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EXPERIMENTAL STUDY ON THE PERFORMANCE AND OIL RETURN CHARACTERISTICS OF MULTI-SPLIT AIR-CONDITIONING SYSTEM FOR MEDIUM SIZE BUILDING

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ABSTRACT

The present study experimentally investigated the effect of tube length and the head on the heating and cooling performance and oil return pattern of multi-split air-conditioning system. The system was installed in a ten-story-building with the maximum system tube length of 102m and the maximum head of 45m between indoor and outdoor unit. The maximum vertical head between adjacent indoor units was 13.5m. The system (nominal heating capacity of 28.1kW and cooling capacity of 26.4kW) consisted with one outdoor unit with both one scroll compressor with fixed capacity and the other scroll compressor with variable capacity, and five indoor units. The oil return pattern was observed through the sight glass and recorded by CCD cameras for the cases with and without oil U-traps installed every 10m.

The cooling capacities of the system were decreased by 10% and 5% due to long system tube and high head respectively. The heating capacities of the system were decreased by 3% and negligibly small due to long system tube and high head respectively. The adjacent indoor units with the head of 13.5m showed the differences of 3% for the cooling capacity and 5% for the heating capacity comparing with the nominal capacities. The oil levels in the scroll compressors showed the same levels for cases with and without oil U-traps. It means that the oil U-trap is not required for the building with the multi-split air-conditioning system with the tube length of 102m and the vertical head of 45m.

1. INTRODUCTION

High efficient air-conditioner is required to meet the demand for thermal comfort and convenience in residential and commercial zone. Multi-split air-conditioning system for building application has to be able to control the indoor unit for separate zone. The system is usually consisted of a number of indoor units and one outdoor unit. It may be installed in the office building residential apartments with very long tube length of approximately 100m and very high vertical head of approximately 50m.

Some experimental and theoretical studies have been carried out on the optimization of the multi-split air-conditioning system, reliability of electric expansion valve control and load following characteristics. Kim et al. [1] studied the performance enhancement of the air-conditioner system adopted modulated compressors. Hong et al. [2] studied heating capacity enhancement of the heat pump system with the digital scroll compressor and electric heater at low outdoor air temperature. Han et al. [3] studied numerical simulation for the cooling and heating capacity of multi-split air-conditioner. Choi et al. [4] studied the capacity modulating characteristics of the invert-driven multi-split air-conditioner with two indoor units. Lee et al. [5] studied performance enhancement of a multi-split air-conditioner with digital scroll compressor. Kim et al. [6] studied the distribution profile of compressor oil inside two compressors with different load. With the help of the flow visualization technique, oil distribution inside two compressors was visualized as proper level. Kesim et al. [7] studied analytically for the oil entrainment in the vertical pipe. He estimated the minimum refrigerant velocity required to entrain the oil in the vertical tube. Winandy and Cuevas [8] studied the oil return characteristics in a pair of scroll compressors with part load.

Most of studies on the multi-split air conditioning system have been done without considering long tube and high vertical head of the system. The effect of the tube length and the vertical head on the cooling and heating performance has to be studied for practical application. The multi-split air conditioning system with long tube and high head may have the trouble with oil recirculation in the system. The oil return characteristics in the multi-split air conditioning system have to be also investigated

The present study experimentally investigated the effect of system tube length and the height of head on the heating and cooling performance and oil return pattern of multi-split air-conditioning system.

2. FIELD TEST SYSTEM AND PROCEDURE

2.1 Field test system

As shown in Figure 1, the field test system was installed in a ten-story-building to measure the cooling and heating capacity and oil level in the scroll compressor of the multi-split air conditioning system. The multi-split air-conditioner consisted of five indoor units and one outdoor unit. The outdoor unit with one fixed scroll compressor and one digital scroll compressor was located at the roof. Compressors were controlled by the PWM (Pulse Width Modulation). Two out of five indoor units (#0, #1 units) as 4-way cassette type were located at the second floor as shown in Fig. 1 and Table 1. Two out of five indoor units (#2, #3 units) as 1-way cassette type were located at the first floor. The other one indoor unit (#4 unit) as 1-way cassette type was located in the basement of the second level. Table 1 shows the specifications of indoor and outdoor units. As shown in Fig. 1, the maximum tube length was 102m between the outdoor unit and the #4 Indoor unit, while the maximum head between the outdoor unit and the #4 indoor unit was 45m. The maximum vertical head between adjacent indoor units was 13.5m. Oil return tests were performed for two different circuits with and without (by-pass) oil U-trap installed every 10m. Thermocouples and humidity sensor were installed at the inlet and the outlet of all indoor units for measuring cooling and heating capacity of the indoor units.

