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Study on Performance Evaluation of a Split Air Conditioning System Under the Actual Conditions

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ABSTRACT

This paper deals with an actual performance of split air conditioning systems.
In recent years, the split air conditioning system is installed in a building more than 100000 square meters in Japan. The performance of these units is evaluated by JIS (Japan Industry Standard) rules, however these tests is done in static condition, and the actual performance is not evaluated. These false estimates produce a different anticipation of future energy consumption or waste heat contamination.
Setting various weather conditions, the experiment that assumed the actual operating condition is done. As the experimental results, performance characteristics and thermal characteristics of the system have been estimated, and influences of the weather conditions and thermal load have also been investigated.

1. INTRODUCTION

The market share of a split air conditioning system has been growing rapidly, because of high cost performance and easy installation, and it goes to be replaced by central air conditioning systems.
JIS rules on the performance of split air conditioning systems, an “air-enthalpy method” using a room type calorimeter is used widely in order to evaluate it. But, in this “air-enthalpy method”, a performance test is done in static condition and it is so difficult that it indicates an actual operating condition. Also, on the rating test, for a test conditions, only temperature and humidity are defined by JIS rules and not required to operation conditions of test unit.
The actual performance receives a large influence by environmental factors such as temperature, humidity, SHF and thermal load etc. Therefore, the ratings performance was completely different from actual performance. The clarification of actual performance is so useful for the design of conventional air conditioning facilities.
In this paper, fluctuating condition tests and starting performance tests are done to clarify actual performance that assumed actual operating conditions.

2. EXPERIMENTAL EQUIPMENTS AND METHODS

The two different experiments are done in this paper. One is a measurement of total energy consumption under the fluctuating conditions. And another one is for starting performance. The thermal load assumed the actual weather condition is supplied to a room type calorimeter chamber and the temperature and humidity of outside (condenser side) and inside (evaporator side) room is controlled.

2.1 Experimental Apparatus

In this experiment, the room type calorimeter chamber which own Kogakuin University is used.
This chamber has been used for evaluation of building environment and designed for architecture environment system, and it has a pair of chambers for comparative experiments. We installed an outdoor unit (condenser in cooling cycle) and an indoor unit (evaporator in cooling cycle) in each chamber. The floor plan of experimental unit is shown in figure 1 and the specification of a calorimeter chamber is shown in Table 1.
Thermal load of chambers is controlled by supply air conditions (e.g., temperature, humidity and air volume). The air conditioning system of this chamber has cooling and heating coil, steam generator and VAV (Variable Air Volume) system as shown fig. 2. As this chamber is not able to set a freezing condition, a refrigerating machine is attached to compensate it. The test unit is general marketing air conditioning system which is inverter controlled and split type. The specification of a test unit is shown in Table 2.
Figure 3 shows a deification of supplied thermal load to a test chamber. The generated available heat of test units is defined as supplied thermal load to chamber for measurement term.

Table 1: Specification of a calorimeter chamber

Designation	Specifications
Refrigerator	Air cooling chiller (45kW)
Heater	Electric heater (40kW)
Cool bath	FRP sandwich panel ($3m^3$)
Heat bath	Monocoque steel ($2m^3$)
Outdoor air conditioning unit	Air volume ($1000m^3/h$)
Air conditioning system for chambers	Air volume ($1000m^3/h$)
Package air conditioner for thermal buffer zone	Multi type, 8 indoor units (5Hp)
Controllable temp.	-5 to 50 (°C)
Controllable humidity value	10 to 100 (%)
Chamber size	5.9 (L)×4.1 (W)× 5.5 (H)
Wall heat transfer coefficient	Under $0.2W/m^2K$
Thermal insulation	Polystyrene foam (200mm)

Table 2: Specification of a test unit

Designation		Specifications
Electric Source		3Φ 200V
Refrigerant		R - 410A
Cooling capacity		3.60 kW
Heating capacity		4.00 kW
Rated COP	Cooling	4.13
	Heating	4.26
Indoor unit		Ceiling suspended type

