THERMAL LOAD TEST OF ICE THERMAL STORAGE TYPE MULTI-SPLIT SYSTEM AIR CONDITIONER AND PACKAGED TYPE AIR CONDITIONER

Katsuaki Nagamatsu, Chubu Electric Power Co., Inc., 20-1 Kitasekiyama, Ohdaka-cho, Midori-ku, Nagoya, Aichi, 459-8522 Japan

Choyu Watanabe, Chubu Electric Power Co. Inc., 20-1 Kitasekiyama, Ohdaka-cho, Midori-ku, Nagoya, Aichi, 459-8522 Japan

Toru Matsuda, Chubu Electric Power Co., Inc., 20-1 Kitasekiyama, Ohdaka-cho, Midori-ku, Nagoya, Aichi, 459-8522 Japan

Noburo Osa, Chubu Electric Power Co., Inc., 20-1 Kitasekiyama, Ohdaka-cho, Midori-ku, Nagoya, Aichi, 459-8522 Japan

ABSTRACT

Our test apparatus was able to test multi-split system air-conditioners and the packaged type air-conditioners with varying thermal load conditions.

Using our test apparatus, tests of the multi-split system and the packaged type electric air-conditioners (both types of thermal storage and non-storage), gas engine air-conditioners were performed.

It was made clear that the electric air-conditioners were superior to the gas engine air-conditioners in the performance characteristics. As a result, the cooling and heating capacity ratio of the measured values to the specific values was over 95% for the electric air-conditioners and about 80% for the gas engine air-conditioners. The primary energy efficiency was 0.7-1.2 for the electric air-conditioners and 0.6-0.8 for the gas engine air-conditioners.

INTRODUCTION

The annual electric power load leveling is important in order to supply electric power stably at low cost. The spread of the thermal storage type air-conditioner system has been promoted as the best promising measure to level the electric power load. In recent years, the ice thermal storage type multi-split system air-conditioners and packaged type air-conditioners have been developed and spread. However, the performance characteristics and the season energy efficiency of these systems were not clarified.

This paper clarifies the performance characteristics and the season energy efficiency of the multi-split system and the packaged type air-conditioners (both types of thermal storage and non-storage) and gas engine air-conditioners by tests with varying weather conditions and thermal load conditions.

TEST APPARATUS

A schematic view is shown in Figure 1. There are two apparatuses, No.1 is for the multi-split system air-conditioners as shown Table 1 and No.2 is for the packaged air-conditioners as shown Table 2.

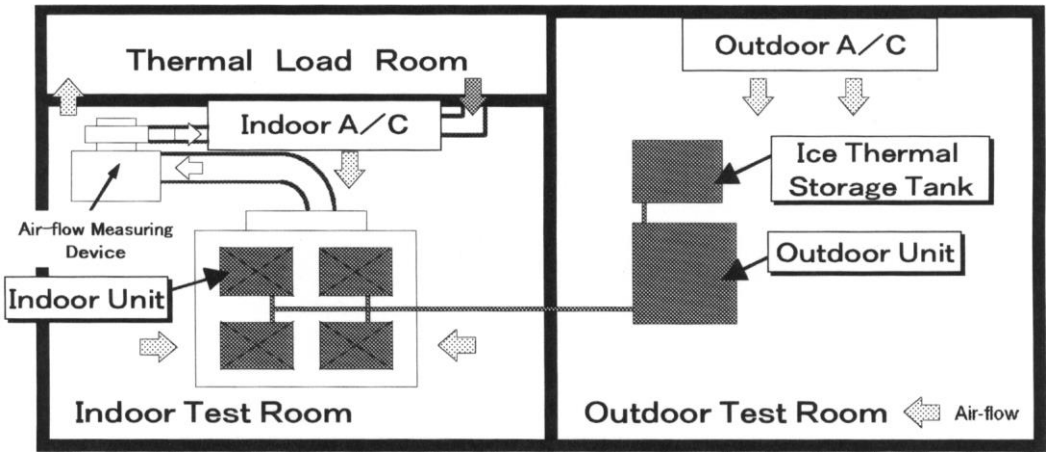

Figure 1. Schematic Diagram of Test Apparatus

Table 1. Main Specifications of Test Apparatus No.1

Types of Tested Air-Conditioner	Multi-split System, Packaged Type (Thermal Storage, Non-Storage, Gas Engine)	
Test Range	Cooling Capacity	8～45kW
	Heating Capacity	10～53kW
	Humidifying Capacity	Max. 35 liter / h
	Air-flow	10～160m^3/min
	Power Supply	AC3φ200V 60Hz
Range of Temperature and Humidity	Indoor	+2～+50℃ 30～90%RH
	Outdoor	-20～+60℃ 30～90%RH
Dimension	Indoor	11.8m(L)×8.8m(W)×4.0m(H)
	Outdoor	16.8m(L)×16.4m(W)×11.7m(H)