Table 1 : Specifications of indoor and outdoor units

Unit name	Nominal capacity(kW)		Installed floor	Tube length* (m)	Head* (m)
	Cooling	Heating			
outdoor unit	29.0	31.5	Roof	0	0
#0 indoor unit	7.2	7.6	2F	77	-27
#1 indoor unit	7.2	7.6		79	
#2 indoor unit	4.0	4.3	1F	61	-31.5
#3 indoor unit	4.0	4.3		59.5	
#4 indoor unit	4.0	4.3	B2F	102	-45

*from the outdoor unit

2.2 Test procedure

Five different operating conditions were shown in Table 2. System performance with full and partial loads was measured. The case operated two indoor units was tested to investigate the effect of the maximum head between two adjacent indoor units of 13.5m on the heating and cooling performance. The case operated one indoor unit was tested to investigated the effect of the maximum length of on the heating and cooling performance and the oil return characteristics under the most severe condition. The oil levels in the compressor were visualized by using CCD camera.

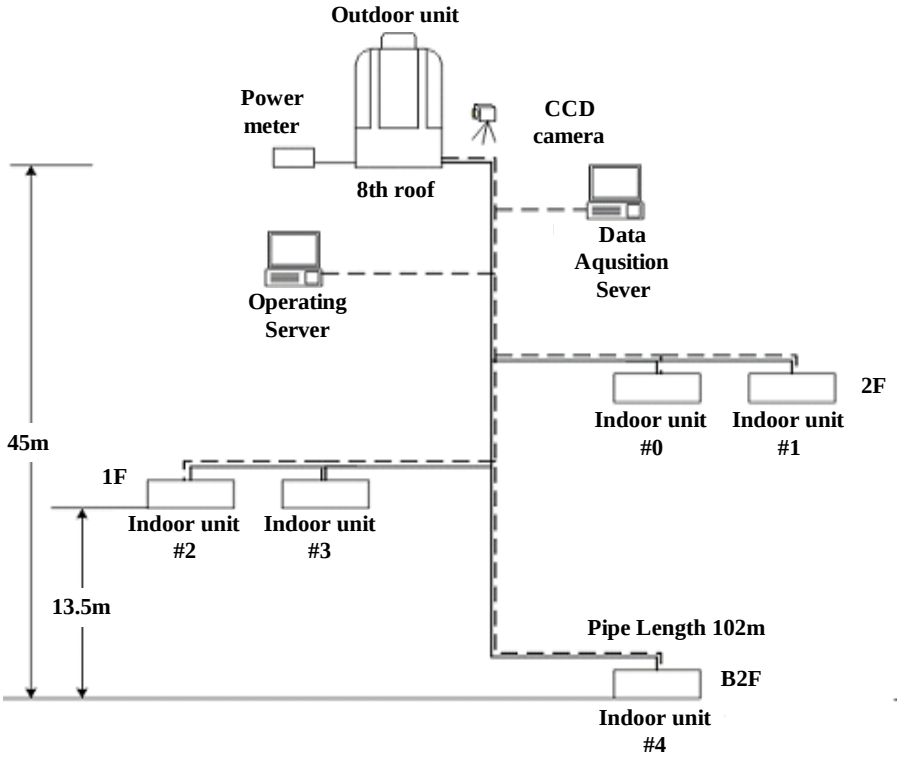

Figure 1 : Schematic diagram of the experimental system

Table 2 : Test conditions

Experiment	Indoor Unit				
	#0	#1	#2	#3	#4
operating all indoor units	○	○	○	○	○
operating 4 indoor units		○	○	○	○
operating 2 indoor units			○		○
operating 1 indoor unit (without oil U-trap)			○		
					○
operating 1 indoor unit (with oil U-trap)			○		
					○

