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Development of a New Mechanism for Dual Rotary Compressor

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ABSTRACT

After the Great East Japan Earthquake, it is an urgent necessity for us to cut down the vain use of the power. Beforehand we have proposed the reduction of the power consumption used in “actual” air-conditioner operating load is low, and we have produced Dual rotary compressor can make only one of two compression units run (in the following, refer as “Dual system”) and provide high efficiency since 2004 and have made still better of it¹). This time we developed another Dual rotary compressor with a new mechanism. To put Dual system in practice, the compression units have one of two vanes pushed into and pulled apart its roller depending on conditions. As compared with the conventional dual compressor has the way of controlling pressure in the cylinder in order to balance pressure of the compression unit inside with that of the case inside and rear of the vane, the new one has the different method of doing so. Being still applied the idea of balance of pressure, a new mechanism controls pressure at the rear of the vane. We expanded it into 1-suction piping twin rotary compressor is our unique production and developed the new dual compressor. This new compressor bettered by 3% of Annual Performance Factor (APF) efficiency in Japan than that of our conventional model and the air-conditioner with it can cool and heat operation by minimum 45W, and it has been produced since Oct. 2011. And it will be expected to load except air-conditioners with itself because it can run until high compression ratio under low capacity operation in comparison to the same size compressor.

1. INTRODUCTION

Reduction of the power consumption to prevent global warming has been conducted for a few past decades in Japan, and lately the urgent matter of power need has been added. In Japan, APF as a guide line index of energy saving for air-conditioners has been used and well known is standard against air-conditioning load and using time in a year. But recently, residences with high heat insulation increasing in number, the air-conditioners have come to often run in lower load condition except starting point. So, we should consider APF and also the efficiency under lower load as the target of reduction of the power consumption. But in this case, common scroll and rotary compressors intermittently run because of securing reliability, and not only does they make the efficiency worse but the indoor temperature fluctuating. Of course, we can avoid it by using smaller compressors, but we would feel that something of cold or hot is missing for a while after starting. We thought the dual compressor can change freely the number of compression units, or its displacement in answer to using condition and air-conditioning loads would solve their matters. We produced it and have tried to better it.

A few of the subjects are 1)verifying the problems of the conventional dual compressor, 2)developing Dual system applying itself to 1-suction piping twin compressor is our unique production and higher efficiency and to large capacity compressors. We found their solution and developed a new mechanism of Dual rotary compressor. The following presents their contents in comparison to our conventional dual compressor.

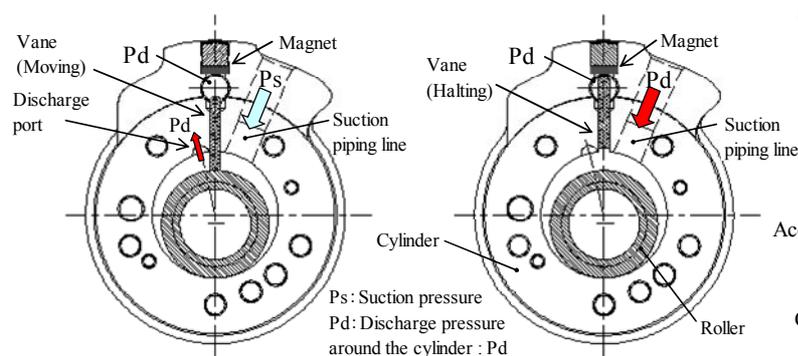
2. DUAL SYSTEM

First of all, we define Dual system in twin rotary compressor as having mechanism to make one of two compression units compress and idle as we like. To realize this it is essential to be able to make the vane of the compression unit push into and pull apart its roller outside freely. When you need large capacity, both vanes are pushed, if not only one is pushed and the other is pulled apart its roller. As the results, the compression unit with the roller pushed realizes to compress and the other does to idle. And we think methods of controlling the vane are three types written the followings. Generally, most of high efficient rotary compressors for air-conditioner have high (discharge) pressure inside the main case in running, and their vanes are always pushed by the pressure difference between in their compression units and in the main case. So this paper deals on the basis of high pressure in the main case.