Table 2. Main Specifications of Test Apparatus No.2

Types of Tested Air-Conditioner	Packaged, Room Type (Thermal Storage, Non-Storage, Gas Engine)	
Test Range	Cooling Capacity	2.5～16kW
	Heating Capacity	3～20kW
	Humidifying Capacity	Max. 15 liter / h
	Air-flow	4～50m^3/min
	Power Supply	AC3φ200V 60Hz
Range of Temperature and Humidity	Indoor	0～+52℃ 30～90%RH
	Outdoor	-20～+52℃ 30～90%RH
Dimension	Indoor	4.1m(L)×4.8m(W)×3.2m(H)
	Outdoor	4.5m(L)×4.8m(W)×2.7m(H)

Each apparatus consists of an outdoor test room, an indoor test room and a thermal load room.

An outdoor unit and an ice thermal storage tank are set in the outdoor test room and indoor units -cassette type mounted on the ceiling- are set in the indoor room. Using these apparatuses based on loop air enthalpy test-method, the cooling and heating capacity of the tested air-conditioners can be obtained up to about 50kW.

In the case of the rated capacity test, the rated performance characteristics of the tested air-conditioners can be obtained by keeping the rotational speed of the compressor of the tested air-conditioners under the constant air temperature and humidity of the outdoor test room and the indoor test room.

Additionally, our test apparatus are able to vary air temperature and humidity of the outdoor test room and give the tested air-conditioners the varying thermal load from thermal load room, which is simulated the air conditioning actual load of the building in the field.

Therefore the total performance characteristics including the capacity control and the indoor room temperature control can be obtained.

TEST METHOD

The specifications of the tested air-conditioners are shown in Tables 3 and 4, which are three multi-split system air-conditioners and two packaged air-conditioners.

The rated capacity test and the thermal load test simulated the operating condition in the field were performed.

The rated capacity test was based on JIS-B-8615 and JRA (The Japan Refrigeration and Air Conditioning Industry Association)-GL-12-2000. Table 5 shows the conditions of the rated capacity test.

Table 3. Specifications of Tested Multi-split system Air-Conditioners

Type	Electric		Gas
	Thermal Storage	Non-Storage	Gas Engine
Standard Cooling Capacity (kW)	35.5	35.5	35.5
Standard Heating Capacity(kW)	35.5	40.0	42.5
Type of Indoor Unit	Ceiling mounted cassette		
Number of Indoor Units	4		
Indoor Unit Capacity(kW)	9		
Quantity of Thermal Storage in Ice(MJ)	580	-	-
Quantity of Thermal Storage in Hot Water(MJ)	250	-	-

Table 4. Specifications of Tested Packaged Air-Conditioners

Type	Electric	Gas
	Non-Storage	Gas Engine
Standard Cooling Capacity (kW)	14.0	14.0
Standard Heating Capacity(kW)	16.0	18.0
Type of Indoor Unit	Ceiling mounted cassette	
Number of Indoor Unit	1	
Indoor Unit Capacity(kW)	14	

Table 5. Conditions of Rated Capacity Test

	Outdoor-side Air		Indoor-side Air	
	D.B.T.	W.B.T.	D.B.T.	W.B.T.
Cooling (Standard)	35.0 ±0.3℃	-	27.0 ±0.3℃	19.0 ±0.2℃
Heating (Standard)	7.0 ±0.3℃	6.0 ±0.2℃	20.0 ±0.3℃	15.0 (max.)
Heating (Low Temperature)	2.0 ±0.3℃	1.0 ±0.2℃	20.0 ±0.3℃	15.0 (max.)
Ice Thermal Storage	25.0 ±0.3℃	-	-	-
Hot Water Thermal Storage	2.0 ±0.3℃	1.0 ±0.2℃	-	-

In the case of the thermal load test, the mean temperature and humidity of every hour for each month in Nagoya City from the meteorological data of representative day for each month by the maximum thermal load calculation program MICRO-PEAK were adopted as an outdoor-side air condition. And the thermal load condition (indoor-side air condition) of every hour for each month was calculated, whose maximum thermal load was 80% of the rated capacity. The varying ratio of thermal load was decided by collating the measured thermal load result of our company building (number of floors; 7, total floor space; 6,700m^2) with the calculated thermal load result using thermal load calculation program Leonardo CALC.