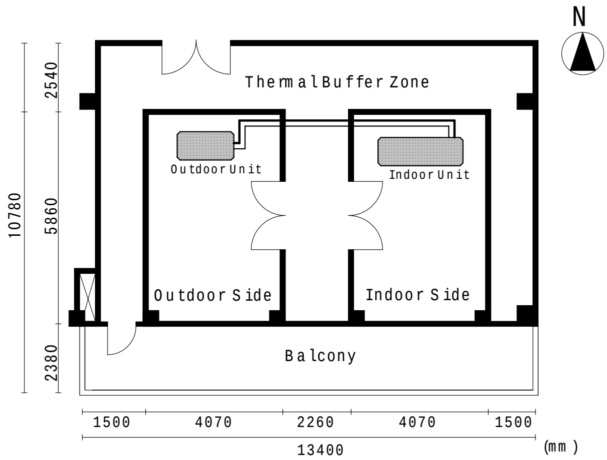

Fig. 1: Floor plan of calorimeter chamber

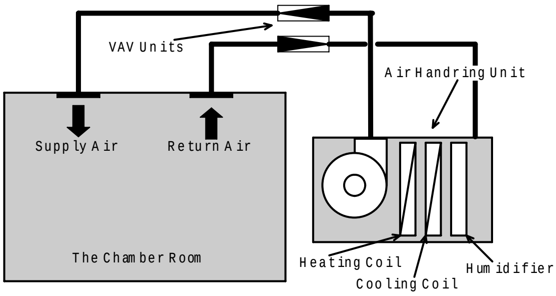

Fig. 2: Piping diagram of heat source

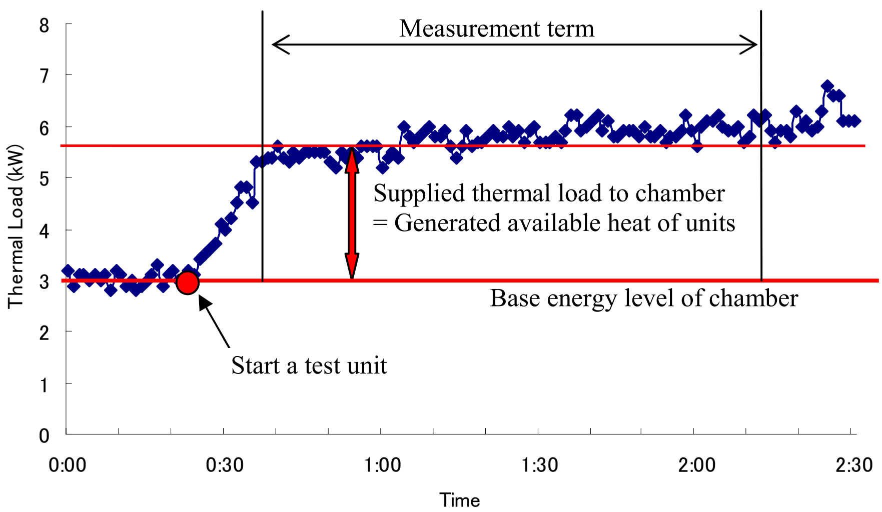

Fig. 3: Definition of supplied thermal load

2.2 Experimental Method

(1) Fluctuating Condition Test

In a calorimeter chambers, it is difficult to reproduce an actual thermal load pattern exactly. So, we arranged simply thermal load pattern using "CASCADE3 "(Computer Aided Simulation for Cogeneration Assessment & design) which is typical office building load pattern in Japan.

The simulated operating term is 8:00 to 19:00. The thermal load and weather data assumed actual condition by "CASCADE3 "are shown in Fig. 4(winter) and Fig. 5(summer).

