GAS ENGINE-DRIVEN HEAT PUMP AIR-CONDITIONER FOR COOLING IT EQUIPMENTS

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Abstract: In recent years, due to the spread of IT equipments accompanying advances in computers and telecommunications, air conditioning loads for cooling IT equipments are increasing. In the buildings designed for installation of a lot of computers and equipments for telecommunications, the equipments installed in the interior consume electrical power in massive amounts, and measures to reduce power consumption are very important. To resolve these problems, Tokyo Gas Co., Ltd developed a GHP which is designed exclusively for cooling of telecommunications equipment rooms jointly with Yanmar Energy System Co., Ltd.

Key Words: gas engine-driven heat pump air-conditioner, Telecommunications Equipment Rooms

1 INTRODUCTION

Since they were first marketed in 1987, gas heat pumps (GHPs) have found increasing utilization in the market owing to their benefits, such as decreased consumption of electrical power and lower running costs. In almost all cases, they are applied to condition the air in space for human activity.
Recent years have seen the fast-paced spread of information technology (IT) equipment along with the advances in computer and communications technology. Meanwhile, in communications equipment rooms of data centers and other such facilities, the density of equipment installation has been rising along with progressive hardware downsizing, and this is expanding the air conditioning (cooling mode) load. The situation is compelling installation of more air conditioners, and there are apprehensions about the impact on the capacity of existing power receiving facilities in the host buildings. The GHPs that are the subject of this report are designed exclusively for use in the communications equipment rooms of data centers and other such facilities. They are aimed at resolving the aforementioned issues due to their power-saving merit. Their development was initiated in a joint project by Tokyo Gas Co., Ltd. and Yanmar Energy System Co., Ltd., with the cooperation of NTT Communications Corporation. Upon field tests in buildings of NTT Communications, they were commercially launched in April 2007 as GHP systems constituting the first gas-fueled air conditioners for installation in communications equipment rooms.
Figure 1 shows the photo of the outdoor unit, and Table 1, specifications of the outdoor and indoor units. As compared to electric-powered air conditioners with an equivalent cooling capacity, this GHP systems consume only about 30% as much power.

Figure 1: GHP outdoor unit for telecommunications equipment rooms

Table 1; GHP for telecommunications equipment rooms -- Main specs

(3-phase 200V 50Hz/60Hz)

Cooling capacity (kW)		56.0
Outdoor unit	Fuel consumption (kW)	40.7 (City gas 13A)
	Electrical power consumption (kW)	1.15/1.24
	Weight (kg)	950
Indoor unit	Type	Floor-mounted type (top inlet, bottom outlet)
	Electrical power consumption (kW)	5.00/5.80
	Fan capacity (m^3/min)	320
	Weight (kg)	565
Refrigerant		R410A

※ Operating conditions: an indoor unit inlet air temperature of 27°C DB, 19°C WB, and an outdoor unit inlet temperature of 35°C DB.

※ Sensible heat factor under these conditions is 0.95.

2 DEVELOPMENT OF THE TECHNOLOGY

The GHP systems for communications equipment rooms were developed and commercialized through the following approach.
Air conditioners for communications equipment rooms are characterized mainly by annual cooling operation and high sensible heat factor to cool the heat load imposed by such equipments efficiently. As a first step, the development team measured the operation of the electric air conditioners installed in NTT Communications in order to ascertain the characteristics of the operation of systems for communications equipment rooms. In parallel with this task, it developed the first GHP prototype, conducted field tests, confirmed the ability to deliver annual cooling operation under a high sensible-heat load with a GHP, and determine the status of energy use and operating load.
Lastly, the team field-tested the second GHP prototype, which had quasi- commercial specifications, to make a final determination on the specifications. These initiatives and activities are described in more detail below.

3 MEASUREMENTS FOR THE OPERATION OF ELECTRIC AIR CONDITIONERS

3.1 Units measured

The team made measurements for indoor units of the floor-mounted type, with a top inlet and bottom outlet. Their specifications are shown in Table 2.

Table 2; Specifications of units measured

(3-phase 200V 50Hz/60Hz)

	Medium-size unit	Large unit
Cooling capacity (kW)	15.7	39.0
Electrical power consumption (total for indoor and outdoor units) (kW)	7.1/7.3	15.5/15.8
Indoor fan capacity (m^3/min)	90-70-52-36	230-180-140-100
Refrigerant	R22	Same as left

※ Operating conditions: an indoor unit inlet air temperature of 27°C DB, 19.5°C WB, and an outdoor unit inlet temperature of 32.5°C DB.

