DEVELOPMENT OF ENERGY PERFORMANCE COMPARISON METHOD FOR RESIDENTIAL ELECTRIC APPLIANCES – APPLICATION TO AIR CONDITIONERS

Hoang-Luong Pham, Vice President, Hanoi University of Science and Technology, Hanoi, Vietnam*
Viet-Dung Nguyen, Ngoc-Anh Lai, Deputy Directors, Institute of Heat Engineering and Refrigeration, Hanoi University of Science and Technology, Hanoi, Vietnam
Nguyen-An Nguyen, Head of Heat Engineering Department, Institute of Heat Engineering and Refrigeration, Hanoi University of Science and Technology, Hanoi, Vietnam
Shogo Tokura, International Manager, Heat Pump and Thermal Storage Technology Center, Tokyo, Japan
Satoshi Nakamura, Senior Consultant, Mitsubishi UFJ Morgan Stanley Securities, Ltd., Tokyo, Japan
**Corresponding Author, email: hoang-luongpham@mail.hut.edu.vn*

Abstract: An investigation was carried out on a simple and easy measurement laboratory set-up to compare the energy performance of a non-inverter air-conditioner (AC) and that of an inverter one having the same rated capacity of 12000 BTU/hr. Under part load ratios of 45%, 70%, and 95% and outside-inside temperature differences of from 1K to 7K, it was found that the inverter AC can save 9.3% to 26.9% of electricity consumption over the non-inverter one. It also showed that the use of inverter AC instead of non-inverter AC is most effective in reducing energy consumption at a part load ratio of 70%. The coefficient of performance (COP) of the inverter AC and non-inverter AC was found in the range of from 3.4 to 6.3 and from 3.0 to 4.9, respectively. This work has shown a potentially suitable use of the developed set-up to demonstrate the energy performance of other modern electrical appliances that would be used in developing countries to reduce energy consumption and CO_2 emissions.

Key words: Air Conditioner (AC), inverter, comparison, coefficient of performance (COP), energy saving

1 INTRODUCTION

During the last decade, energy consumption in the residential sector in Vietnam has been increasing with an average growth rate of 8% per annum. This is caused by a modernized life style especially in urban cities where a rapid progress in diffusion of home electrical appliances such as refrigerators, electric water heaters, and air conditioners can be observed In 2006, the Government of Vietnam endorsed the Vietnam National Energy Efficiency Program (VEEP) to promote energy efficiency technologies and management thus contributing to a saving in investment in the power sector. The VEEP targeted to reduce 3% to 5% and 5 % to 8 % of the energy consumption for 2006-2010 and 2011-2015, respectively compared to the business as usual scenarios for these two periods (VNG 2006). Identifying and then promoting nation-wide high energy efficiency appliances is therefore needed to meet the demand from the local end-users and yet achieve the targets of the VEEP.

In subtropical regions, AC is normally used for comfort of the occupants in the residential and commercial sectors. Recent surveys in Hanoi indicated that energy consumption for AC normally accounts for 30% to 60% of the total electricity use in most residential buildings (Pham et al. 2010). In Hong Kong, AC is the single largest electricity consuming item accounting for 40% to 60% of the total electricity use in commercial buildings (Chan 1994), (Lam and Chan 1995). The introduction of high energy efficiency AC is therefore significantly important for energy saving in all building types in the regions.

A number of studies has been conducted on the coefficient of performance (COP) of ACs. Shao et al. pointed out that the COP of an inverter AC is highly influenced by its compressor frequency (Shao et al. 2004). Yu and Chan found that the highest COP of air-cooled centrifugal chillers occurs at a part load ratio of 0.71-0.84 rather than at full load (Yu and Chan 2007). For a 10 Hp variable refrigerant volume AC, a maximum value of 3.8 was stated by Zhu for its COP at a part load ratio of 40% (Zhu 2006).

As recommended by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRE), a standard laboratory system is commonly utilized that can artificially control both indoor and outdoor environmental conditions to provide highly accurate evaluation for energy performance of electric appliances. Such comprehensive system is however not affordable in most developing countries. This study focuses on the development of a least cost and yet simple method to investigate the energy performance of non-inverter and inverter ACs. It is expected that the developed method would be potentially applicable for verifying energy savings of other modern electric appliances.

2 EXPERIMENTAL SET-UP AND CALCULATION METHOD

2.1 Experimental Set-up

An experimental set-up was designed, fabricated and constructed in Hanoi University of Science and Technology (HUST), as shown in Figure 1.