2.1 Controlling Pressure “in a Cylinder”

This is the method to control pressure “in the cylinder” to make the compression unit idle. When you need to make it idle, you lead high (discharge) pressure gas in there. Doing so takes away pressure difference between in the cylinder and in the case or especially at the rear of the vane opened to case-inside and make pressure balance and also remove the pushing force into its roller, because of high pressure in the case. Although under this condition the cylinder performs to idle in theory, inertia force caused by its roller revolving makes the vane move and the idling comes to be incomplete according to circumstances. It is necessary the device to keep the vane in order to realize dual system certainly. We recommend the use of a permanent magnet as the device from convenience. To back to compressing, we lead low pressure gas into the cylinder. Although the pushing force caused by its pressure difference is much stronger than absorbing force with the magnet, the vane is pulled apart the magnet, push into the roller and comes to compress.

Figure 1 shows an example of the horizontal cross section of the cylinder on the side of controlling pressure with one suction pipe. As the low pressure gas leading into it, it comes to compress, as the high pressure gas doing so, it comes to idle. Because of just setting the magnet to keep the vane at the rear of it against twin rotaries, it is very easy to produce the compression unit with Dual system. One side of two suction piping lines has the switching valve connected discharge pipe including high pressure gas to switch pressure in the midway. And this dual compressor has obviously two different suction pipes with length against normal twin rotaries. It is necessary to cope with this, because getting worse of its efficiency caused to suction loss of longer one pipe and pressure unbalanced between two pipes is expected. We solved them by modifying each pipe's length and diameter and installing the buffer tank in the midway of the suction pipe and so on, and mass-produced the dual compressor for home air-conditioners for several years²⁾. Figure 2 shows our conventional dual compressor controlling pressure in a cylinder, it has the switching valve in the midway of suction piping line. It has the involved structure around its accumulator, so you suppose that it requests difficult welding or skilled assembling. Also because of the necessity of enlarging the suction pipe and the switching valve to improve loss there, it has awaiting solution for the spread of large capacity compressors.



1). Compression
2). Idling
Figure 1: Controlling pressure in the cylinder on the side of idling

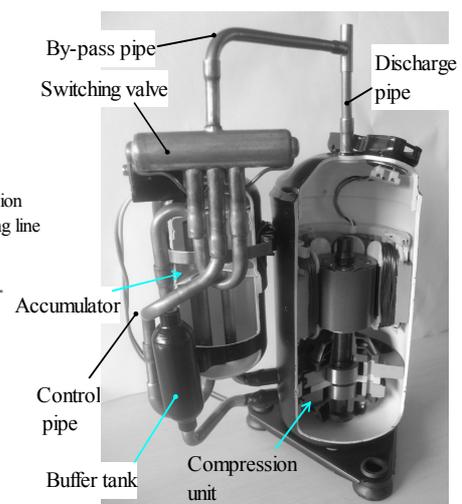
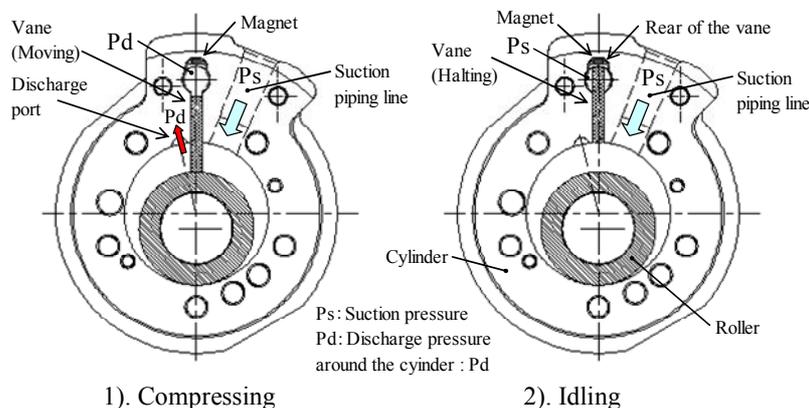


Figure 2: Dual compressor with controlling pressure in a cylinder

2.2 Controlling Pressure “at the Rear of a Vane”

This is the method to control pressure “at the rear of the vane” to make the compression unit idle. You lead “low (suction)” pressure gas in there, when you need to make it idle, because of leading low pressure gas at all times, against above-mentioned the method of controlling pressure in a cylinder. Because of the high pressure inside the case during the operation, it is essential to seal the rear of the vane and also join the added piping to switch pressure in there. Leading to low pressure gas takes away pressure difference between in the cylinder and at the vane’s rear and also the pushing force of it and then comes to idle. When you need large capacity and two cylinder’s operation, you may lead high pressure gas there with the switching valve. Pressure difference between low pressure in the cylinder and high pressure at the vane’s rear makes the vane push into the roller and its compression unit starts to compress. Although there is different to the followings, it may say their concepts are same from the standpoint of the using of pressure balance, there are 1)controlling pressure in a cylinder or at the vane’s rear 2)use of high or low pressure in the idling cylinder.