Figure 2 shows the outdoor-side air condition of the thermal load test. Figure 3 shows the thermal load condition (indoor-side air condition) of the thermal load test by the ratio to the rated cooling capacity, where a positive value means cooling load and a negative value means heating load. The operating conditions of the tested air-conditioners were as follows;

(1) Cooling term; March, June, July, August, September and October

(2) Heating term; January, February, March and December

(3) Number of operating days per month; 23

(4) Operating time of air conditioning; 8:00-18:00

(5) Operating time of thermal storage; 22:00-8:00

CAPACITY TEST RESULTS

Figure 4 shows the ratio of the measured values to the specific values for the multi-split system air-conditioners. The capacity ratio of the electric air-conditioners was over 95%. However, that of the gas engine air-conditioners was about 80%, and it was much lower than that of the electric air-conditioners.

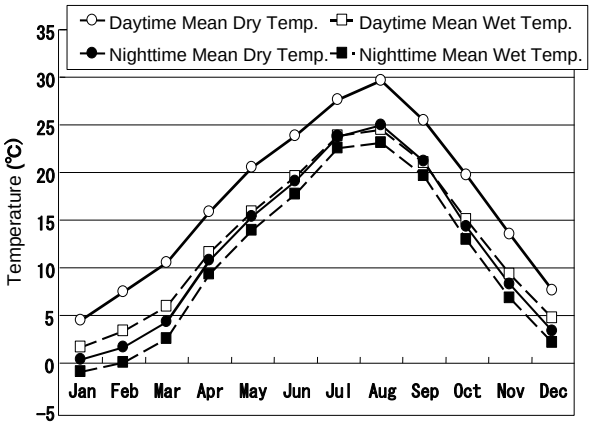

Figure 2. Thermal Load Test Condition of Outdoor-side Air

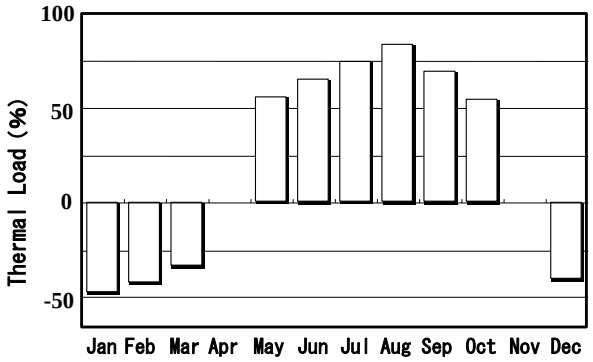

Figure 3. Thermal Load Test Condition of Indoor-side Air (Thermal Load)

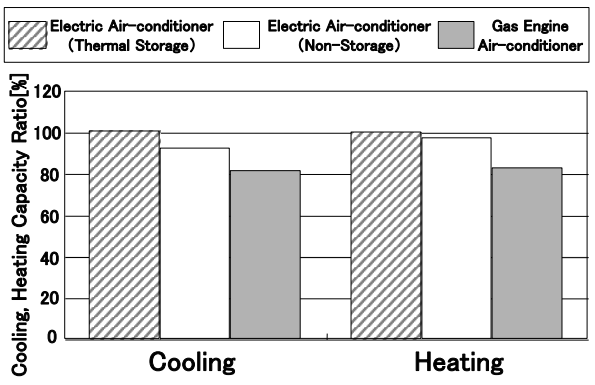

Figure 4. Capacity Ratio of Multi-Split System Air-conditioners at Rated Capacity Test Condition

Figure 5 shows the results of the primary energy efficiency of the multi-split system air-conditioners. The primary energy efficiency is defined as the ratio of the thermal output to the heat value of the fuel consumption. The heat value of the electric power is 2,450kcal/kWh at daytime and 2,300kcal/kWh at nighttime based on the actual generation of thermal power station. The heat value of city gas 13A is 11,000kcal/Nm^3. As a result, the primary energy efficiency was 0.6 in cooling and 0.9 in heating for the electric air-conditioners, and 0.5 in cooling and 0.8 in heating for the gas engine air-conditioner.

Figures 6 and 7 show the test results of the packaged air-conditioners. The capacity ratio and the primary energy efficiency of the electric air-conditioner were over 95% and 1.1 respectively, and they were much higher than those of the gas engine air-conditioner that were about 80% and 0.6-0.8 respectively.

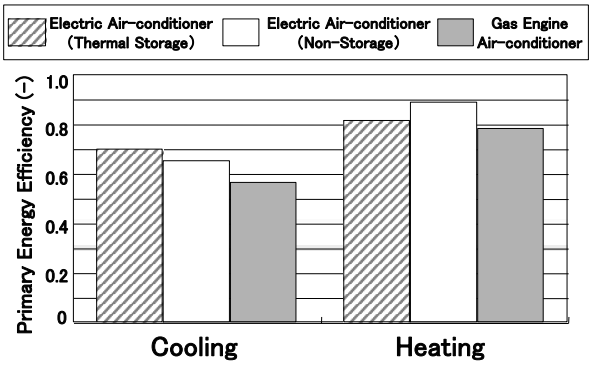

Figure 5. Primary Energy Efficiency of Multi-Split System Air-conditioners at Rated Capacity Test Condition

