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1998

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Kohayakawa, T.; Yamamoto, S.; Sawai, K.; Hase, S.; Morimoto, T.; Ashitani, H.; and Ishii, N., "Performance Evaluation of Horizontal Type Scroll Compressor for Alternative Refrigerant (R410A)" (1998). *International Compressor Engineering Conference*. Paper 1278. <https://docs.lib.purdue.edu/icec/1278>

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# PERFORMANCE EVALUATION OF HORIZONTAL TYPE SCROLL COMPRESSOR FOR ALTERNATIVE REFRIGERANT (R410A)

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## ABSTRACT

A program for total abolition of refrigerants using HCFCs has been adopted and selection of alternative refrigerants to HCFCs is an urgent task, thus enhancing an absolute necessity to develop a reliable and high efficiency scroll compressor for alternative refrigerants. We have developed a scroll compressor for alternative refrigerant, R410A, which is a mixed refrigerant of R32 and R125. Matsushita will put the split type air conditioners used R410A into the market in 1998. Under current market conditions in which there is severe competition to be the leader in energy saving technology, there are great expectations for scroll compressor to be more efficient. In particular, it is demanded that the seasonal energy efficiency ratio (SEER) be improved in response to actual operation loads. The feature of R410A is that pressure is about 1.5 times larger than that of R22. In order to improve the SEER in compact horizontal-type scroll compressor, we designed an optimum shape of the scroll wrap in order to reduce leakage of gas from the compression chamber, and optimized the amount of oil supplied to the compression chamber, and so on.

This paper describes the details of development of basic technologies and final performance of the horizontal-type scroll compressor.

## 1. INTRODUCTION

To protect the ozone layer, it has been internationally agreed to abolish HCFC refrigerants, including R22 which is at present in use for small air conditioners, by the year 2020. The introduction of air conditioners which use HFC refrigerants with zero ozone layer depletion coefficient is the main task now facing the air conditioning industry. Domestically, on the other hand, there is a demand for the development of high-efficiency air conditioners in response to the increasing need for energy saving.

The author and his team have studied several HCFC alternatives with the aim of developing a pseudoazeotropic refrigerant, R410A (R32/R125 = 50/50%). Since the operating pressure and refrigerating capacity of R410A are approximately 1.5 times and 1.4 times that of the current R22 refrigerant, respectively, changes in the basic design of the compressor such as suction volume (cylinder volume) and pressure resistance were required in the course of the development. Also, the constituents of the compressor had to be re-examined from the tribological viewpoint, since the refrigerant contains no chlorine atoms which exert a lubricating effect.

The author and his team have been working on the development of a small scroll compressor using R410A, so this paper primarily reports the development results of a basic technique for improving compressor efficiency.

## 2. STRUCTURE AND MAJOR IN SPECIFICATIONS OF THE COMPRESSOR

The structure of the newly developed small horizontal scroll compressor is shown in Fig. 1. The compressor is a modification of the type currently installed in R22 room air conditioners for the use of R410A. In the new compressor, the suction volume, which is set at 13.4 cc/rev. in the current R22 compressor, was adjusted by reducing the height of the scroll vane. The new compressor is high-pressure type with its main shaft supported at both ends: the compression mechanism side end is supported by a slide bearing and other end by a ball bearing.

### Compression mechanism part

The compression mechanism part comprises a stationary scroll, an orbiting scroll, the main shaft and an Oldham ring: the main shaft turns and rotates the orbiting scroll, carrying out the compression motion. The stationary scroll of cast iron is provided with a suction port, a discharge hole and a bypass port, and is also equipped with a bypass valve which is integral with a check valve for preventing backflow of discharged refrigerant. If overcompression occurs, which is a phenomenon characteristic of scroll compressors with a fixed compression ratio, the bypass valve also serves as an auxiliary discharge valve to reduce losses. The orbiting scroll is made of an aluminum alloy of small mass, taking into account the load imposed on the bearing during inverter-driven high-speed operation. The scroll vane is provided with a tip seal at its top for securing sealing in the axial direction of the compression chamber.