There is obvious difference to influence their efficiencies, however, the latter doesn’t have to have the switching valve in the midway of suction piping line against the former. That is the reason it can improve the suction loss and it is possible to adopt a smaller switching valve and introduce the Dual system for large capacity compressors. As opposed to this, it is necessary to produce the room at the vane’s rear and cope with the worse of the vane lubrication caused by sealing it against the case inside. We describe the way to solve it later. Figure 3 shows an example of the horizontal cross section of the cylinder with the vane’s rear controlled pressure with an introducing piping.



1). Compressing 2). Idling
Figure 3: Controlling pressure at the rear of the vane

2.3 Without Controlling Pressure

This is the method to catch and keep the vane apart the roller with existing pressure difference in front and rear of the vane. The idea of fixing the vane mechanically, for instance fixing by hooking the vane with boring a hole and so on, have been existed before, but there haven’t been still the reliable way. If we find the structure of action with only using compressor’s rotation speed or pressure difference without the switching valve to control pressure, it will be the better way.

3. EQUIPPING 1-SUCTION PIPING TWIN ROTARY WITH DUAL SYSTEM

We have produced 1-suction piping twin rotary is our unique with high efficiency for air-conditioners for several years. It causes that the thin cylinders with reduced the ratio of the cylinder height to its bore diameter and the crank shaft with thinned lower pin and enlarged eccentricity make the leakage loss and the mechanical loss decrease. The other hand, to prevent the suction loss with the smaller piping lines, we made two pipes get together one and it enlarge from the accumulator into the partition. The one big piping is distributed two ways as Y-shaped in the partition, and then we have maintained the high efficiency of it³⁾. From the energy saving point of view, it is expected to equip Dual system for this compressor. As mentioned above, there are three types to equip it. Although controlling pressure in a cylinder is useful, we thought that there would be necessary to change one suction type with the high efficiency. We began examining the equipment of the controlling pressure at the vane’s rear, although we had to find the new method that was suitable for mass production. Because we could expect that it had less

influence of the suction loss and its compressor with the Dual system didn't have the efficiency decreasing. The points and the examination are described that follow.

3.1 Leading Pressure at the rear of the Vane

3.1.1 Fitting the switching valve up directly

This is the method of the switching valve using high and low pressure "inside the main-case". In the case of the controlling pressure at the vane's rear, the amount of mass flow at the vane's rear is necessary to supply only for pushing and pulling the vane under pressure changing by the vane going back and forth. From this, it may have much less than the needful amount of controlling pressure in a cylinder, and we examined the method of the switching valve using high and low pressure inside the case without pipes. Getting low pressure through the suction hole of the partition and high pressure through the hole bored in the bearing, the valve performs the duty of itself that is leading to high and low pressure at the vane's rear. There is outside its driving power.

We could establish the compact merit as the results, but the following problems were proved typically. 1). Moving the valve directly needs relatively large power consumption. 2). About fitting the valve up, it is necessary to high precision in the assembled condition, or to high price. 3) When welding or painting, it is necessary to careful thought.

3.1.2 Fitting the switching valve with pipes up

This is the method of the switching valve using high and low pressure "outside the case" with piping. Getting low pressure through the suction piping and high pressure through the discharge piping, this is the same method as that of the controlling pressure in a cylinder before. We can select either of the upper or lower side of the idling compression unit as supplying pressures at the vane's rear. From the reliability of the bearings of view, we selected the upper compression unit on the main bearing side for the regular compression one and the lower for the idling one. And also the part of supplying pressure is either of the partition side or sub-bearing side. Here, the difference of the above two, doing so from the partition side or sub-bearing side, comes to influence relational location between the supplying part and the suction piping. The former is in the horizontal (rotational) direction and the latter is in the vertical (upper and lower) direction, because our 1-suction piping twin rotary has a suction piping through the partition. We decided the way of supplying pressure through the sub-bearing, or the location in the vertical direction, and begun to examine it, in consideration of the actual results of welding in the 2-suction piping rotary, ease of the diversion of the automatic welding facilities and cost restrictions.