3.2 Measurement results

Measurements were taken over the period from June 20, 2003 to May 31, 2004. The results are presented in Table 3 and Figure 2. The operation rate (i.e., the share of the total operating time occupied by operation in the cooling mode) was calculated on the assumption that a difference of at least 5°C between the inlet and outlet temperatures on the indoor unit indicated operation in that mode.

Table 3; Results of measurement of electric air conditioners for telecommunications equipment rooms

	Medium-size unit	Large unit
Average power consumption (kW)	6.3	7.6
Average cooling output (kW)	15.2	24.3
Percentage of average rated cooling output (%)	96.8	62.3
Average outside air temperature (°C)	17.6	17.6
Outside air temperature standard deviation	8.14	8.14
Average inlet temperature (°C)	26.8	25.8
Inlet temperature standard deviation	0.45	0.63
Average outlet temperature (°C)	18.8	18.9
Outlet temperature standard deviation	2.31	1.57
Average sensible heat factor	0.91	0.92
Proportion of cooling operation (%)	94.1	98.3

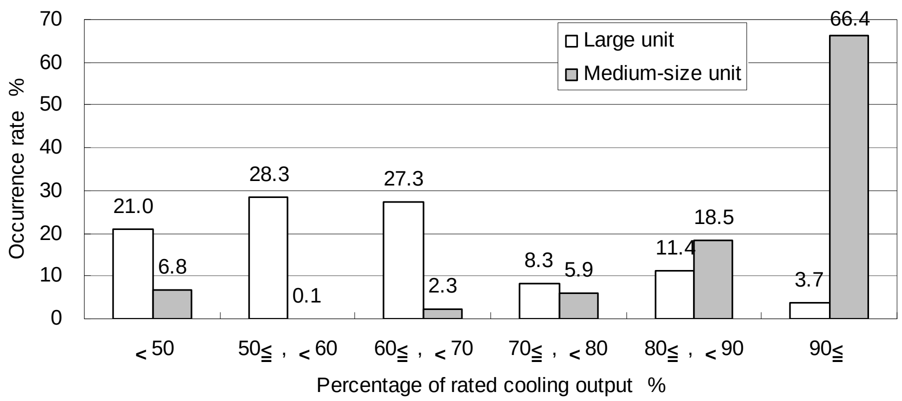

Figure 2: Rate of occurrence for cooling output as percentage of rated output -- comparison by unit size (large/medium)

The average rated output percentage came to 96.8% for the medium-size unit and 62.3%t for the large one. The rate of occurrence of cooling output amounting to at least 50% of the rated one was 93.2% for the former and 79.0% for the latter. Overall, the operating load could therefore be considered high. Regardless of the outside temperature, the temperature at the inlet of the indoor units stayed about the same. The outlet temperature remained below 20°C almost all the time. Although calculated values are only on the reference level because of the margin of error in hygrometer readings, the average sensible heat factor amounted to 0.91 for medium-size units and 0.92 for large ones. This indicated that the units were operated at high levels of sensible heat throughout the year.
The operation rate was 94.1% for the medium-size units and 98.3 for the large ones. The combined duration of fan-only operation and stoppage was therefore very short.

4 FIELD TESTING OF THE FIRST GHP PROTOTYPE

4.1 Profile of the prototype

The first GHP prototype was fabricated by modifing a conventional multitype outdoor unit (utilizing refrigerant R407C) for buildings that was first marketed in April 2003 and has a cooling capacity of 56.0 kW. It forms a system that connects two top-outlet floor-mounted indoor units, each with a base-capacity of 56.0 kW, with a single outdoor unit in order to increase the air-flow rate and the ability to handle a high level of sensible heat. In addition, the team made a change from a standard unit to simultaneous operation of two indoor units, and modified the ceiling capacity of the connected indoor units and refrigerant pressure control. In the light of the need for unmanned operation of the equipment in communications equipment rooms, the team added a function for automatic restart after power outages to the indoor units. Upon resumption of the power supply, the units restart at the settings made before the outage. Table 4 shows the specifications of the first prototype.