Fig. 6 shows the supplied heating load and whether setting and also, Fig. 7 shows the supplied cooling load and whether setting. The experimental condition has 4 term patterns. The outside weather conditions are used the AMeDAS (Automated Meteorological Data Acquisition System) data in Otemachi, Tokyo. As for the temperature and humidity, calculated mean value in July and January are used.
The recommended setting temperature of air conditioning system is 20°C (Heating) and 28°C (Cooling) in Japan. But, according to our research, indoor setting temperatures is higher in winter and lower in summer than it, and set the experimental conditions as shown in table 4 and table 5.

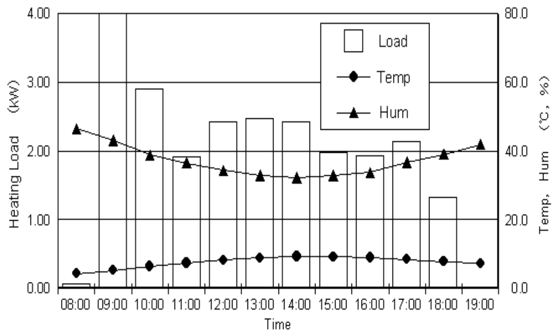

Fig. 4: Weather condition and thermal Load
(Winter, January)

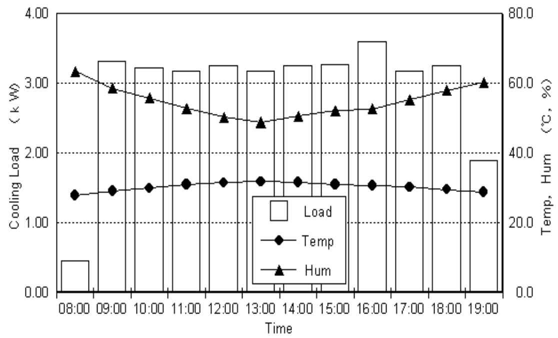

Fig. 5: Weather condition and thermal Load
(Summer, July)

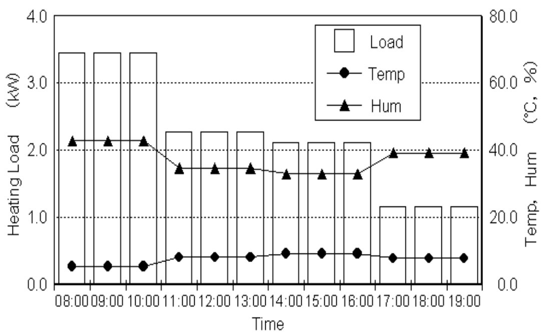

Fig. 6: Supplied heating load and whether setting

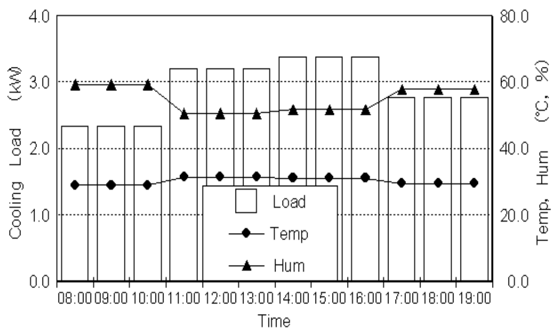

Fig. 7: Supplied cooling load and whether setting

Table 4: Test setting condition (winter)

Indoor Side			Outdoor Side	
DB (°C)	RH (%)	Load (kW)	DB (°C)	RH (%)
23.0	24.0	3.4	5.3	42.8
		2.3	8.1	34.5
		2.1	9.1	32.9
		1.2	7.8	39.2

Table 5: Test setting condition (summer)

Indoor Side			Outdoor Side	
DB (°C)	RH (%)	Load (kW)	DB (°C)	RH (%)
25.0	50.0	2.3	29.0	59.2
		3.2	31.4	50.6
		3.4	31.1	51.7
		2.8	29.5	57.8

(2) Starting Performance test

The starting performance test is done under the conditions which are given in Table 6. The test unit is operated in original control logic till the conditions of chamber reaches the targeted value.
On the summer term in Japan, a short circuit phenomenon by waste heat from condenser occurs, because of the outdoor units are equipped in small area on the top of the building. Then, the efficiency of a heat exchanger on

condenser deteriorates remarkably. Therefore, we set the high temperature condition assumed its phenomenon.
On the middle season between summer and winter, the cooling demands are higher than the heating one. The outside temperature is set to 20°C as a representative of this term.
On the winter term, parameters in the table are typical values in Japan.

