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ABSTRACT

Oil circulation rate is a crucial factor affecting air-conditioning system performance and rotary compressor reliability. This paper illustrates several design concepts to reduce oil circulation rate and discusses their effectiveness. This paper also discusses how to measure the rate in terms of accuracy and repeatability with a statistical significance.

INTRODUCTION

The flow circulating in refrigeration systems is a mixture of refrigerant and lubricating oil. The primary function of lubricating oil is to reduce friction and minimize wear at journal bearing of compressor. Oil pumped out of compressor causes problems both in unit and compressor. The oil concentration in the unit may have significant effects on hydrodynamic and heat transfer performance of condenser and evaporator, because of changes in the thermodynamic and transport properties. So it negatively affects unit efficiency by lowering effectiveness of coil heat transfer. And high oil circulation rates(OCR) may lead to compressor bearing failure in split, multi-evaporator split and heat pump.

Recognizing these important effects of oil in a refrigeration system, the OCR must be kept at minimum level. But the methods to determine OCR with accuracy and repeatability are quite difficult. J.J. Baustian et al. suggested several prospective methods[1]. These are the method utilizing, 1) density measured with the natural frequency of U-tube holding refrigerant/oil mixture, 2) viscosity of mixture. 3) ultrasonic velocity. K.Kutsuna et al. and A. Wada et al. utilized 4) ultraviolet (UV) light absorption behavior of oil[2), 3)]. But they are not in common use yet due to complexity, high cost, calibration problem, and the required limit of liquid line measurement only.

This paper identifies oil discharge mechanism from compressor and how to measure OCR with simplicity, accuracy, and repeatability. Two methods of measuring OCR are suggested. One is suitable for compressor manufacturers which measures percentage(%) of oil in the oil-refrigerant mixture flows in calorimeter, named conveniently Weight Measurement

Method(WMM). The other, Oil Separating Method(OSM), is more suitable for unit manufacturers. Descriptions of experimental procedures and results from laboratory measurements are presented and the correlation between two methods is also discussed. This paper also illustrates several design concepts to reduce OCR and discusses their effectiveness based on oil discharge mechanism.

OiI DISCHARGE MECHANISM

There are three kinds of approaches to reduce OCR in rotary compressor. One of the approaches is to reduce oil concentration itself in the mixture of refrigerant gas and oil. Another approach is to change the distribution density of oil droplet size. And the other is to reduce the gas velocity.

The control of oil droplet size as well as gas velocity provides clues in reducing OCR. Flow resistance on the small oil droplet is due to viscous force, because the Reynolds number is very small[4]. In this case Stoke's equation may be applied to determine the terminal velocity of a particle of a given diameter. If the gas velocity is greater than the terminal velocity of a given droplet size, then the droplet will move to the top of the compressor shell. Whereas if the gravity force on a given droplet size is greater than viscous force, oil droplets return to the oil sump. Figure 1 illustrates the relation between gas velocity and oil droplet size.

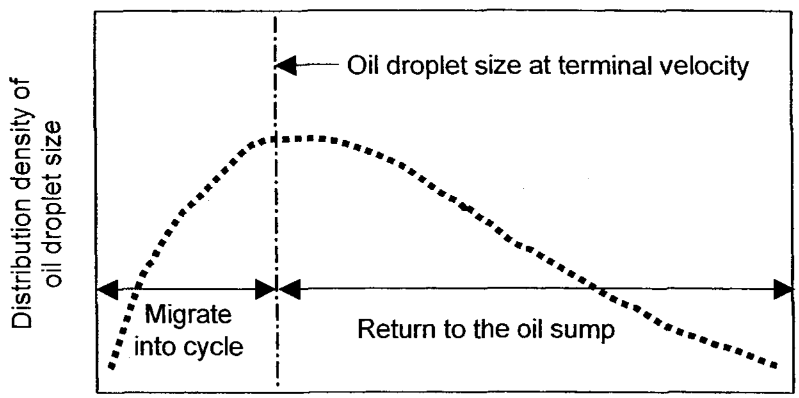

Figure 1 Basic concept of the control of oil droplet size and gas velocity.