4.2 Field testing results

4.2.1 Process

The field test was conducted from March 10, 2004 to February 3, 2005 (Data measurement started on March 11, 2004). In the testing on 10 March, the team found that the inlet temperature was low due to the operation of an existing air conditioner installed in back of the GHP, and consequently decided to commence operation at an evaporation temperature that was somewhat lower than the initial setting. Nevertheless, they halted the operation of the existing air conditioner to raise the load, in reaction to its frequent stoppage by tripping of the thermostat and to the continued problem-free operation of the test units. At the same time, they restored the evaporation temperature to the initial setting and resumed the operation. Thereafter, they lowered the evaporation temperature setting somewhat on September 7, 2004 in response to a request for reduction of the outlet temperature.

Table 4; Specifications of the first GHP prototype

(3-phase 200V 50Hz/60Hz)

Cooling capacity (kW)		56.0
Outdoor unit	Fuel consumption (kW)	40.9 (City gas 13A)
	Electrical power consumption (kW)	1.46/1.82
	Number of compressors	2
Indoor unit	Type	Floor-mounted type (top outlet)
	Electrical power consumption (kW)	2.17/2.30
	Fan capacity (m^3/min)	165

※ Operating conditions: an indoor unit inlet air temperature of 24°C DB, 17°C WB, and an outdoor unit inlet temperature of 35°C DB.

※ Sensible heat factor under these conditions was 0.93.

4.2.2 Tests results

The test results are shown in Table 5 and figures 3, 4, 5, and 6. The average cooling output was 40.8 kW, or 72.8% of the rated output. There were no days on which the cooling output was less than 50% of the rated output; the units operated at a high load even when the outside temperature was low. The average coefficient of performance (COP) during the measurement period was satisfactory at 1.84, or 1.40 times as high as the rated value. The operation duration totaled 7,893 hours, for an operating rate of 99.8%. Stop-start cycles numbered 236, but nearly 80% of them derived from the tripping of the thermostat before the operation of the existing air conditioner was halted. After the existing air conditioner was turned off, there were no thermostat- induced stoppages, only stoppages due to the lubricant supply control, and these occurred only about once every six days. Calculation from readings for the indoor unit inlet and outlet temperature and humidity yielded a figure of 0.99 for the average sensible heat factor during the measurement period. The team did not detect any derivation of drain water even upon a visual check of the drain pan.

Table 5; Field testing results for the first GHP prototype

Outdoor unit average power consumption (kW)	1.22
Outdoor unit average fuel consumption (kW)	20.9
Average cooling output (kW)	40.8
Percentage of average rated cooling output (%)	72.8
Average COP	1.84
Average inlet temperature (°C)	21.6
Average outlet temperature (°C)	15.3
Operating time (h)	7893
Start-stop cycles (number of cycles)	236

※ COP is as defined in JIS B 8627-1. (The same definition applies hereinafter.)

4.2.3 Items of reflection in the second prototype

For the second prototype, the team decided to expand the condition of operation of two compressors, considering that the measurements for the electric air conditioners and the results of the field testing of the first prototype showed that the operating load was high. It also concluded to dispense with the lubricant supply control in order to shorten the stoppage duration. This is because the amount of lubricant consumption was expected to be low due to few thermostat- triggered stoppage.anticipated.

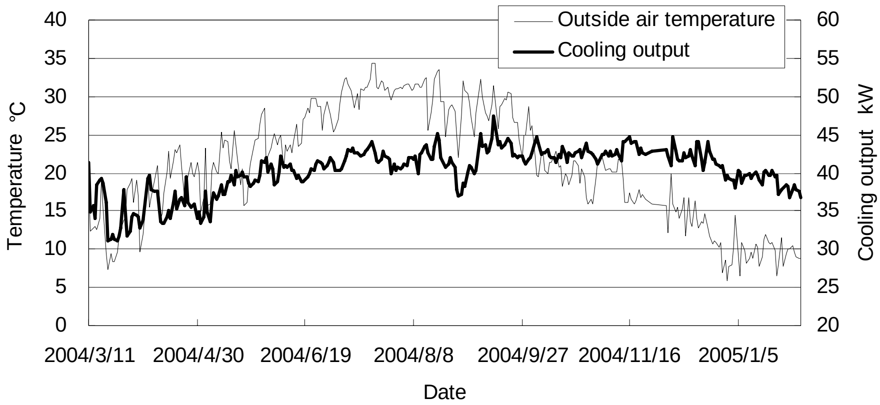

Figure 3: Trend of outside air temperature and cooling output in testing of the first prototype (daily average)