3. Results and Discussion

3.1 Effect of the tube length and the head on the heating and cooling performance

Figure 2 shows the cooling capacity of the multi-split air-conditioner as the function of tube length when all indoor units were operated. The cooling capacities were obtained as the ratio of the measured cooling capacity to the nominal capacity of indoor unit shown in Table 1. The calorimeter data were compared with the field test data. The calorimeter data were obtained for the multi-split air conditioner with long tube at the standard test ambient air conditions of dry-bulb temperature of 35℃ and wet-bulb temperature of 27℃. The calorimeter test conditions had the difference of test temperatures and head with the field test data. The cooling capacity was decreased by 10% as the tube length was longer than 50m. The cooling capacity was decreased by approximately 5% as the head between outdoor and indoor units was as high as 45m.

Figure 4 shows the heating capacity of the multi-split air-conditioner as the function of tube length when all indoor units were operated. The heating capacities were also obtained as the ratio of the measured heating capacity to the nominal capacity of indoor unit shown in Table 1. The heating capacity was decreased by approximately 3% as the

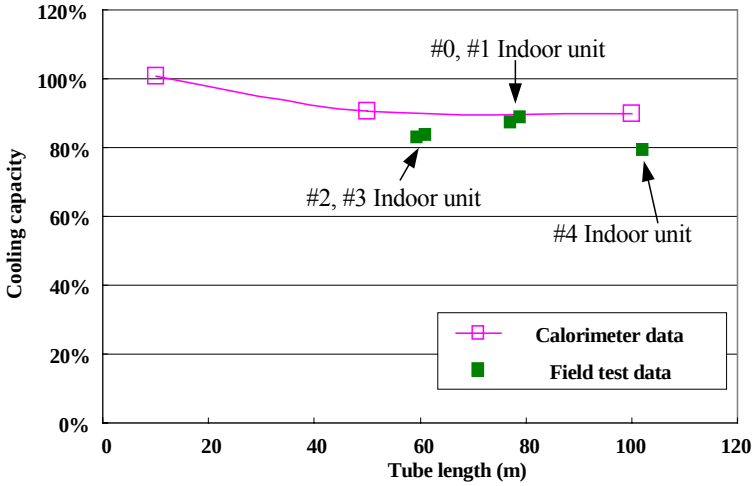

Figure 2 : Effect of tube length and head on cooling capacity

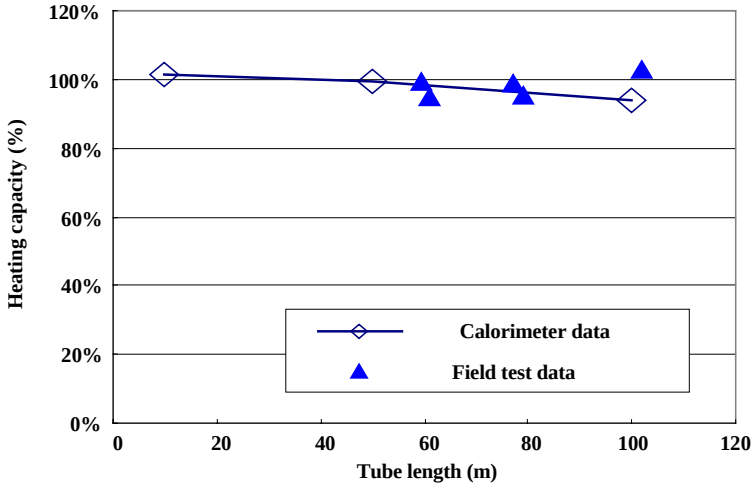

Figure : 3 Effect of tube length and head on heating capacity

tube was as long as 100m. The effects of the head between outdoor and indoor units were negligible. The effects of tube length and the head on the heating capacity were smaller than those on the cooling capacity.
Figures 4 and 5 show the effect of head between adjacent indoor units on the cooling and heating capacity. Two indoor units were #2 and #4 indoor units with the vertical head of 13.5m. The cooling capacity of #2 and #4 indoor units showed the difference of 3% for the individual and simultaneous operations. The heating capacity of #2 and #4 indoor units showed the maximum difference of 5% for the individual and simultaneous operations. The heating capacity for simultaneous operation were larger by the maximum of 8% than those for individual operation.