Oil discharge mechanism of rotary compressors consists of three factors, which are sources, paths, and collectors[4]. They are illustrated in Figure 2.

The distribution density of oil droplet size as well as oil concentration itself in the mixture of refrigerant gas and oil are mainly determined by the sources of the oil discharge mechanism. Most of paths affect the velocity of oil mists, which flow along discharged gas at a specified velocity under a given operating condition. And, collectors mainly control the size of oil droplets that determines its terminal velocity.

Source(ⓢ)

: Oil level, Oil feeding into pump, Vane/vane spring activity, Gas exhausted downward through muffler clearance, Windage by rotor, Oil forming, Oil in the returned gas.

Path(ⓟ)

: Oil pickup tube, Muffler discharge hole, Bearing oil groove Stator core cut area, Air gap / Rotor vent hole, Discharge tube.

Collector(ⓒ)

: Inner surface of case, Cavity inside upper shell / lower. Stator winding coil, Rotor fan plate.

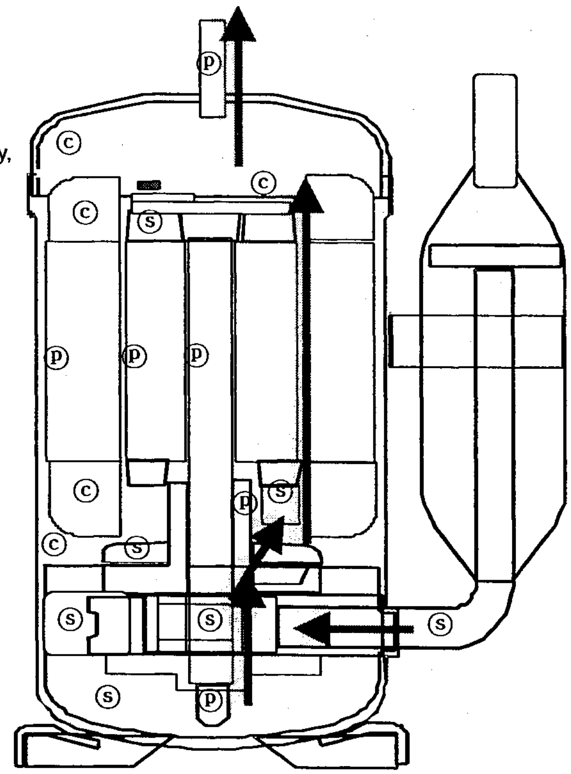

Figure 2 Oil Discharge Mechanism in Rotary Compressor.

INSTRUMENTATION

The Weight Measurement Method(WMM), shown in Figure 3, involves three measurement components; bomb, oil separator and needle valve. The WMM(%) measures the weight-percent of oil in the mixture, and the procedure is very simple to follow. First, the WMM bomb is evacuated and weighed. A sample of the oil-refrigerant mixture must be taken from liquid line. The refrigerant in the bomb is blown off through an oil separator using a needle valve. After that the residual refrigerant inside WMM bomb should be removed by evacuation. Both accuracy and repeatability of actual measurements are found consistent. Table 1 illustrates the results from measurements using the WMM. Repeatability within $\pm$ 0.3% weight-percent oil is possible at 95% confidence level. ASRHE suggests that the allowable error in the measurement is to be $\pm$one weight-percent oil. This method is suitable for use by compressor manufacturers, which are equipped with calorimeter.