### Lubrication route

The new compressor has a positive displacement pump located at one end (the end opposite the compression mechanism part) of the main shaft. The lubrication system in the compressor is as follows: the main shaft turns to operate the pump; lubricating oil in the oil well in the shell is pumped to lubricate the rotary bearing through a channel provided inside the main shaft; then a part of the oil is used for the lubrication of the main shaft bearing; and the rest of the oil is led to the back pressure chamber via the oiling hole in the backside of the orbiting scroll and the restriction mechanism for the lubrication of thrust faces, then led to the compression chamber for sealing.

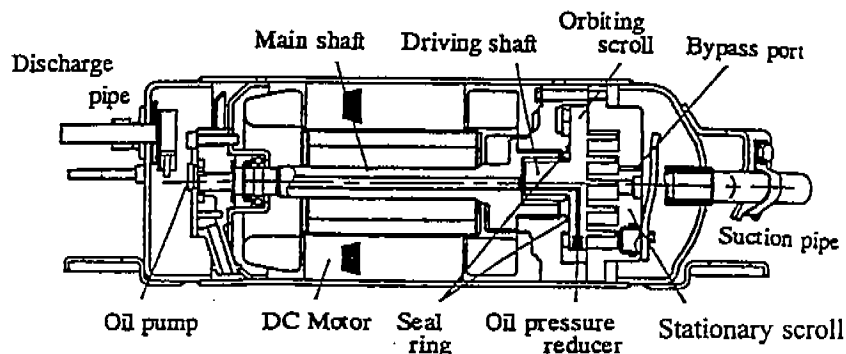


FIG.1 Compressor cross section

## 3. EVALUATION OF COMPRESSOR CHARACTERISTICS

### 3.1 Compressor evaluation condition

Currently, for evaluating the energy-saving performance of small air conditioners, SEER (Seasonal energy efficiency ratio), that is, the energy consumption efficiency of an air conditioner throughout its use for a year is calculated based on the frequency of occurrence of out door air temperatures at representative areas in Japan. The performance of an air conditioner is measured at its rated, medium, and minimum-capacity points representing cooling and heating conditions. The characteristics of the compressor must also be evaluated at these representative points.

In this study, the compressor was evaluated based on the measurement of the evaporation temperature, condensation temperature and operating frequency during the operation of a 2.5 kW version of the new room air conditioner under specified conditions. It should be noted that because the evaluation was for a single compressor, constant values were used for superheating and supercooling conditions.

### 3.2 Definition of compressor efficiency

The evaluation result of the efficiency of a compressor largely depends on the physical properties of the refrigerant used. In this study, the following definition was used to enable the evaluation of a single compressor including not only its mechanical part but its driving parts such as motor and inverter and to eliminate any influence of the physical properties of the refrigerant.

$$\text{Compressor efficiency } \eta_{\text{comp}} (\%) = \text{Theoretical compression power} / \text{Power input},$$

where power input means the inverter input value.

## 4. STUDY IN EFFICIENCY IMPROVEMENT

### 4.1 Selection of stroke volume

In the study of R410A as a substitutive refrigerant, its physical properties necessitated a change in the suction volume of the current compressor designed for R22. Generally, R410A is said to have a capacity 1.4 times that of R22. Table 1 shows compressor suction volume values which will allow R410A to demonstrate a capacity equivalent to R22 under each operating condition, calculated using the theoretical refrigeration cycle. In calculating physical properties, the Thermophysical Properties Table<sup>1)</sup> published by the Japanese Association of Refrigeration was used for R22 and REFPROP ver.4.01<sup>2)</sup> for R410A.

As seen in Table 1, the theoretically optimum stroke volume varies according to operating conditions. Therefore, when selecting the suction volume of a compressor, its influence on compression efficiency must be checked beforehand. In this study, the effect of the theoretically minimum suction volume value 9.0 cc/rev. at the minimum-capacity point in heating was compared with that of the maximum value 9.4 cc/rev. at the rated-capacity point during cooling. Suction volume value was changed only by changing the height of the vane, and operating frequency values were varied so that comparable capacities could be obtained under both conditions. As can be clearly seen in Fig. 2, high compression efficiencies are obtained with a suction volume of 9.0 cc/rev. in all regions. Specifically, a significant increase in efficiency is seen under minimum-capacity conditions of low speed and low load: this is because an increase in operating frequency significantly reduces leaks, resulting in an increase in volumetric efficiency at a higher rate than the operating frequency itself. On the other hand, the degree of improvement in efficiency under rated-capacity heating conditions of comparatively

Table.1 Suction Volume(cc/rev.)

