

# High-Efficiency Technologies for Small and Medium-Sized Air Conditioning Equipment Using R410A

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## 1.Introduction

The situation faced by refrigerating and air conditioning industry has become increasingly severe, and the greatest issue involved is the global environment. CFC refrigerants, which contain the ozone-depleting substance chlorine, were completely abolished in 1995 in developed countries as a result of the Montreal Protocol signed in 1987. Even HCFC refrigerants were regulated in 1996, and limitations imposed on these substances will lower the level of their use to practically zero by 2020. Consequently, most refrigeration and air conditioning equipment has been transitioning to HFC refrigerants, which contain no chlorine. However, to reduce greenhouse gas emissions in response to the 3<sup>rd</sup> Session of the Conference of the Parties to the United Nations Framework Convention on Climate Change (COP3) held in Kyoto, the changeover to HFC refrigerants in air conditioning equipment in Japan has been accompanied by efforts to improve the energy efficiency of such equipment. This paper presents an overview of the high-efficiency technology that is used in compressors, heat exchangers, and refrigerant circuits, which are key components in small- to medium-sized air conditioning equipment using R410A.

## 2.Technology for Greater Efficiency and Reliability in Compressors

Figure 1 shows the range of types and capacities of typical compressors used in refrigeration and air conditioning equipment.<sup>[1]</sup> Displacement type compressors are generally classified by use into reciprocating, rotary, scroll, and screw-type according to the capacity required. Issues that are involved when compressors are converted to HFC refrigerants can generally be classified under performance (capacity and COP) and reliability.

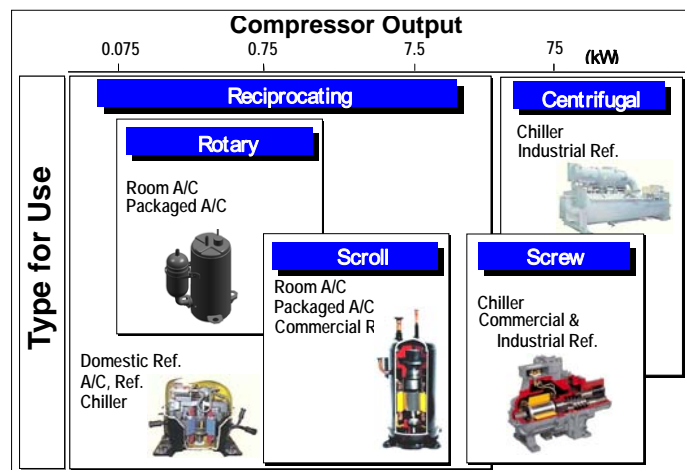


Figure 1. Type for Use of Compressor

Compressor reliability depends largely on the durability of sliding elements. This is affected by the shape of the sliding parts, load, sliding speed, materials, lubricant properties, lubrication conditions, and so on. Improvements were therefore made to mechanisms and materials according to their sliding properties that depend upon the refrigerant and lubricant being used.<sup>[2]</sup>

Meanwhile, in terms of performance, improvements were made in other areas.

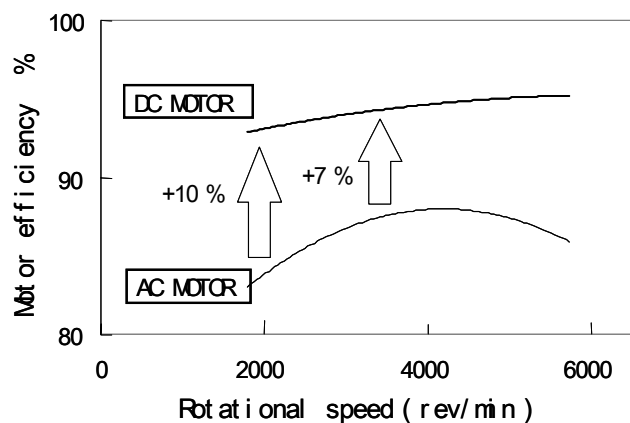


Figure 2. Improvement of Motor Efficiency

Stroke volume was optimized for the physical properties of the refrigerant, and improvements intended to reduce leakage and mechanical loss were made in compressor working parts.

In addition, to enhance the efficiency of scroll compressors, the motor that drives the compressor uses rare earth magnets (neodymium magnets) with high magnetic flux density for the rotor. Furthermore, the motor is a compact, lightweight inverter-driven DC motor with outstanding performance. As shown in Figure 2, use of the DC motor provides greater efficiency regardless of the motor speed.<sup>[3]</sup>

### 3.Heat Exchangers Using R410A

R410A is a high-pressure refrigerant characterized by high specific heat in the liquid phase. Consequently, the relationship between pressure loss and heat transfer performance in the heat transfer tubes must be improved for the use of R410A. As shown in Figure 3, efficiency can also be improved by increasing the amount of subcooling by the condenser.<sup>[4]</sup> Heat exchangers that use R410A require not only improvement of heat transfer performance, but also the development of a refrigerant flow path that enables a greater amount of subcooling.