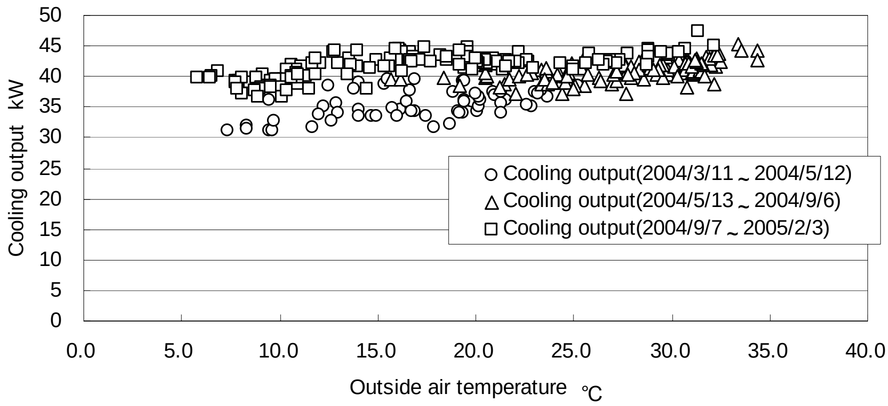

Figure 4: Outside air temperature and cooling output in testing of the first prototype (daily average)

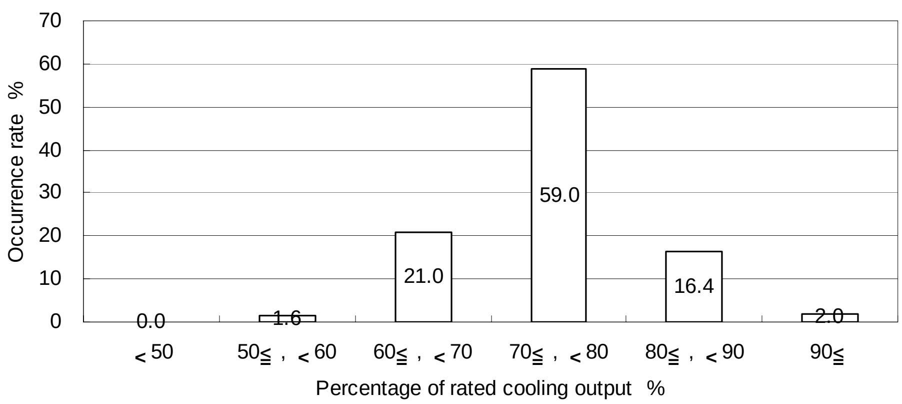

Figure 5: Rate of occurrence for cooling output as percentage of rated output in testing of the first prototype (daily average)

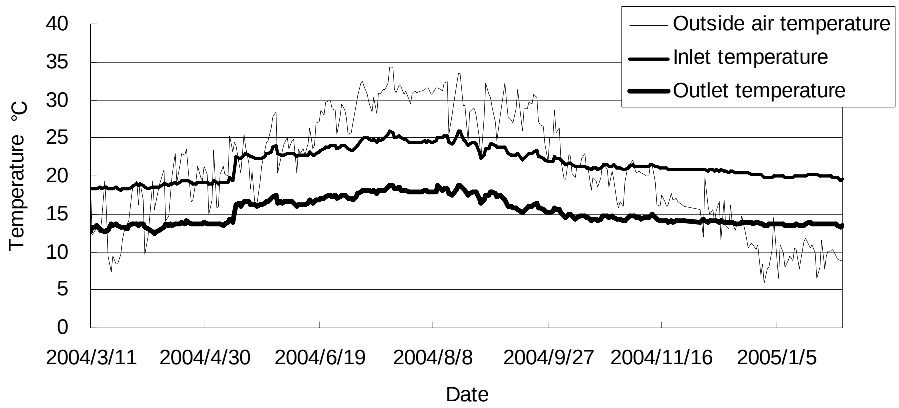

Figure 6: Outside air temperature, inlet temperature, and outlet temperature in testing of the first prototype (daily average)

5 FIELD TESTING OF THE SECOND GHP PROTOTYPE

5.1 Profile of the prototype

The second GHP prototype was fabricated by modifing a conventional multitype outdoor unit (utilizing refrigerant R410A) for buildings that was first marketed in April 2005 and has a cooling capacity of 56.0 kW. It forms a system that connects one bottom-outlet floor-mounted indoor unit with a single outdoor unit. It incorporated the items of reflection noted in Section (4.2.3) above and outlet temperature control. Because control of lubricant supply was not applied, the maintenance interval was changed from 10,000 hours to 6,000 hours. Table 6 shows the specifications of the first prototype.