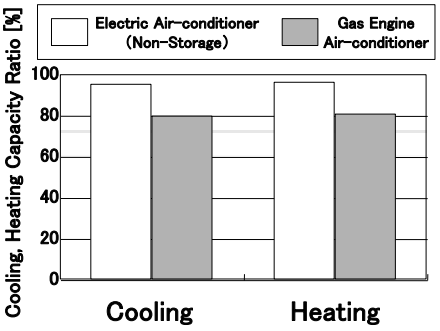

Figure 6. Capacity Ratio of Packaged Air-conditioners at Rated Capacity Test Condition

THERMAL LOAD TEST RESULTS

Figure 8 shows the primary energy efficiency for each month of the multi-split system air-conditioners. That of the electric air-conditioners was 0.9-1.2 at cooling term and 0.7-0.8 at heating term. However, that of the gas engine air-conditioner was about 0.6 at both terms, and it was lower than that of the electric air-conditioners.

Figure 9 shows the primary energy efficiency for each month of the multi-split system air conditioners. That of the electric air-conditioners was 1.2-1.4 at cooling term and 1.0-1.1 at heating term. However, that of the gas engine air-conditioner was about 0.6 at both terms, and it was lower than that of the electric air-conditioners.

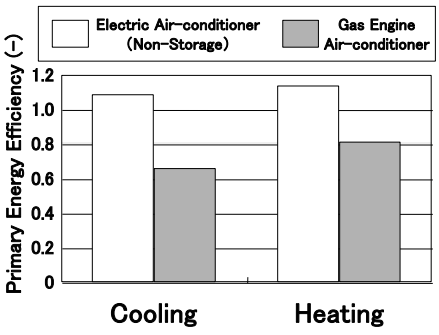

Figure 7. Primary Energy Efficiency of Packaged Air-conditioners at Rated Capacity Test Condition

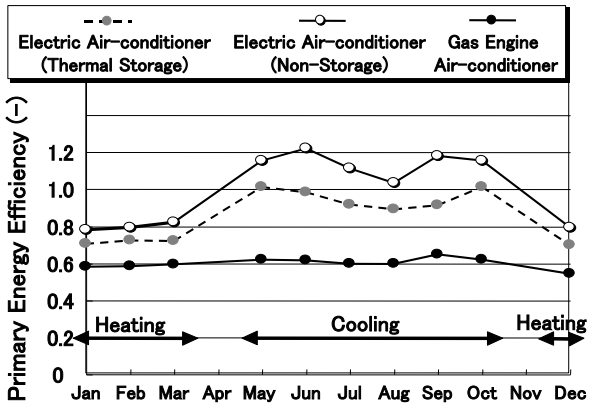

Figure 8. Primary Energy Efficiency for Each Month of Multi-Split System Air-conditioners at Thermal Load Test Condition

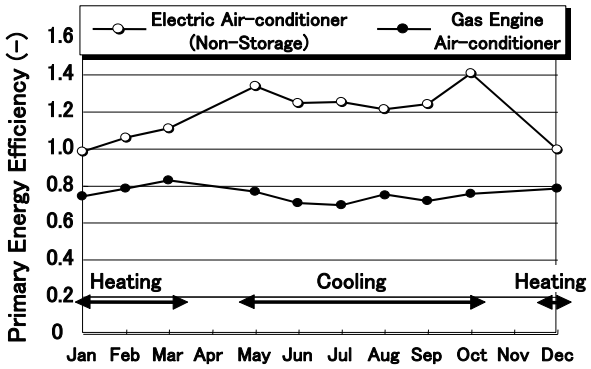

Figure 9. Primary Energy Efficiency for Each Month of Packaged Air-conditioners at Thermal Load Test Condition

CONCLUSIONS

This paper presented the performance characteristics and the season energy efficiency of three multi-split system air-conditioners (thermal storage, non-storage, gas engine) and two packaged air-conditioners (non-storage, gas engine) with varying weather conditions and thermal load conditions. The results obtained in this paper are concluded as follows;

(1) The rated capacity ratio of the measured values to the specific values was over 95% for the electric air-conditioners. However, that of the gas engine air-conditioners was about 80%, which was much lower than that of the electric air-conditioners.
(2) The annual primary energy efficiency was 0.7-1.2 for the electric air-conditioners. However, that of the gas engine air-conditioners was about 0.6, which was lower than that of the electric air-conditioners.

REFERENCES

Watanabe, C., Kawamura, J., Shinnou, Y., and Nagamatsu, K., 1999. Thermal Load Test of Ice Thermal Storage Type Air Conditioner, 36th National Heat Transfer Symposium of Japan, Vol. 3, pp. 827-828 (in Japanese).