STUDY ON EFFECTIVE OPERATION AND ENERGY-SAVING OF VRF AIR CONDITIONING SYSTEM IN CASE OF OPERATING BY INDOOR-UNIT ZIGZAG ARRANGEMENT

Hiroyuki, Arai, Student, Kogakuin University, Tokyo, Japan;
Tatsuo, Nobe, Professor, Department of Architecture, Kogakuin University, Tokyo, Japan;

Abstract: The authors propose a method for the effective operation of air-conditioning systems; the method is referred to as Indoor-Unit Zigzag-Arrangement Operation. The method helps in increasing the cooling load of an indoor unit operating only half unit. However, aspect of the indoor environment should be uniform. The authors examined the Indoor-Unit Zigzag-Arrangement Operation in an indoor environment by carrying out subjective experiments. As a result, it was found that the proposed operation did not impress the subjects. The authors inspected the energy-saving capability of the operation by considering data collected at Hokkaido, Japan. The authors used data on cooling and heating operations and compared the energy consumption for normal operation with that for high-load operation. The proposed operation was observed to save energy by 31% compared to normal operation.

Key Words: VRF Air-Conditioning System, Energy Saving, Subjective Experiment

1 INTRODUCTION

Recently, VRF air-conditioning systems have come to be extensively used in large buildings. When these systems are used, it is possible to accurately adjust the temperature distribution for the entire building. In addition, since the operation of an indoor air-conditioning unit can be well controlled, a person can use it to obtain a favorable thermal environment indoors. According to the observations made in an actual investigation, there are many types of low-load operations in the case.

2 CONCEPT OF INDOOR-UNIT ZIGZAG-ARRANGEMENT OPERATION

Although all indoor units are usually used as air-conditioners for the purpose of cooling, in this research, half of the indoor units were used as air-conditioners and the other half were used as fans. In addition, the indoor-units were arranged in a zigzag pattern. This gives load twice as much as the normal use and increases the effectiveness of the units. Figures 1 and 2 show the usual operation and zigzag-arrangement operation, respectively.

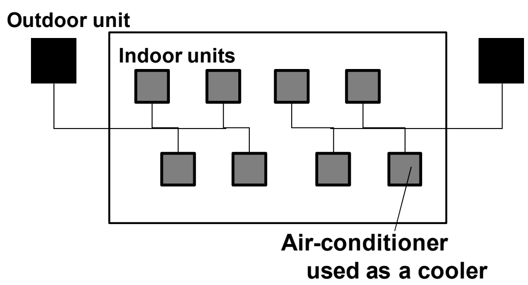


Figure 1: Usual operation

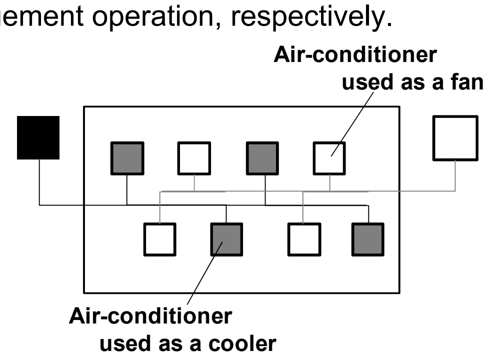


Figure 2: Zigzag-arrangement operation

3 SUBJECTIVE EXPERIMENTS

3.1 Experimental conditions

Subjective experiments were conducted from November 11 to December 6, 2009, in the climatic chamber of Kogakuin University in Japan. The plan of the experimental room and a photograph of the room are shown in Figures 3 and 4, respectively.The indoor unit was set to maintain a temperature of 28 °C with mild flow. The only variable parameter was the flow direction. There were two indoor units in the room with the vents making an angle of 45° relative to the horizontal. This angle was set so as to prevent the air flows from the two systems from colliding. One indoor unit was operated as an air-conditioner and the other was operated as a fan. There were four seats; seat nos. 1 and 2 were located on the side of the air-conditioner, and seat nos. 3 and 4 were located on the side of the fan.

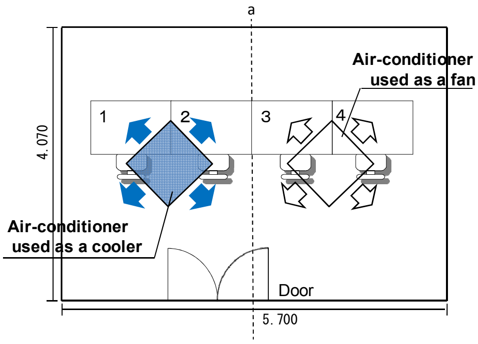


Figure 3: Plan of the experimental room

Figure 4: Photograph of the experimental room

Figure 5 shows photographs of the subjects. The subjects were tested in the climatic chamber. Their metabolism rate was set to 1.2 met, which was equivalent to that for a clerical job. The subjects were given jigsaw puzzles to solve and were paid to ensure that they were motivated. Figure 6 shows a schematic of the experimental procedure. The elapsed time is also indicated. The subjects changed into clothes provided to them, and sat for thirty minutes in the anteroom, where the air temperature was set to 28 °C. This temperature was the same as that of the experimental room.