	Rated	Medium	Minimum
Heating	9.1	9.2	9.0
Cooling	9.4	9.3	9.2

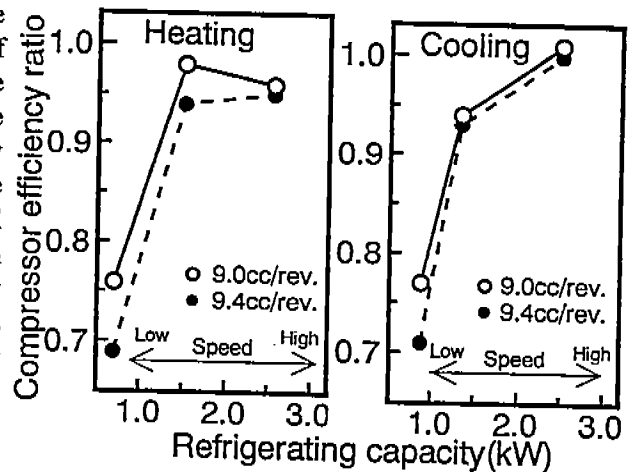


Fig.2 Suction volume vs. Performance

high speed and high load is smaller than that under minimum- capacity conditions where losses due to leaks are comparatively large: this is presumably because thrust losses in the bearing parts increase with increasing volumetric efficiency. These results indicate that the optimum stroke volume of a compressor changes with operating conditions, which must be carefully examined before determining the stroke volume. In this study, a stroke volume value of 9.0 cc/rev. was selected as the base of continuing development work.

#### 4.2 Development of variable volume mechanism

As previously stated, optimum suction volume values of a compressor vary according to operating conditions. A compressor should, therefore, ideally be structured to allow its suction volume to be changed to suit the operating conditions. The author and his team have developed a novel basic technique for achieving this principle using the simple strategy described below.

Fig. 3 shows a comparison of the configuration and indicator diagram of the newly developed compressor with that of the above-mentioned conventional compressor. In the newly developed compressor, as seen in the figure, the configuration of the winding-end part (suction channel) of the vane of the stationary scroll was changed from the conventional circular- arc to a shape in which the vane-end approaches an extended involute curve while maintaining a constant degree of offset from the curve. As the indicator diagram shows, with the new vane-end configuration, the offset space proximate to the extended involute curve partly serves as a compression chamber during high speed operation, resulting in an apparent increase in suction volume. During low speed operation, the offset space serves as the suction channel, as in a conventional compressor. Thus, the newly developed variable volume mechanism is a technique which allows suction volume to be optimally adjusted to operating speed by the use of a specially designed space. Characteristically, the ratio of increase in power input to increase in capacity decreases with increasing operating speed, resulting in a significant improvement in efficiency.

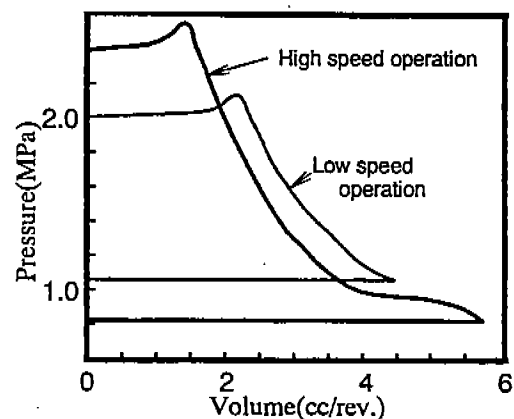
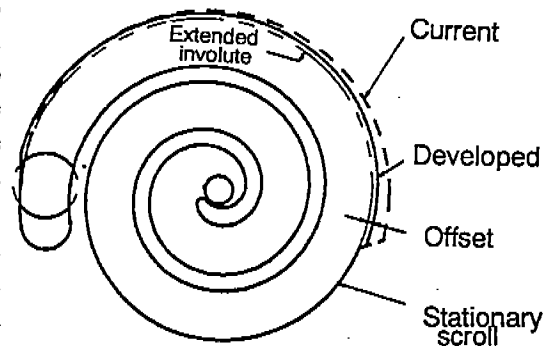


FIG.3 Configuration of variable volume mechanism and Indicator diagram

#### 4.3 Study of the optimization of standard suction volume

The author and his team verified that an improvement in compressor performance during high speed operation, such as under rated-capacity conditions, can be achieved by employing the above-described variable volume mechanism. However, the newly developed technique alone is insufficient for achieving an improvement in performance under low speed operation such as under medium- and minimum-capacity conditions. Hence, the optimization of standard suction volume was studied with the aim of further improving efficiency under all operating conditions including low speed operation.