The performances of switching about two ways, using pressure inside or outside the case, as pushing and pulling the vane apart the roller don't have difference, because of only depending on the pressure difference between the vane's rear and the cylinder inside in the idling compression unit if under same condition. As the results, although the latter size is worse than the former one, assembling and welding are easier and its cost is lower, we judged that the method of using pressure outside the case as switching of pushing and pulling the vane was suitable for mass-production. The following describes the dual compressor fitted the switching valve with piping up.

Figure 4 shows the vertical cross section of the compression unit that is disclosed different faces in order to understand easily. The vane's rear room is sealed with the partition connected the pressure piping and the vane cover. Figure 5 shows the new mechanism circuit diagram of Dual system imagined. During two compression units running, the rear room is led high pressure, during one compression unit running and the other idling, it is done low pressure, and their changes are used by the switching valve according to air-conditioning load. Here, the point of wide difference from our conventional dual compressor controlling pressure in a cylinder is that the piping and valve to switch pressure aren't in flow line in the refrigeration cycle. In there, the flow generates only when pressure difference appears by switching, during the regular running the flow doesn't appear.

3.2 Parts of Keeping Vane

During one of two compression units idling, it is desirable that you should hold the vane not to move with inertia forth caused by the roller rotating. We haven't found easier way to do so with permanent magnet ever. In the case of the controlling pressure at the rear of the vane, after the valve is switched from two compression units running to one of them idling, immediately the pressure in the rear room comes to low pressure and that in the cylinder comes to action pressure. And the pressure difference between in the rear room and in the cylinder comes to pull the vane apart the roller so that the magnet is not desired catching the vane but holding it. In this method, it isn't essential to the force of pulling the vane toward the magnet, and the magnet can be smaller.

As the results of switching and reliability test, we could miniaturize the volume of this magnet by 32% (68% reducing) comparison to that of our conventional dual compressor with controlling pressure in a cylinder.