Table 6: Test conditions for performance test including start period

	Indoor side			Outdoor side	
	DB (°C)	RH (%)	*T.L.F (%)	DB (°C)	RH (%)
Summer	25.0	50.0	100,50	40.0	24.0
Middle				20.0	40.0
Winter	23.0	40.0		0.0	55.0
				5.0	24.0

*T.L.F: Thermal Load Factor

3. EXPERIMENTAL RESULTS

3.1 Fluctuating Condition Tests

The experiment results of a fluctuating condition test are shown in Fig. 8 and Fig. 9.
At the winter condition test, the test units frequently repeat start and stop following a defrosting, and indoor temperature changed less than 3 degrees Celsius. Also, because the control of attached refrigerating machine is not good, the outside temperature is changed remarkably.
At a summer condition tests, as a thermal heat load is high, a compressor is running continually. For this reason, the test result is comparatively good.

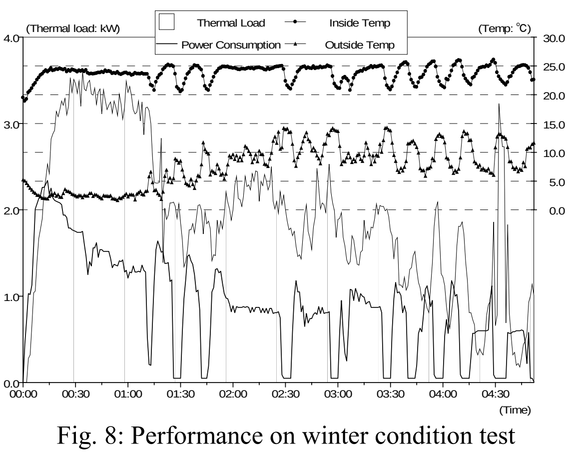

Fig. 8: Performance on winter condition test

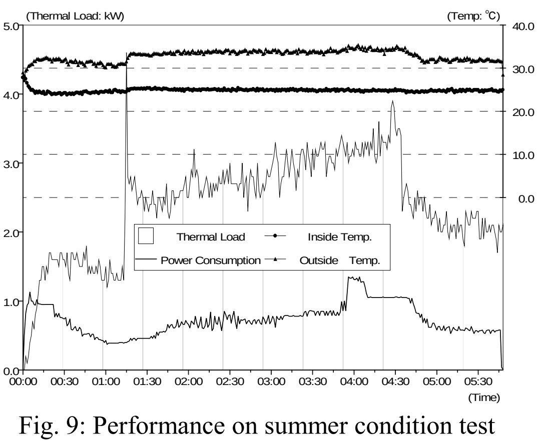

Fig. 9: Performance on summer condition test

Table 7: Results of fluctuating condition test

	Total power consumption (kWh)	Supplied thermal load (kWh)	Measured COP	COP Ratio (%)
Summer	4.28	13.16	3.07	74.45
Winter	4.43	8.29	1.87	43.93

Table 7 shows results of fluctuating condition test.
By the test that assumed a summer week day in an office building, the average of measured COP is 3.07. This value is equivalent to about 75% of a rated COP (catalogue) value. In the same way, the test results that assumed winter week day is 1.87 and this one is equivalent to about 44% of a rated COP.
In this way, a result of the winter season is particularly different from its rated COP value.

