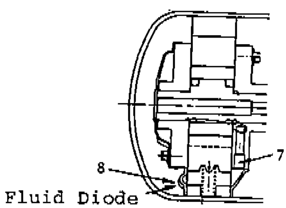
System	Oil Supply Mechanism
a) Differential Pressure	
b) Gas Carry	
c) Vane Pump	

Fig. 3 Features of Representative Oil Supply Mechanisms for Horizontal Type Rotary Compressor

1.Sub-bearing
2.Cylinder
3.Main-Bearing
4.Shaft
5.Roller
6.Vane
7.Oil Supply Line
8.Oil Supply Port

Figure 4 shows the characteristics of respective oil supply system. The vane pump system has been exhibiting a superior characteristics in oil supply volume.

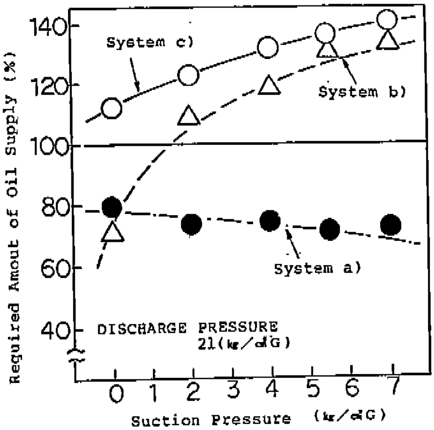


Fig. 4

3-3. Keeping the Lubricant at a certain Level by the Pump Mechanism and the Motor Cooling

During the horizontal rotary compressor is not in running the oil level is low even the same volume of lubricant as that in a comparable vertical type rotary compressor is charged and the greater part of the pump mechanism is exposed in the gas. Moreover, there is a possibility that lubrication is interfered with by a change in the oil level during the condition when a high volume of refrigerant is being circulated.

On the other hand, although the compressor motor employ heat resist and refrigerant resist characteristics, these components must be cooled by means of the refrigerant gas.
In the case of vertical compressors, the motor is placed between the pump mechanism and the discharge pipe, the temperature of the winding of the motor, therefore, is cooled down by means of the flow of gas discharged. The lubricant separated by the rotation of the motor falls by its own weight and returns back to the lubricant pool at the bottom of the shell.

However, when the horizontal type rotary compressors use same flow as that of the vertical type, the oil in chamber B elevate its level due to pressure differrentiation before and after the motor as shown in Figure 5. It is feared that a great amount of oil is discharged to the heat exchanger by the agitating action of the motor rotor. The oil level in chamber A, accordingly, is lowered, which would result in not only interfere with lubrication, but also cause the deterioration of the performance. One method of preventing such an undesirable oil level is to place the compressor on the slant so that chamber B is higer in position than chamber A to avoid the unequal oil level. This method, however, is still not good enough to decrease the height of the compressor as aimed at achieving in the first instance.

Accordingly, in order to stabilize the oil level by utilization of the pump mechanism and to cool the motor, the system as shown in Figure 6 was designed. The shell was separated into two chambers (chamber A for the pump mechanism and chamber B for the motor) with a partition plate. The refrigerant gas compressed by the pump mechanism is fed to chamber B to cool the motor and is returned through the return hole of the shaft to chamber A. This gas flow produces pressure differentiation between chamber A and B, and keeps a higher oil level in chamber A than that as ordinary produce for the oil supply and meantime can cool the motor.

Pressure	Chamber A > Chamber B
Oil Level	Chamber A < Chamber B

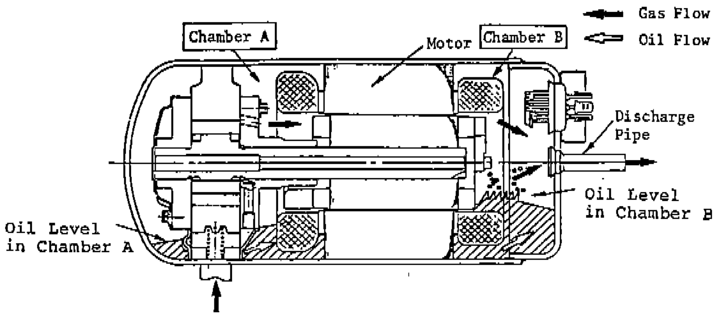


Fig. 5 Structure of the same Gas Line as that of the Vertical Type

Oil is pressed up to the side of the discharge pipe.

Pressure	Chamber A < Chamber B
Oil Level	Chamber A > Chamber B

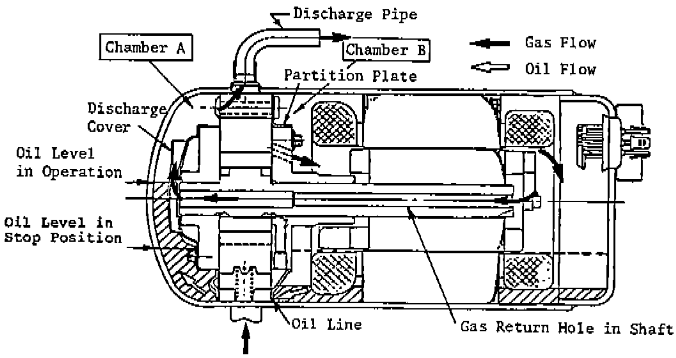


Fig. 6 Gas Line and Oil Level of the New Horizontal Type Rotary Compressor

The gas discharged from the pump mechanism cools the motor and flows out through the discharge pipe.