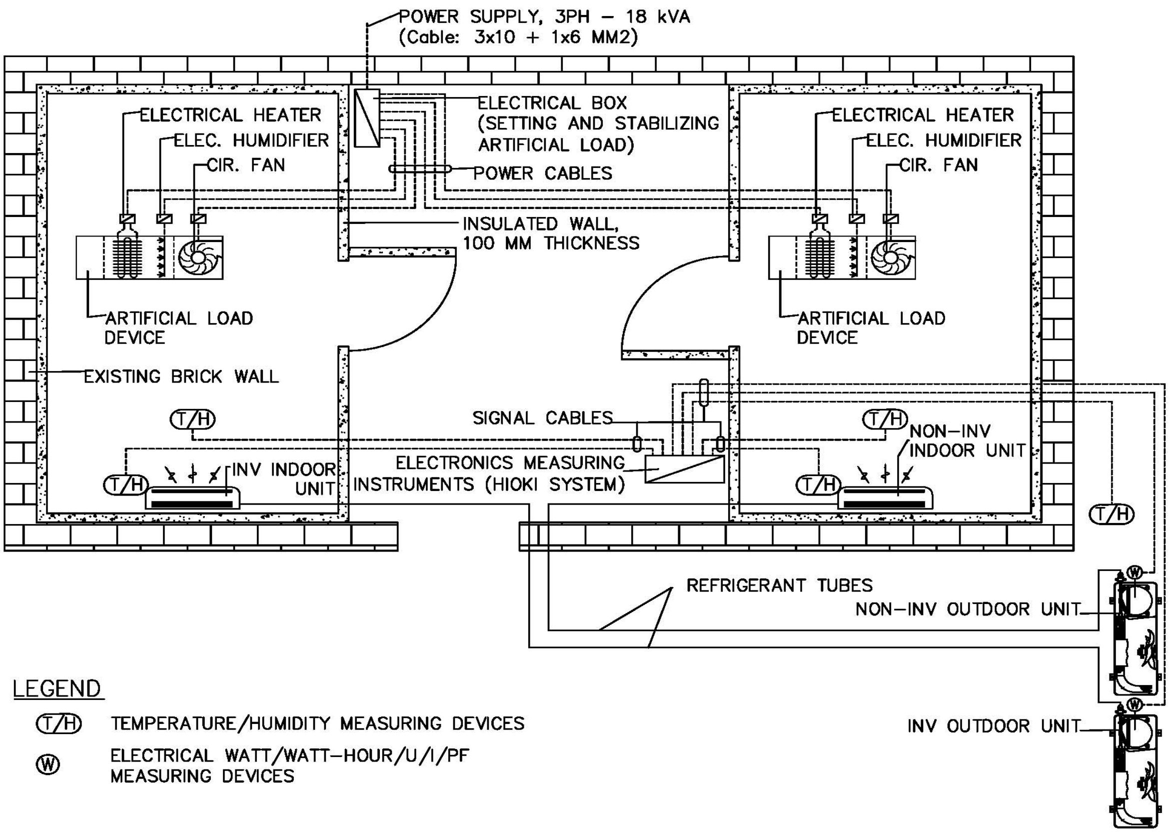

Figure 1: A schematic diagram of the experimental set-up

The set-up consists of two identical testing rooms each having a dimension of 4.9 m width, 3.0m length and 3.2m height. The walls and ceilings of each room were formed with 100mm thickness polystyrene panels. For each room, a door was made using the 100mm thickness polystyrene panel and rubber is used as a frame for keeping it airtight.

In one room, a non-inverter AC of 12,000 BTU/hr rated capacity was installed while in the other, an inverter AC having the same rated capacity was provided. In each room, an artificial load device was made from two electric heaters of 2 kW each, an electric humidifier of 2 kW, and a circulation fan. The artificial heating load can be set manually. Finally, a HIOKI system with high accuracy temperature and humidity sensors, and power cramp was finally installed in the set-up for the ACs' inlet, outlet, ambient conditions, and power measurement and recording.

2.2 Calculation Method

For each testing room, power of AC can be calculated as below.

$$P = V \times I \times PF \quad (1)$$

where P is in W. V, I and PF are voltage (in V), current (in Ampere) and power factor (in %) of AC, respectively. All of these quantities are measured and recorded by the HIOKI instrument during the experiments.

Coefficient of performance of an AC is defined by the following equation.

$$COP = Q_o / P \quad (2)$$

where Q_0 is cooling capacity. The values of Q_0 can be obtained from flow rate of the air through the AC and the measured temperature, relative humidity. It is noticed that for each testing room, the cooling capacity is the sum of artificial heat load and natural heat load. The latter includes: i) heat transferred through the envelope of the room due to outdoor - indoor temperature difference, ii) heat present in the leak air from outside into the room, iii) heat stored in the room structure and other objects in the room, and iv) heat present in the indoor air.

3 EXPERIMENTAL PROCEDURES, RESULTS AND DISCUSSIONS

3.1 Airtightness and Insulation Test

Before starting the investigation on energy performance of the ACs, quality of air tightness and of insulation for each testing room was carefully checked by measuring the amount of drained water coming out from its respective AC.

For this test, the doors of the two rooms were first kept closed. By turning off the artificial heating system, the ACs were simultaneously turned on with a 20^{o}C setting. During this operation, the amount of drained water coming out from each AC was measured in every 10 minutes. After a couple of minor adjustments, the amounts of water from both rooms were found identically increasing and they became stable after 3 hours of operation, as shown in Table 1.