#### (1) Heat Transfer Tube Performance Improvement

There is less refrigerant pressure loss with R410A than with R22. Consequently, greater increases in the efficiency of the equipment can be expected from improvement of the heat transfer coefficient in the tube than from the effect of pressure loss in the tube.

Table 1 shows the specifications of the tube with helical groove developed for use with R410A. The number of grooves was increased relative to the tube for R22 and the helix angle was also increased to improve the heat transfer coefficient in the tube. The groove height was reduced to bring pressure loss to an appropriate level. The developed heat transfer tube has achieved enhanced efficiency with 1.7% COP in cooling and 2.4% COP in heating.<sup>[4][5]</sup>

#### (2) Fin Performance Improvement

Efforts to improve air-side heat transfer performance have long been made by setting up louvers on the fins in order to raise their heat transfer performance. To use R410A, a still higher performance louver shape was adopted by cutting louvers into both sides of the fins, reducing the influence of the thermal boundary layer on the side from which the air is flowing. The fin pitch was also increased from 1.2 mm to 1.3 mm in order to match the air ventilating resistance. Figure 4 shows the results in terms of the overall heat transfer coefficient. Efficiency is 10% higher than with the conventional technology<sup>[6]</sup>.

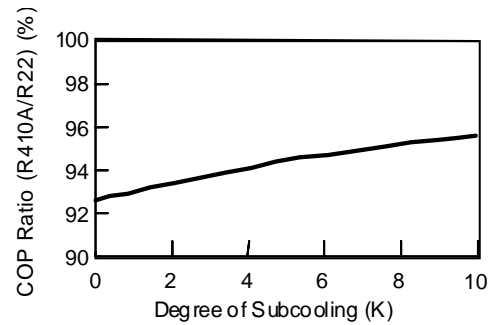


Figure 3. Effect of Subcooling

Table 1 Specification of Groove Tube

	New-Type	Conventional
Height [mm]	0.20	0.23
Number of Groove	60	50
Screw Angle [deg]	35	12

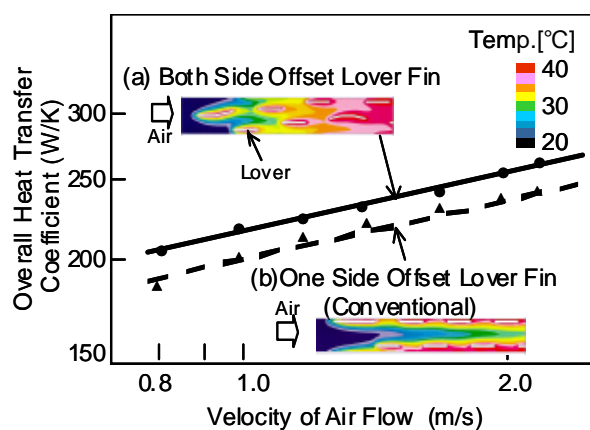
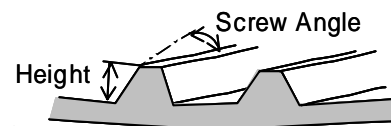


Figure 4. Effect of Both Side Offset Louver Fin

#### 4.High Efficiency Refrigeration Cycle Technology

Technologies to increase refrigeration cycle efficiency include gas injection and subcooling bypass. Two examples of gas injection will be described first.

##### (1) Gas Injection Cycle

The first example of the gas injection cycle is shown in Figure 5. In this cycle, the condensed liquid refrigerant is depressurized to an intermediate pressure and the gas generated by this depressurization is injected into the

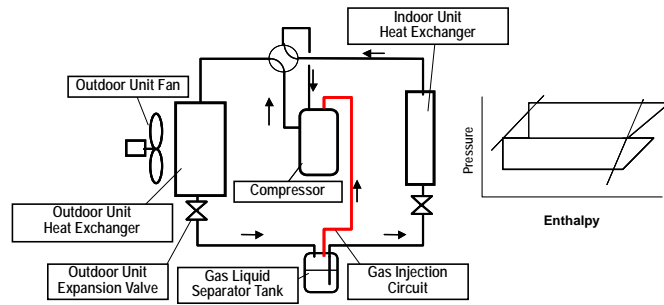


Figure 5. Gas Injection Cycle

compression chamber, thus heightening efficiency by reducing the compressive power and increasing the capacity on the low-pressure side. When injection is used with the compression process in a scroll compressor, the average COP for cooling and heating improves by approximately 3%.<sup>[7]</sup>