5.2 Field testing results

5.2.1 Process

The field test was conducted from August 11, 2005 to March 31, 2007 (the data measurements were taken until March 31, 2006). Due to the relatively light indoor load, the team raised the temperature setting on the existing air conditioner and increased the load on the GHP system on 9 November 2005.

5.2.2 Test results

The test results are shown in Table 7 and figures 7, 8, 9, and 10. The average cooling output was 45.7 kW, or 81.5% of the rated output. As in the case of the testing with the first prototype, there were no days on which the cooling output was less than 50% of the rated output, and the units operated at a high load even when the outside temperature was low. The average COP during the measurement period was satisfactory at 1.77, or 1.18 times as high as the rated value. The operation duration totaled 5,551 hours, for an operating rate of 99.8%. Stop-start cycles numbered 26, but all stoppages were for maintenance or other such reasons; none were induced by the thermostat. A visual check of the drain pan as well did not detect any derivation of drain water, and confirmed that the operation was marked by a high level of sensible heat. The system remained in operation until March 31, 2007 in order to check the lubricant, but there were nevertheless no stoppages by the thermostat or shutdowns due to abnormalities.

Table 6; Specifications of the second GHP prototype

(3-phase 200V 50Hz/60Hz)

Cooling capacity (kW)		56.0
Outdoor unit	Fuel consumption (kW)	36.3 (City gas 13A)
	Electrical power consumption (kW)	1.04/1.15
	Number of compressors	2
Indoor unit	Type	Floor-mounted type (bottom outlet)
	Electrical power consumption (kW)	5.00/5.80
	Fan capacity (m^3/min)	320

※ Operating conditions: an indoor unit inlet air temperature of 24°C DB, 17°C WB, and an outdoor unit inlet temperature of 35°C DB.

※ Sensible heat factor under these conditions was 0.91.

Table 7; Field testing results for the second GHP prototype

Outdoor unit average power consumption (kW)	0.57
Outdoor unit average fuel consumption (kW)	25.24
Average cooling output (kW)	45.7
Percentage of average rated cooling output (%)	81.5
Average COP	1.77
Average inlet temperature (°C)	21.3
Average outlet temperature (°C)	15.0
Operating time (h)	5551
Start-stop cycles (number of cycles)	26

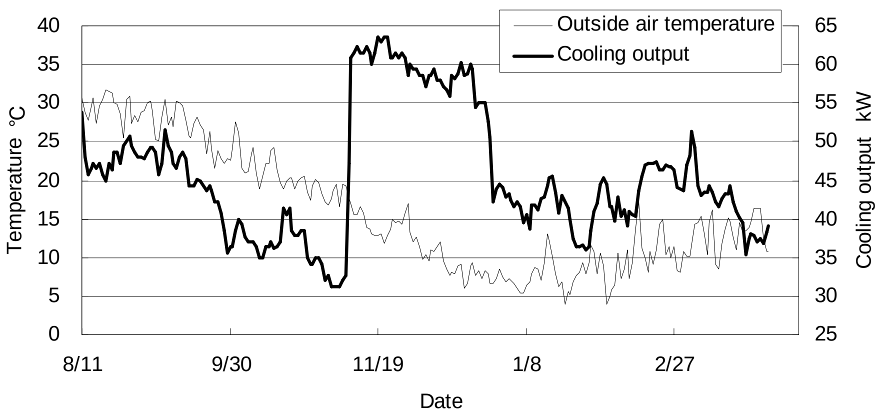

Figure 7: Trend of outside air temperature and cooling output in testing of the second prototype (daily average)

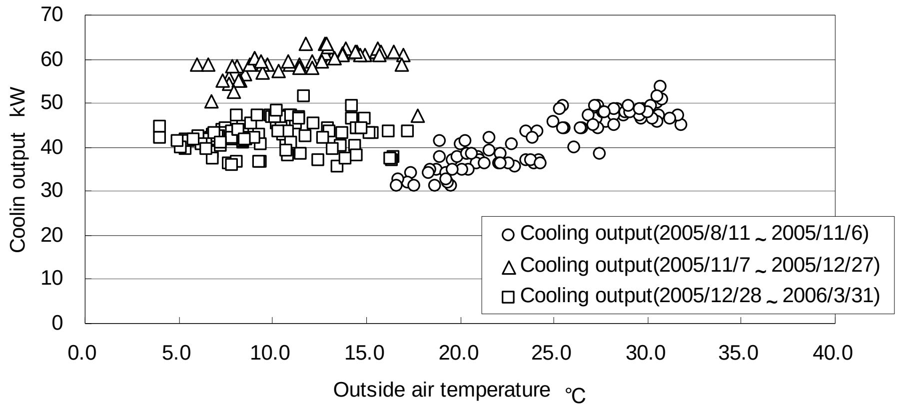

Figure 8: Outside air temperature and cooling output in testing of the second prototype (daily average)