Subsequently, the subjects moved to the experimental room and the experimental method was explained to them for fifteen minutes after they took their seats. They were given jigsaw puzzles to work on for thirty-five minutes. Afterward, the subjects changed their seats, and they were again given jigsaw puzzles to work on for thirty-five minutes. . This process was repeated until every subject had sat on all the seats (nos. 1 to 4).

This experiment was performed for two cases: in Cases 1 to 4 in Figure 6, the indoor unit's louver was fixed, while in Case 5, the indoor unit's louver was continuously moving.

Throughout the experiments, the subjects provided information about thermal sensation (hereafter referred to as thermal sensation vote (TSV)) and comfort sensation (hereafter referred to as comfort sensation vote (CSV)) at three-minute intervals on desktop computers. Table 1 shows the voting scales.

Figure 5: Photograph of the subjects

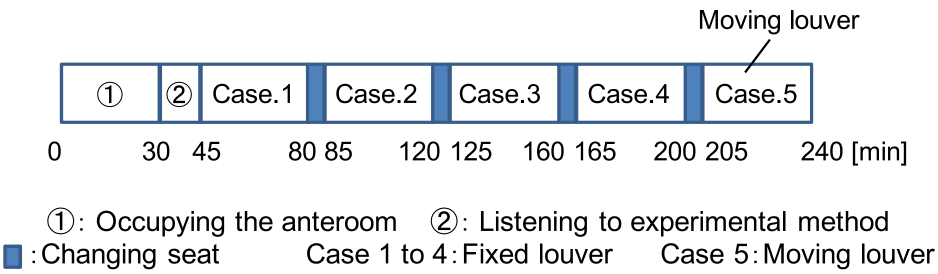


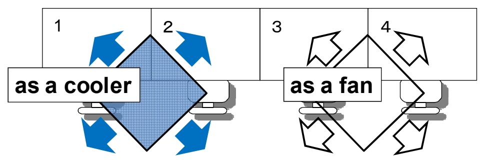
Figure 6: Experimental procedure

Table 1: Voting scales

Declaration items	Voting scales						
Thermal sensation Vote	-3 Cold	-2 Cool	-1 Slightly cool	0 Neutral	1 Slightly warm	2 Warm	3 Hot
Comfort sensation Vote	-3 Very uncomfortable	-2 Uncomfortable	-1 Slightly uncomfortable	0 Neutral	1 Comfortable	2 Comfortable	3 Very comfortable

3.2 Experimental results

Figures 7 and 8 show the resultant frequencies of the TSV and CSV for the case where the louvers were fixed. We compared TSV and CSV among the seats. Box plots gave the range of the TSV and CSV to be about 0 to 1. The median values of the TSV and CSV were also in this range. Thus, the indoor environment was highly uniform for the Indoor-Unit Zigzag-Arrangement Operation.



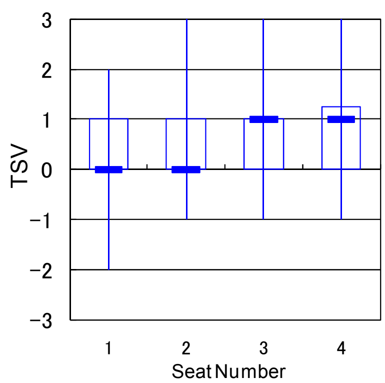


Figure 7: Thermal sensation vote

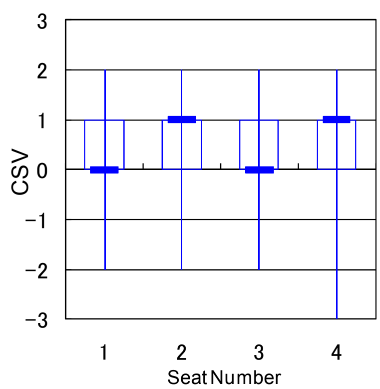


Figure 8: Comfort sensation vote

Figures 9 and 10 show a comparison of resultant frequencies of the TSV and CSV between the case where the louver was fixed and that where the louver was in motion. In the latter case, the subjects felt cooler and more comfortable. Thus, the subjects felt more comfortable when the indoor unit's louver was in motion, which corresponded to the Indoor-Unit Zigzag-Arrangement Operation.