3.2 Starting Performance test

The total energy efficiency including starting period is measured. Fig.10 to Fig. 15 shows each starting performance results with 100% and 50% thermal load in the winter, middle and summer season.
On the winter condition with 50% thermal load, as the test units frequently repeat start and stop following a defrosting, the energy consumption efficiency is getting lower. Test unit has this operation mode for refrigerant circuit and hardware protection. At the summer condition, power consumption is twice as high by comparison rated power consumption.

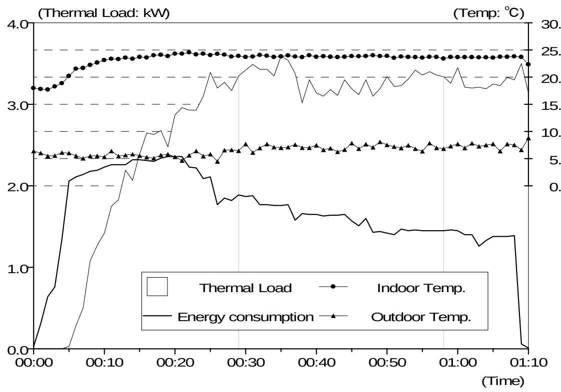

Fig. 10: Starting performance on winter condition (100% thermal load)

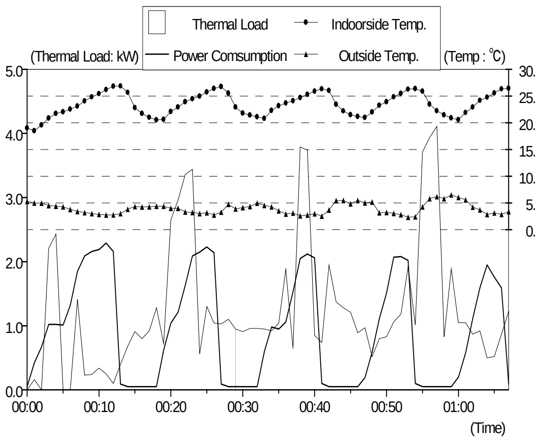

Fig. 11: Starting performance on winter condition (50% thermal load)

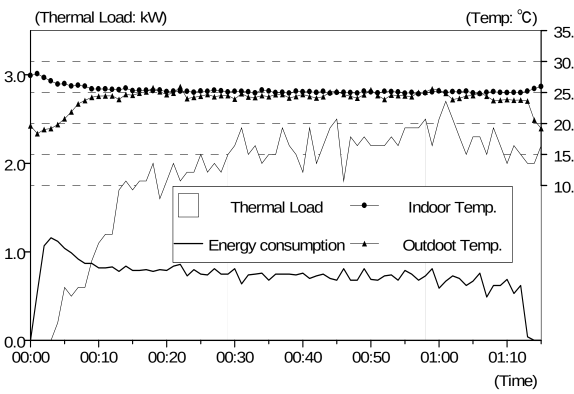

Fig. 12: Starting performance on middle condition (100% thermal load)

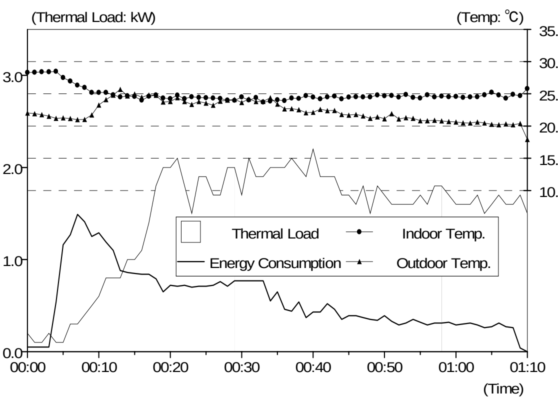

Fig. 13: Starting performance on middle condition (50% thermal load)