Figure 7 shows the data how it vary in the oil level of chamber A and B during control of the horizontal type rotary compressor, to which this system was adopted. The oil level in chamber A goes up very sharply immediately after starting and becomes stable approximately 30 seconds later.

Figure 8 shows the oil level obtained during actual operation and the relative data checked during a wide-range of operation including cooling, heating and defrosting. Chamber A always exhibits a higher oil level than that in chamber B and the oil in chanber A is kept at a sufficiently higher level than the suction level of the oil supply pump which limit is a lower limit level.

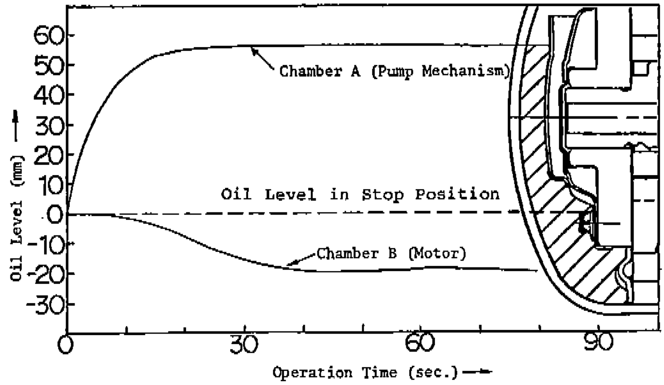
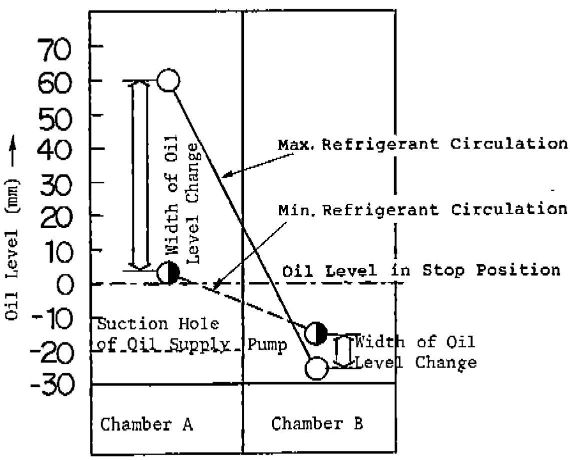


Fig. 7 Change of Oil Level in Control and at Starting



Oil Level in actual Operation

Fig. 8

3-4. Accumulator

The one of great merits in use of the rotary compressor is that the heating of suction gas is low and volume efficiency is better than that of reciprocating compressor because the suction pipe of rotary compressor is directly connected to the pump mechanism.

However, under the conditions where liquid refrigerant in the suction gas is too much during operation or specially at starting at low outdoor temperature, liquid refrigerant is sucked into the pump mechanism so that the lubricant is diluted and inferior lubrication is likely to experience. An accumulator to separate the liquid refrigerant, therefore, is required for a rotary compressor in order to prevent such a phenomenon.

Figure 9 shows the structure of the accumulators as examples for both conventional vertical type rotary compressor and for new horizontal type rotary compressor. The accumulator for the vertical type consists of two cups vertically installed. The screen for dust removal is equipped in the accumulator and the flow-out pipe connected to the compressor is lengthen to a positon near the screen. Liquid refrigerant in flow during the refrigeration cycle is separated from the refrigerant gas and is gathered in the bottom.

However, whenever it needs to decrease the height of a room air conditioner, the accumulator of such vertical configuration is not suitable, but a horizontal type is most preferable as well as the horizontal type rotary compressor. The insides of an alsolutely horizontal accumulator developed for the new horizontal type rotary compressor is segregated into three chambers with separator A and B. The mixture of refrigerant gas and liquid refrigerant flowing from the suction pipe is passed from cut A to the top wall of the central chamber for large volume, liquid refrigerant of a heavy mass is separated and falls, so that only gas will flow to the pump mechanism. Without damage to liquid separation performance, the accumulator and the compressor can be produced as one body and this design will perform space savings in addition to lower height.

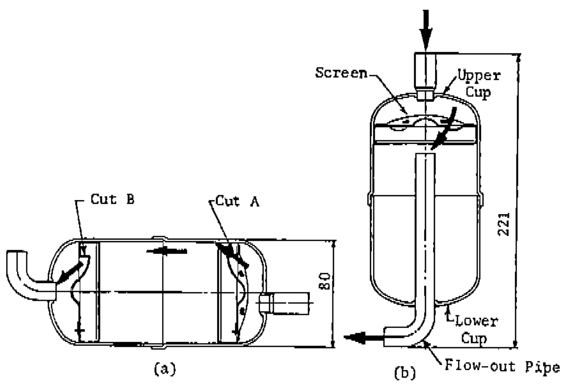


Fig. 9 Structure of Accumulator

(a) New Horizontal Type Accumulator

(b) Conventional Vertical Type Accumulator

4. Conclusion

In summerizing several discussions, the following measures are considered effective;

1) Adoption of the oil supply mechanism by the vane pump system to the horizontal type rotary compressor for room air conditioners.
2) The compressor structure where the compressor chamber was separated into two; the pump mechanism chamber and the motor chamber, and the gas line was located in the shaft. By means of this structure, pressure differentiation could be produced between the chambers and the oil level in the pump mechanism could be always lifted up to the level required for oil supply and its stabilization.
3) By means of the structure above, moreover, the motor could be cooled with the gas flow in the same manner as applied to the vertical type rotary compressors.
4) Modification of accumulator for horizontal arrangements.

Those developments have been proved to be remarkable achievements having a high reliablility in the actual operation of horizontal type rotary compressors.

5. References

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