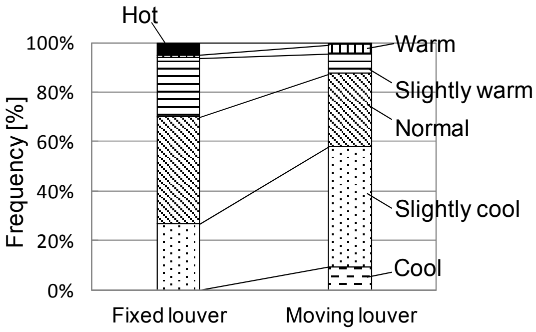


Figure 9: Thermal sensation vote

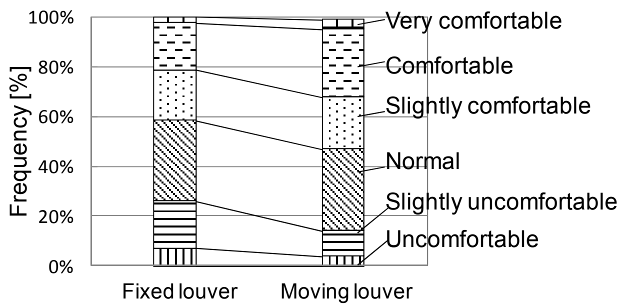


Figure 10: Comfort sensation vote

4 SIMULATION FORECAST OF ENERGY-SAVING

4.1 Method of Simulation Forecast

The authors anticipated the energy-saving capability of the Indoor-Unit Zigzag-Arrangement Operation from observed data. Figure12 shows Location Surveying Data of VRF air Conditioning System. The data were collected at Hokkaido in Japan and obtained by using the Probe Insertion Method.
Purpose of this study gives load twice as much as the normal use and increases the effectiveness of the units. Thus, for example, assuming that at 20 percent load factor 40% of energy is required. And, we calculated the consumption energy of the Indoor-Unit Zigzag-Arrangement Operation. This calculation is used in case of 10% to 50% load factor. Because, at least 50 percent load factor is high load operation and good operating efficiency. Therefore, when more than 50 percent load factor was calculated as the consumption energy of the normal operation.

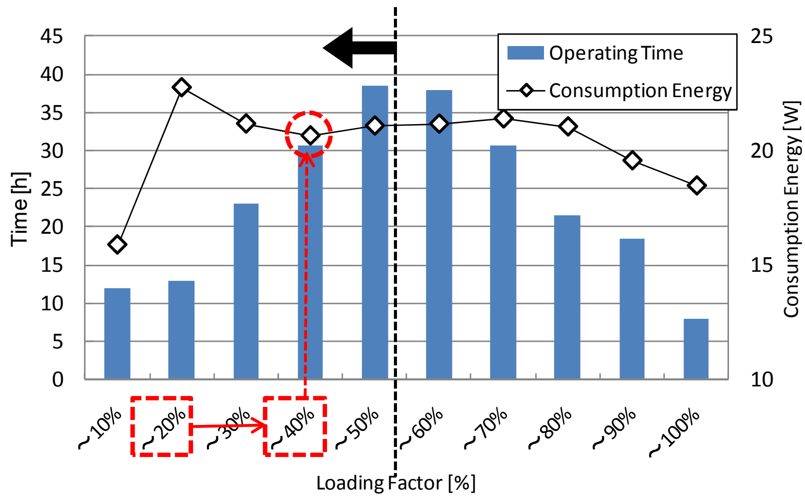


Figure 11: Location surveying data of VRF air conditioning system

4.2 Result of Simulation Forecast

Figure 12 shows a comparison between resultant frequencies of the energy consumption in the case of normal operation and those for the Indoor-Unit Zigzag-Arrangement Operation. The latter operation was observed to lead to an energy saving of about 31%.

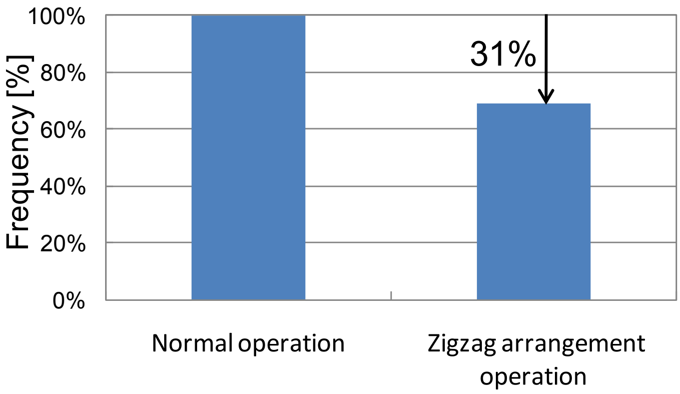


Figure 12: Comfort sensation vote

5 CONCLUSION

In the subjective experiments, the subjects did not find the performance of the air-conditioning system exceptional in the case of the Indoor-Unit Zigzag-Arrangement Operation. The continuous movement of the louver of the indoor unit made the subjects feel cool and comfortable. Finally, it was found that the proposed operation could help save energy.

6 REFERENCES

Kotaro. Tanaka, Hokuto. Nakamura, and Tatsuo. Nobe, “Long-Term On Site Evaluation of VRF System” *Proceedings of Healthy Buildings 2009*, paper 629.

Kosuke, Satoh. 2008. “Behavior of the Multiple Packaged Unit Air Conditioning System and the Future of this System” *SHASE,* Vol. 82, Part 1, pp. 43–49.