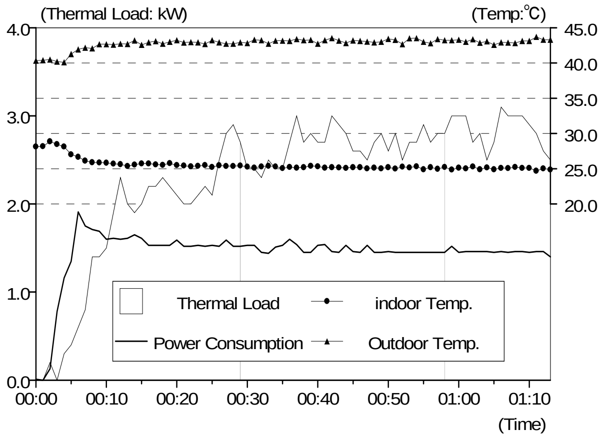

Fig. 14: Starting performance on summer condition (100% thermal load)

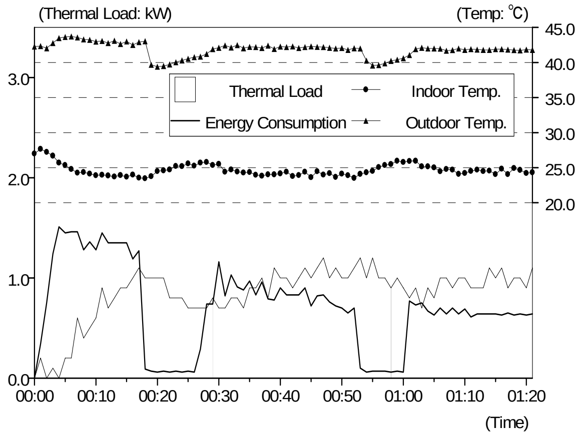

Fig. 15: Starting performance on summer condition (50% thermal load)

At the starting period, the unit demands many power resources, so the energy efficiency is getting lower. The COP ratio is about 50%. The fluctuation of room temperature with the defrost operation at heating. On the summer condition test, test unit is following to the change of the condition. It shows the inverter control has much influence to the energy saving.

The performance including start period is lower than rated value. The rush current is characteristic phenomenon at start period, but arrow for that, lowers performance at the winter conditions.

On a winter condition, on-off operation for defrost is observed. Because of that, the total energy consumption efficiency is lower than summer condition. The performance of middle season is favorable. It is thought of as the designing concept of air conditioner matches this range.

Table 8: Results of start performance test

Condition	Thermal Load Factor (%)	Total Energy Consumption (kWh)	Supplied Thermal Load (kWh)	Measured COP	COP Ratio (%)
Summer	100	1.76	2.34	1.33	32.19
	50	0.97	0.78	0.80	19.47
Middle	100	0.93	1.90	2.04	49.47
	50	0.55	1.60	2.91	70.44
Winter	100	1.96	3.19	1.63	38.21
	50	1.09	1.42	1.30	30.62

4. CONCLUSION and DISCUSSION

In this experiment, we obtained following conclusions.
In the fluctuating condition tests, the measurement performance does not reach to the rated performance. The performance of test unit is received large influence with circumstance conditions. Therefore,
By a current test method, i.e. air-enthalpy method with static conditions, it is difficult that estimate an actual performance. The evaluation of actual performance is important for air conditioning facility designs.
On the basis of these results, we suggest that it is necessity to establish the evaluation method under actual conditions.
The split air conditioning system will become the mainstream of it in the next generation. In addition, an estimate of generated effective thermal capacity based on a rating test is not clear.
It is important that we know the generated effective thermal capacity in a real use, if we design an air conditioning.
Rating test is necessary for indication of product design. The problem what standards should be applied on the product design. The split air conditioning system is respond to the demands of the times. The requirement of air conditioner involves the amenity and energy-saving. Rated test result but also actual evaluations are draw attention as quality production. So, we suggest that the evaluating actual performance is the most important thing for the developing air conditioning system as one of building equipments.
As for the air conditioner, it should be done evaluation from a user side. This is the item which is so important in a design of an air conditioner. The false estimates produce a different anticipation of future energy consumption or waste heat contamination. Therefore, establishment of immediate evaluation technique is expected.

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