Table 1. Repeatability of Weight Measurement Method

Item	Sample #1	Sample #2	Sample #3	Sample #4
Charged oil(g)	1.24	2.31	2.61	4.53
Charged refrigerant(g)	112.80	97.88	141.79	131.35
Residual oil after removing refrigerant (g)	1.27	2.37	2.59	4.74
Actual(%) – WMM(%)	-0.04	-0.06	0.01	-0.15

This method is, however, inadequate for measuring oil movement characteristics under transient condition. Another method is introduced to overcome this shortcoming of measuring OCR. The Oil Separating Method(OSM, cc/min), shown in Figure 3, requires an oil separator in compressor discharge line. While oil which flows along with refrigerant gas is separated by passing through an oil separator and collected into the sight glass, refrigerant gas passes through the oil separator and circulates in the cycle. This method is capable of testing transient oil migration and does not affect the system operation. Figure 4 illustrates the correlation between WMM and OSM for five samples. The OSM is slightly lower than theoretical line shown in Figure 4, for OCR is reduced as oil level in the compressor oil sump becomes lower because of oil trapped in the sight glass.

These two methods are very simple, reliable, easy to install, and can be used not only in the laboratory but also in the refrigeration systems in the field as well.

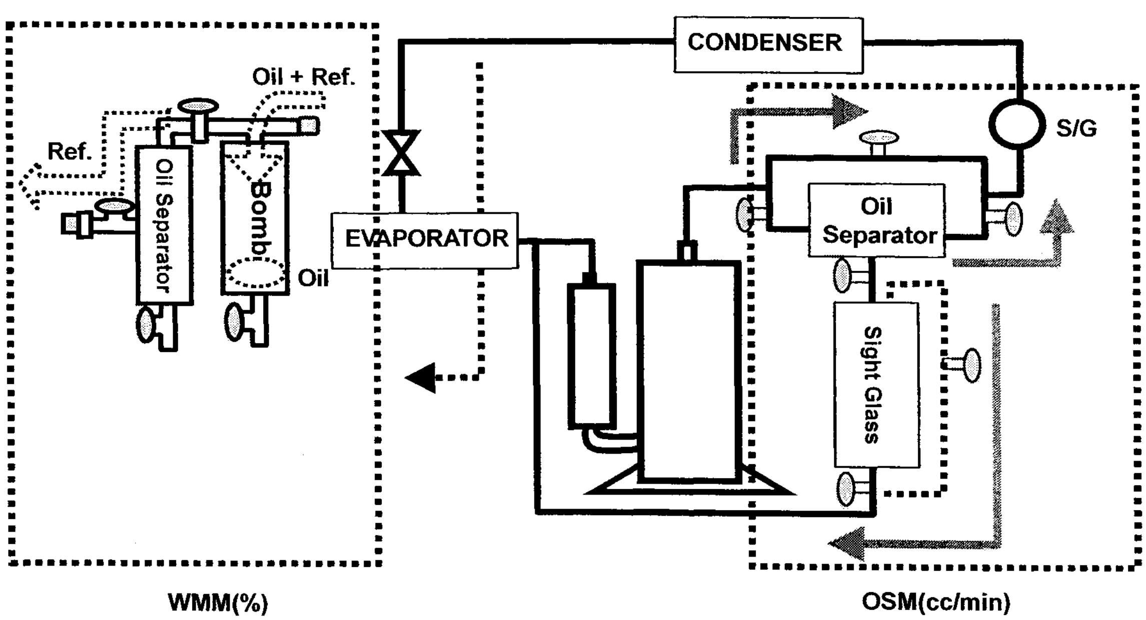

Figure 3 Schematic diagram of the apparatus of WMM(%) and OSM(cc/min)