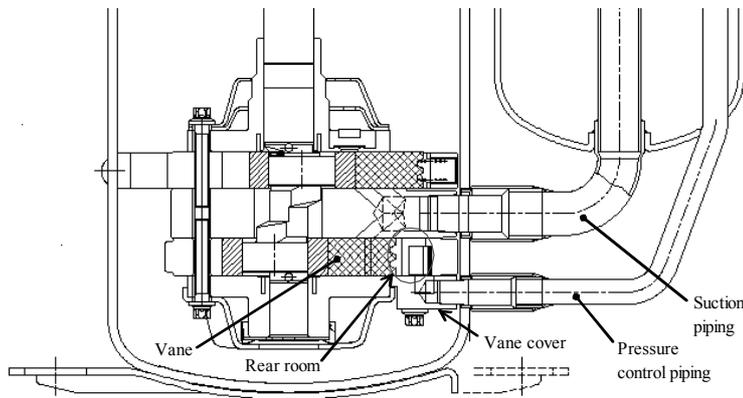


Figure 4: Vertical cross section of the compression unit

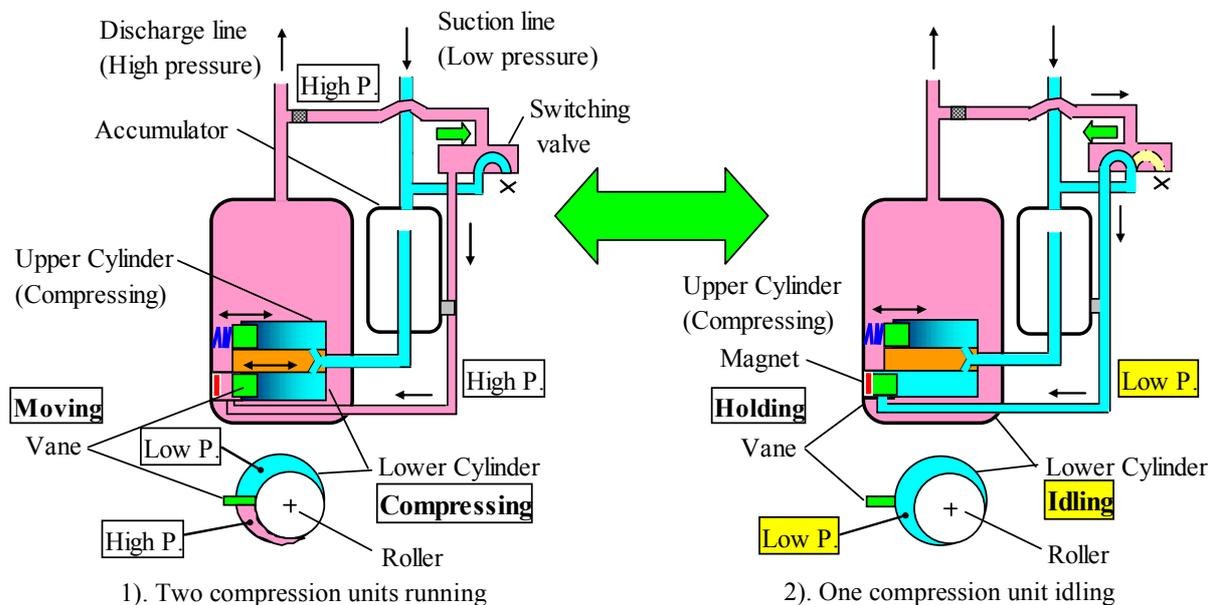


Figure 5: A new mechanism circuit diagram of Dual system

3.3 Lubrication of the Vane

The vane needs to have proper lubrication not to wear or adhere at own moving place. In the case of rotary compressors and our dual one have high pressure inside the case, because the rears of their vanes are opened case inside, they usually get oil for vane groove by soaking itself in oil or with scattering oil clinging and can keep proper lubrication. In this point, there is an important problem to keep reliability about this method with the vane isolated from oil, which is how to lead oil to there during two compression units running but keep the rear room seal during one of them idling. There when the compression unit compresses it needs to supply oil, but it idles it needs to seal around itself. We made moderate groove leading to the vane moving place at the partition surface and also made the vane side fit up with vertical groove against its moving direction. And we confirmed this structure that it makes sure of high efficiency and high reliability. Figure 6 shows relation between location of the vane side groove and that of the partition groove.

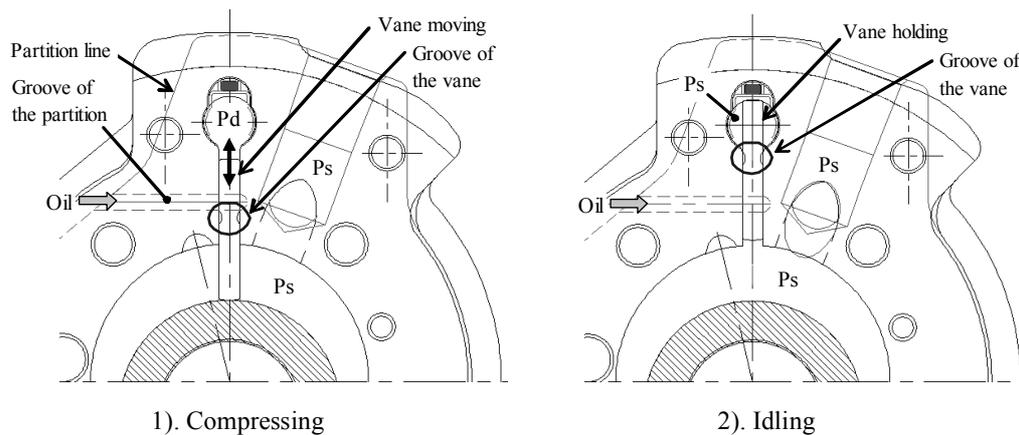


Figure 6: Location of the grooves of partition and vane

4. A NEW DUAL ROTARY COMPRESSOR

Figure 7 shows a new dual rotary compressor with controlling pressure at a rear of the vane which is for air-conditioners with cooling capacities of 2.8 to 4.0kW. Because it is the twin rotary with 1-suction piping separated in the partition inside the compressor, it shapes compact and may look like the twin rotaries in semblance. Figure 8 shows efficiency of the new dual compressor and that of our conventional dual one in Annual Performance Factor in Japan. The new one performed an efficiency improvement of 3 % with reduction of suction piping loss and dimension changed that had 1-suction piping twin rotary. And figure 8 also shows efficiency ratio of the new air-conditioner installed this Dual compressor comparison to conventional one and it has greatly enhancement. This time other composition parts of this air-conditioner were tried to improve and figure 9 shows each contribution ratio of its enhancement, and the Dual compressor has the highest contribution there although it didn't need high expenses. You can appreciate how important the enhancement of the compressor efficiency is. Table 1 shows each specification of compressors.