In a practical study, as shown in Fig. 4, the suction

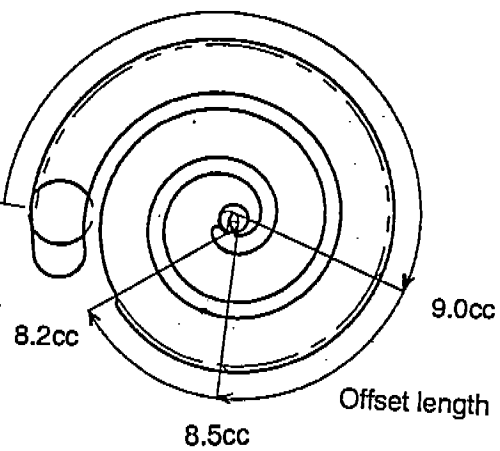


FIG.4 Change of offset length (Standard suction volume)

volume of the compression chamber on one side was changed in three stages (in the range from 8.2 to 9.0 cc/rev. by total volume) by changing the length of the offset part of the winding-end of the vane. The relationships between the changes and the compressor performance on each operating condition were then examined: the results are shown in Fig. 5. It was concluded that 8.5 cc/rev. is the optimum suction volume value for demonstrating high efficiencies under all operating conditions.

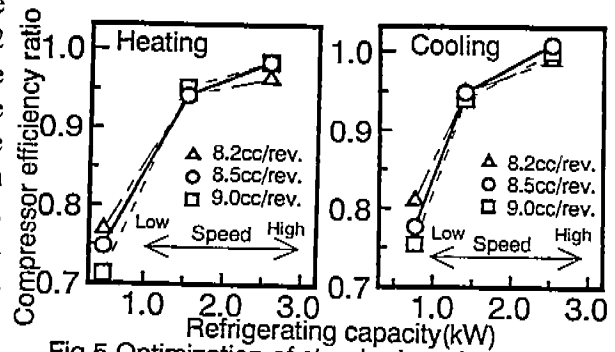


Fig.5 Optimization of standard suction volume

4.4 Characteristics of the variable volume mechanism and optimization study

It has been stated that the newly developed variable volume mechanism is largely dominated by operating speed and the length of the offset (standard suction volume). Since the new mechanism is a technique based on the use of an added space, it is logical to conclude that it would be also dominated by other factors, including the degree of offset (degree of spacing) and the height of the vane (height of the space). (Refer to Table 2.) As these parameters which dominate compressor performance influence each other in a complex manner, it is important to untangle these conditions by the use of simulation.

Table 2 Qualitative characteristics(Performance) of variable volume mechanism

	Degree of offset		Offset length		Vane height		Operation speed	
	Small	Large	Short	Long	Low	High	Low	High
High speed	○	×	○	×	×	○	○	×
Low speed	×	○	×	○	○	×	×	○

In this study, optimized application of the variable volume mechanism to a practical compressor was examined by the use of a new calculation method which takes into account the leaks corresponding to the degree and the length of offset. Fig. 6 shows the compressor performance and the indicator diagram which were calculated using the newly introduced simulation. The results were reasonably consistent with the performance of the actual compressor, demonstrating that the optimization of parameters by simulation is an effective strategy.