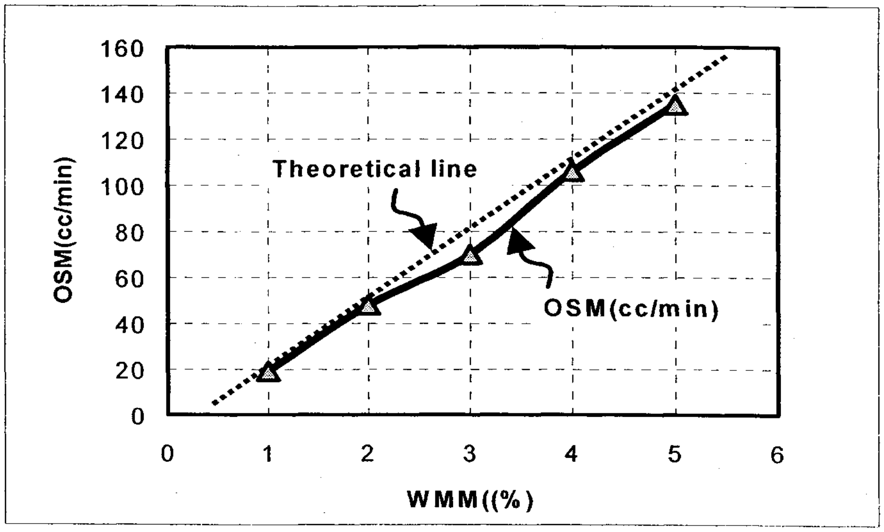

Figure 4. Correlation between WMM(%) and OSM(cc/min)

TEST RESULTS

Improvement in OCR can be obtained by controlling the source, path, and collector of the oil discharge mechanism. Figure 5 illustrates several design items to reduce OCR and their effectiveness. It shows the relative effectiveness in improving OCR of rotary compressor.

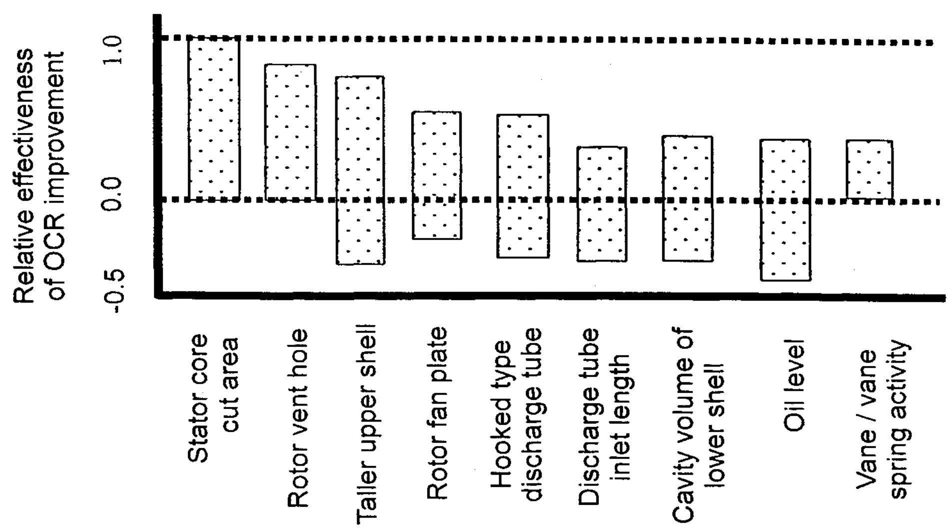

Figure 5. OCR Improvement Items and their effectiveness.

(Y-axis values are relatively indexed)

Stator core cut area and rotor vent hole, which are related with pressure drop across motor, are major factors to reduce OCR as paths are related with gas velocity. Also, how far the discharge tube is inserted into the upper shell is important factor in reducing OCR because the gas velocity varies inside upper shell. Inner surface of shell, stator winding coil and rotor fan plate may be used to increase the oil droplets size as oil collectors. The OCR becomes very sensitive to the oil level above a specified level, especially in a flooding condition when much refrigerant dissolves into oil. The vane/vane spring activity and windage by rotor affect OCR at high rotational speed

CONCLUSION / SUMMARY

In this study, the two measurement methods of oil circulation rate and factors affecting the rate have been discussed. The two methods, WMM and OSM, are recommended to measure OCR for simplicity, reliability, accuracy, low cost and repeatability. Both WMM and OSM work well, and there is strong correlation between two methods.

This paper also identifies theoretical oil discharge mechanism of the rolling piston type rotary compressor and the controlling methods of the oil droplet size and gas velocity. Several design concepts to reduce OCR and their effectiveness based on oil discharge mechanism are suggested.

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