And as the outstanding points of the Dual compressor, the air-conditioner can perform cooling and heating by minimum power consumption of 45W which is as low as that of an electric fan (set to strong wind mode) or a light ball. From this it has continuously running with extremely small consumption power, when air-conditioning load comes to much lower, although the normal twin rotary and scroll compressor have intermittent running. This continuously running proves comfortable room without fluctuating indoor temperature. This Dual compressor has its rotation speed from 8 rps at one compression running to 130 rps at two compression running and the variability of capacity reaches 33 times for min. to max.. We confirmed its reliability by putting various environmental tests into practice that include two compression running, one compression running, switching and so on.

5. CONCLUSIONS

We have proposed to decrease the power consumption of air-conditioners under actual using conditions and examined a new mechanism for dual rotary compressor that can make one of two compression units idle (refer as "Dual system") and don't have intermittent running in lower load. This time we obtained the follows.

- We completed a new mechanism Dual system with controlling pressure at the rear of the vane.
- We combined the Dual system with our unique 1-suction piping twin rotary with high efficiency and achieved mass-producing.
- This new dual compressor performed its capacity range (min. – max.) by 33 times and efficiency enhancement by 3 % against our conventional dual compressor in APF in Japan.
- The air-conditioner with this Dual compressor provides cooling and heating by minimum 45W.

We expect greatly to adopt this new mechanism for large capacity rotary compressors and so on, because new mechanism doesn't have the switching valve in the midway of suction piping line and is able to use compact valve

and smaller piping, or we can restrain the expenses. And also it will be expected to load except air-conditioners with itself because it can run until high compression ratio under low capacity operation in comparison to the same size compressor. We will continue to develop new technology and further contribute to global environment conservation and environmental comfort.

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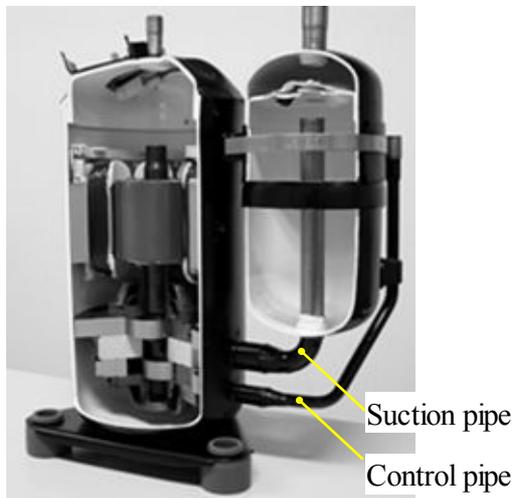


Figure 7: A new dual rotary compressor

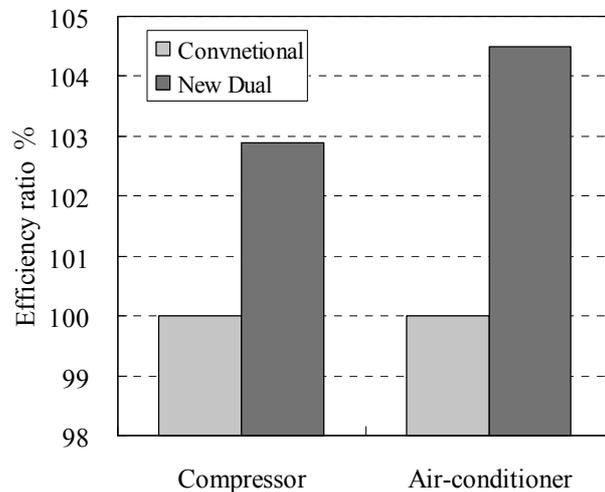


Figure 8: Comparison of APF efficiency

Table 1: Specification of compressors

Shortened title	Conventional	New Dual
Compression type	Dual rotary 2 suction	Dual rotary 1 suction
Dual system type place of controlling pressure	inside a cylinder	at the rear of a vane
Displacement (cm ³)	11.1	12.8
Motor type	Brushless DC motor	
Motor Rotor Magnet	Rare-earth (Nd-Fe-B)	
Weight * (kg)	9.6	9.6
Outside diameter×Height	φ 116×282	φ 116×282

*. except switching valve

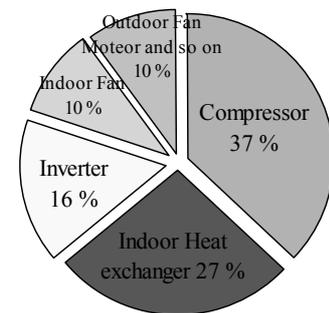


Figure9: Contribution ratio of enhancement in Air-conditioner