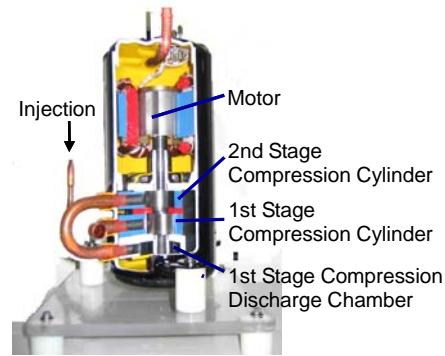


Figure 6. Gas Injection Rotary Compressor

The second example is shown in Figure 6. The figure shows a gas injection rotary compressor developed for room air

conditioner use. It has two compression cylinders of differing volumes, and gas is injected in between them. A heat pump incorporating this compressor showed an improvement of approximately 6% in both cooling and heating COP.<sup>[7]</sup>

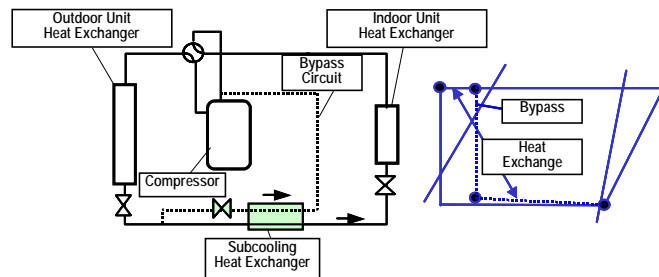


Figure 7. Subcooling Bypass Cycle

##### (2) Subcooling Bypass Cycle

Next, an example of the subcooling bypass cycle is shown in Figure 7. This includes a heat exchanger for subcooling.

In this method, a portion of the liquid refrigerant is depressurized and caused to undergo heat exchange with liquid refrigerant in the main circuit so as to increase the subcooling. It can raise the COP 15% when cooling.

The methods in these examples lower the enthalpy of the liquid refrigerant, thereby increasing the enthalpy difference at the evaporator. The amount of circulating refrigerant that flows into the evaporator is reduced, but the pressure loss on the low-pressure side is also reduced so that the heat of vaporization is higher, thus enabling improvement of the COP.

### (3) COP Improvement Effect

Figure 8 shows the COP improvement effect in a model 140 unit for use in shops (rated cooling capacity of 12.5kW).<sup>[3]</sup> Use of the high-efficiency scroll compressor described above, improvement of the heat exchanger, adoption of a gas injection refrigeration cycle, and conversion to refrigerant R410A realize the high efficiency rating of COP 4.40.

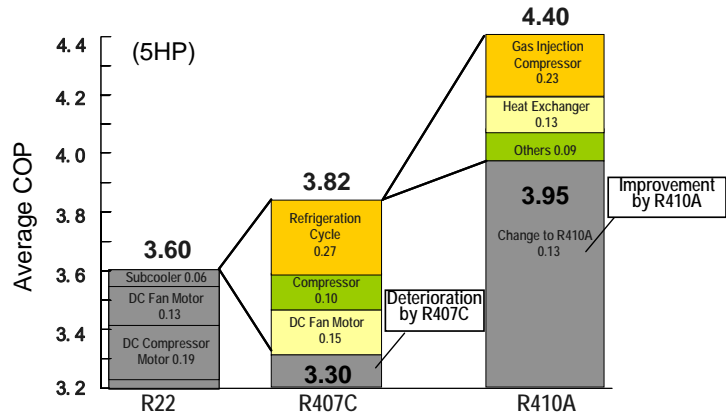


Figure 8. COP Improvement of Model 140 Unit

Figure 9 shows annual CO<sub>2</sub> emission of the model 140 unit using R22 and R410A. It has been cut 46% by using R410A.

### (4) Leak tightness

Due to differences in refrigerant properties, the design pressure is higher when using R410A compared to R22. Therefore, the thickness of each component and part (e.g., flare nut and union) has been changed according to the design pressure and industrial standards. The resulting leak rate of R410A equipment is the same as that of the traditional R22 equipment (an estimated 0.3 grams/year).

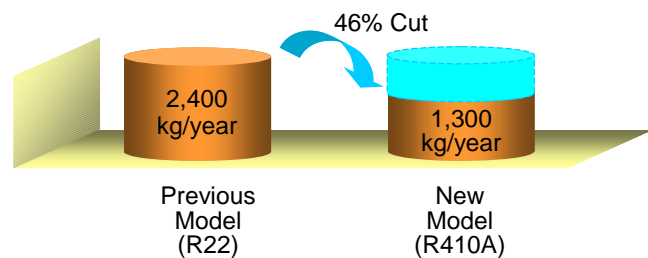


Figure 9. Annual CO<sub>2</sub> Emission

## Conclusion

The preceding has presented an overview of high-efficiency technology that is used in compressors, heat exchangers, and refrigerant circuits, which are key components in small to medium-sized air conditioning equipment. The adoption of HFCs, together with energy-saving technologies, are issues of growing importance, and it will be necessary to continue forging ahead with development of technology in these areas.

## References

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