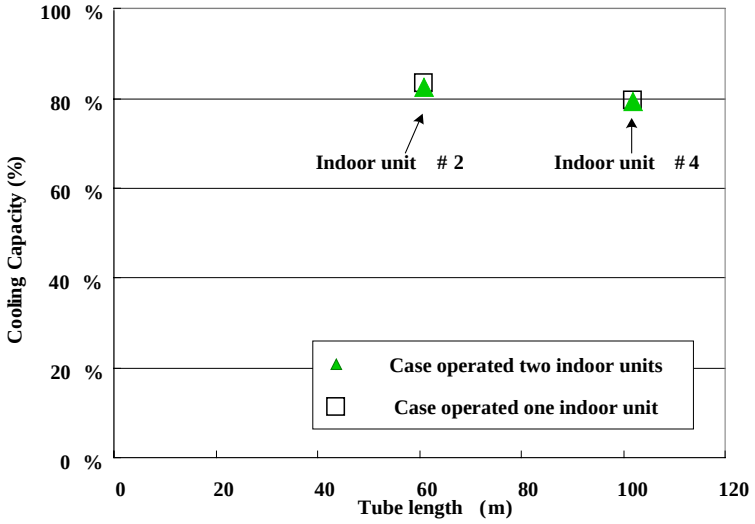

Figure 4 : Effect of head between adjacent indoor units on the cooling capacity

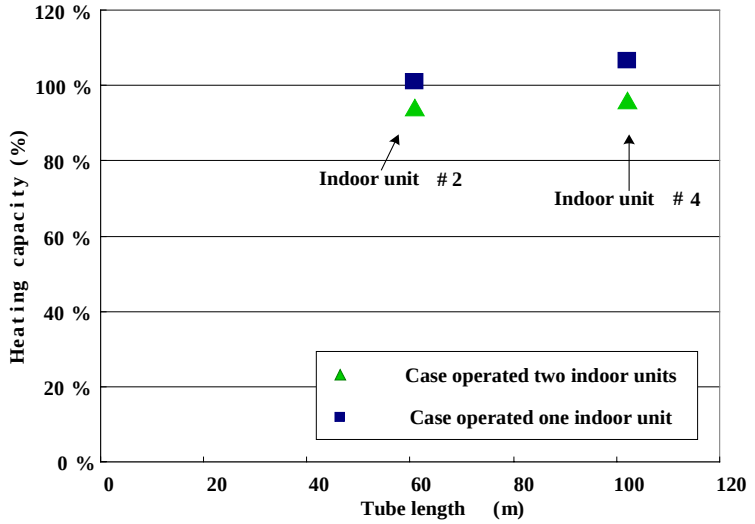

Figure 5 : Effect of head between adjacent indoor units on the heating capacity

3.2 Oil return characteristics in the scroll compressors

Multi-split air conditioning system utilized oil U-traps installed every 10m prior to the present study. If the U-traps are not needed for the multi-split system applied for the building with the height of approximately 50m, construction cost can be reduced due to space saving. The oil levels in the scroll compressor of the outdoor unit were visualized by a couple of CCD camera as shown in Fig. 6. The oil level of 70mm is the middle of the sight glass as shown in Fig. 6. The oil return characteristics may be the worst case among the field test cases shown in Table 2 when only #4 indoor unit is operating. Figure 7 showed the oil levels with and without oil U-traps as the function of time when only #4 indoor unit was operated. The oil levels were ranged from 68 to 83 mm for both heating and cooling modes. No changes were observed for both with and without U-traps. It means that the U-trap is not needed for the multi-split air conditioner under the test conditions. Figure 8 showed the comparison of cooling and heating capacities for the cases with and without U-traps. The differences of cooling and heating capacities were negligible.