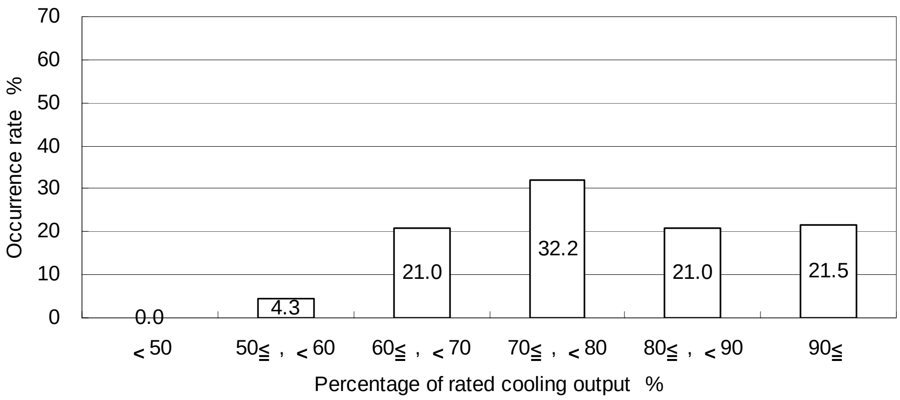

Figure 9: Rate of occurrence for cooling output as percentage of rated output in testing of the second prototype (daily average)

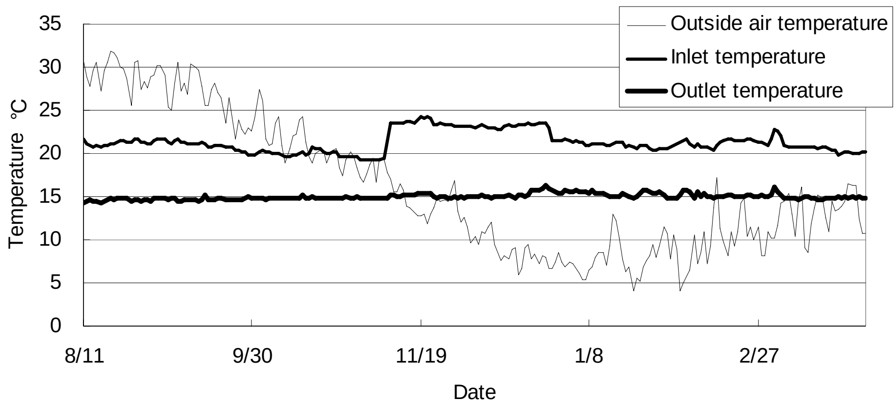

Figure 10: Outside air temperature, inlet temperature, and outlet temperature in testing of the second prototype (daily average)

5.2.3 Confirmation of specifications

The team confirmed the following specifications through the field testing.

a) Applicatuon of an indoor unit with outlet temperature control
b) Exclusion of lubricant supply control
c) Maintenance interval of 6,000 hours
d) Automatic restart upon resumption of power supply after outages

e) Exclusion of communications among outdoor units in order to shorten the automatic restart time

The check of the lubricant in the second prototype revealed little deterioration of the lubricating action and confirmed that the maintenance interval could be lengthened to 8,760 hours or one year. Continued studies are to be made in order to examine the prospect of such a lengthening (i.e., to 8,760 hours or one year) for several commercial systems.

6 CONCLUSION

a) The team ascertained the operating characteristics of air conditioners for communications equipment rooms through measurement of values for electric-powered air conditioners and field tests.
b) In the field testing, the GHP system operated around the year in the cooling mode with a high level of sensible heat without stoppages due to abnormality, and demonstrated high reliability.
c) The first GHP designed for use in air-conditioning communications equipment rooms was commercially launched in April 2007.

7 REFERENCES

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8 ACKNOWLEDGEMENTS

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