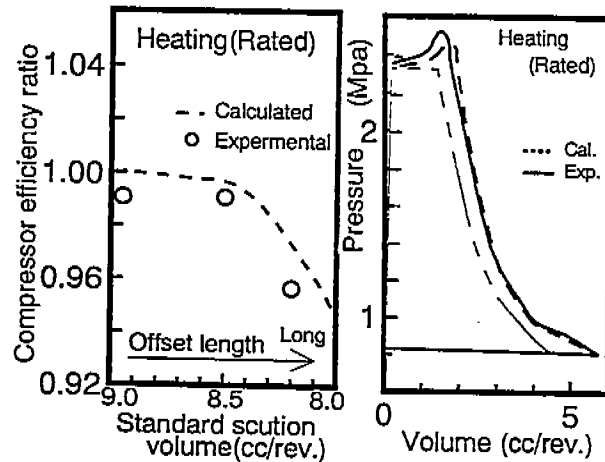


Fig.6 Simulation results and consistency with practical compressor

Fig. 7 shows the results of the application of the simulation of the newly developed compressor, where the compressor efficiencies during high speed and low speed operations were calculated using the length and the degree of offset as parameters. The figure shows that the compressor efficiency increases in close proportion to the length of the offset at low speed operation but decreases, showing an inflexion point (in the vicinity of 8.5 cc/rev. by suction volume conversion), during high speed operation. These results demonstrate that the newly developed compressor is substantially optimized.

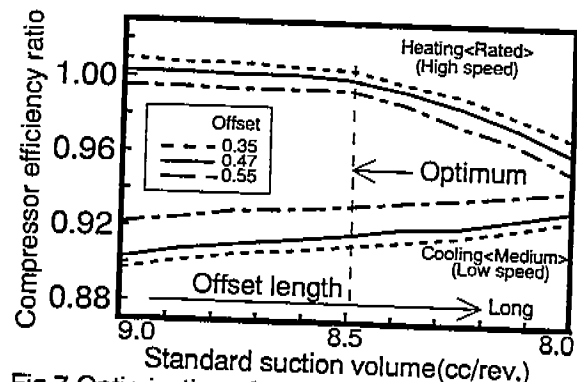


Fig.7 Optimization of variable volume mechanism

## 5 . PERFORMANCE OF THE NEWLY DEVELOPED COMPRESSOR

Fig. 8 shows the performance of the newly developed compressor whose specifications were determined through the abovementioned study, compared with the performance of the development conventional compressor and the current R22 scroll compressor. The figure indicates that the newly developed compressor achieves a performance surpassing the conventional compressor by approximately 5% as well as an efficiency surpassing the current R22 compressor.

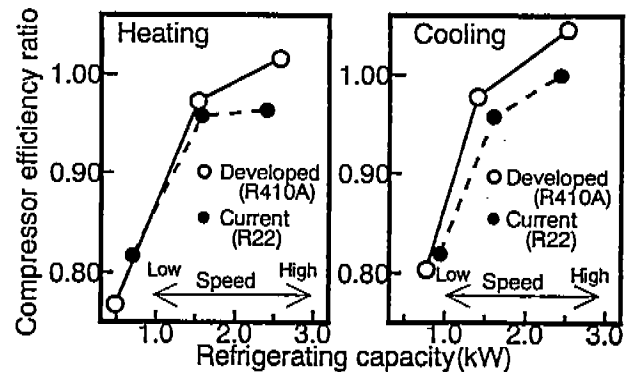


Fig.8 Performance of newly developed compressor

## 6 . CONCLUSION

The author and his team have been working on the development of a small scroll compressor which employs CFC-alternative R410A. This paper describes the studies leading to improvement in its efficiency: we were able to achieve a compressor efficiency surpassing that of the current R22 scroll compressor through the development of a variable volume mechanism, a novel element technique introduced in this paper, the optimization of the sealing structure and the optimization of the flow of lubricating oil into the compression chamber.

## REFERENCES

- (1) Thermophysical Properties of Refrigerants (R22), Japanese Association of Refrigeration, 1975
- (2) National Institute of Standards and Technology : "Thermodynamic Properties of Refrigerants Mixtures Database (REFPROP) Ver.4.01
- (3) S.Yamamoto, et al., "Performance Evaluation of Scroll Compressor for R-410A", The International Symposium on HCFC Alternative Refrigerants '96, p180-183
- (4) S.Hase, et al., "Development of a Compact Horizontal-Type Scroll Compressor for Alternative Refrigerants", Proc. International Compressor Engineering Conference at Purdue, Vol.1, July 1996, p303-309
- (5) T.Morimoto, et al., "Development of a High SEER Scroll Compressor", Proc. International Compressor Engineering Conference at Purdue, Vol.1, July 1996, p317-322