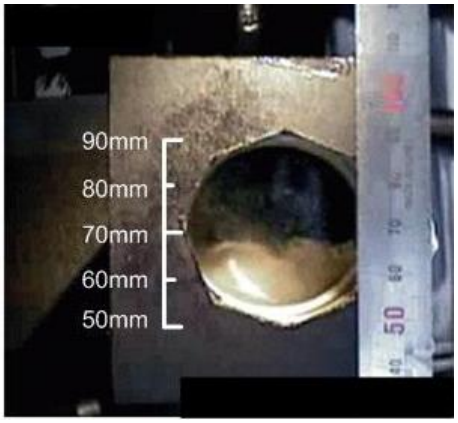

Figure 6 : Visualization of oil level in the scroll compressor

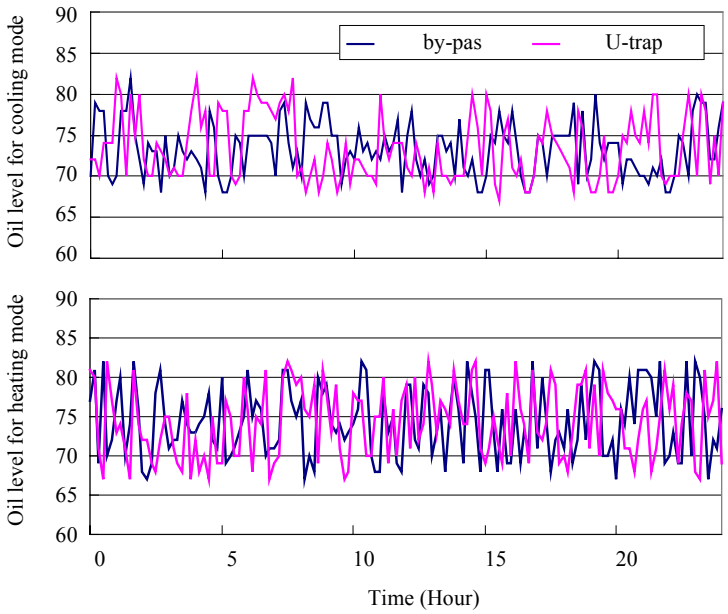

Figure 7 : Oil levels with and without oil U-traps

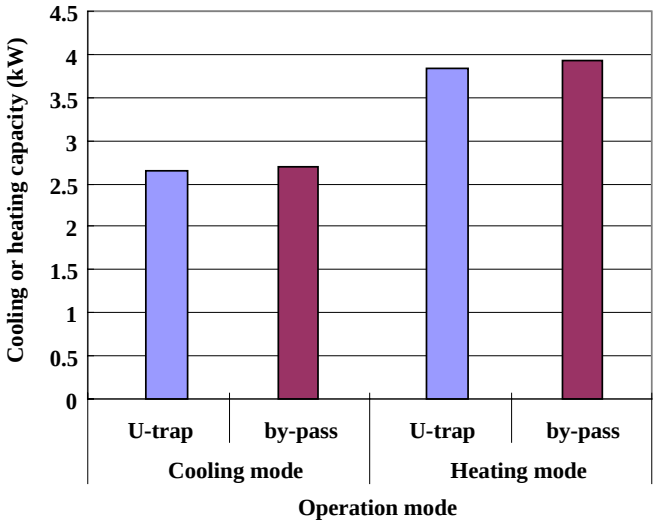

Figure 8 : Comparison of cooling and heating capacities for the cases with and without U-traps

4. CONCLUSIONS

1. The cooling capacities of the multi-split air conditioning system were decreased by approximately 10% due to the tube length of 102m and 5% due to the maximum head of 45m between outdoor and indoor units comparing with the nominal cooling capacities.
2. The heating capacities were decreased by approximately 3% due to the tube length of 102m and negligibly small due to the maximum head of 45m comparing with the nominal heating capacities. The effects of tube length and the head on the heating capacity were smaller than those on the cooling capacity.
3. The adjacent indoor units with the head of 13.5m showed the differences of 3% for the cooling capacity and 5% for the heating capacity.
4. The oil levels in the scroll of compressors showed the same levels for the cases with and without U-traps. It means that the U-trap is not required for the building with the multi-split air conditioner with the tube length of 102m and the vertical head of 45m.

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