Change in enthalpy of the air in the two rooms after turning off the ACs is mainly due to the variation of the natural heat load during the experiments. This change can be defined based upon the measured temperature and relative humidity of the air.

By operating the set-up with the same indoor temperature of 20^{o}C for both ACs and under various artificial heat load conditions, an averaged value of the natural heat load were found to be approximately 811 W (Pham et al. 2010). This value can be used to evaluate the energy performance of the two ACs used in this study.

Table 1: Drained water from the two testing rooms

No.	Time	Drained water [g]	
		In the room with Inverter AC	In the room with Non-Inverter AC
1	14.20	35.2	17.3
2	14.30	258.8	246
3	14.40	399.7	406.5
4	14.50	471.4	458.2
5	15.00	484.2	474.3
6	15.10	489.1	479.3
7	15.20	494.9	488.7
8	15.30	500.4	498.6
9	15.40	504.5	510.5
10	15.50	512.3	518.8
11	16.00	521.9	526
12	16.10	526.5	532.9
13	16.20	538.0	540.2
14	16.30	551.0	547.8
15	16.40	561.6	553.1
16	16.50	572.0	562.9
17	17.00	585.6	571.6
18	17.10	598.8	579.7

3.2 Humidifier and Heater Test

The test of humidifiers was carried out by using the same power supply of 549W for each humidifier for 14 hours continuously. During the test, the doors of testing rooms were closed, the indoor temperatures of the ACs were set at 20^0C. At the end of this test, the amounts of drained water from the non-inverter and inverter ACs were 9158.5 g (654.2 g/hr) and 9170.2 g (655.0 g/hr), respectively. This result proves that the two humidifiers generate the same amount of moisture with the same power input.

The humidifiers and heaters of the 2 artificial load devices used electricity as the energy source. Power of humidifiers and heaters was controlled by the pulse width modulation method. This makes it feasible to create a variety of indoor conditions for the experimental study on energy performance of the ACs.

3.3 Energy Performance of The Air Conditioners

In order to evaluate and compare the power (P) and COP of the inverter and non-inverter ACs, 2 experimental cycles were carried out in HUST with target indoor temperatures of 25°C and 27°C and under 3 artificial heat load ratios of 25%, 50%, 75% of its rated capacity for each day during August 22 to September 3, 2010. In the last day, for each room, the artificial heat load was changed in every 2 hours for the values of 25%, 50%, 75%. Taking into account the averaged natural heat load of 811 W, the part load ratios for the ACs were finally calculated as 45%, 70% and 95% of their rated capacity.

The experimental parameters such as voltage, current, power factor of the ACs, temperature at the inlet and outlet of the cooling units, temperature of the ambience where the condensing units are located were measured in every minute with the HIOKI instrument. Due to the instability and long thermal respond time of sensors and experimental data, difference in outside - inside temperatures, cooling load, power consumption and COP for each AC were calculated on every 30 minute basis. A complete set of the experimental data were given elsewhere (Pham et al. 2010). Some selected experimental data and calculated results are given in Table 2. It is noticed that there were some sudden rainy and thus cool periods of time during the experimental work. As a result, the outdoor temperatures in such periods were found to be lower than the indoor ones.

Table 2: Experimental data and calculated results of the non-inverter and inverter ACs

Date	Real time from	Real time to	Part load ratio [%]	$\Delta T = t_{outside} - t_{inside}$ (K)		Q_0 [kW]	Inverter AC		Non-inverter AC	
				inverter	Non-inverter		P [kW]	COP [-]	P [kW]	COP [-]
25-Aug	08:30	09:00	45	0.83	0.55	1.6	0.30	5.25	0.34	4.64
25-Aug	09:00	09:30	45	1.44	1.08	1.6	0.30	5.19	0.38	4.14
25-Aug	09:30	10:00	45	1.88	1.54	1.6	0.31	5.17	0.35	4.50
26-Aug	15:00	15:30	45	2.70	2.09	1.6	0.27	5.84	0.35	4.54
25-Aug	21:30	22:00	45	2.87	2.72	1.6	0.31	5.08	0.41	3.81
26-Aug	15:30	16:00	45	2.96	2.28	1.6	0.27	5.90	0.38	4.12
26-Aug	16:00	16:30	45	3.07	2.34	1.6	0.28	5.72	0.34	4.61
26-Aug	18:00	18:30	45	3.07	2.40	1.6	0.27	5.83	0.32	4.92
26-Aug	17:30	18:00	45	3.26	2.54	1.6	0.25	6.23	0.32	4.95
25-Aug	21:00	21:30	45	3.28	2.64	1.6	0.28	5.59	0.32	5.00
26-Aug	16:30	17:00	45	3.41	2.62	1.6	0.28	5.70	0.35	4.53
26-Aug	17:00	17:30	45	3.47	2.66	1.6	0.27	5.84	0.36	4.43
01-Sep	08:30	09:00	45	4.22	2.69	1.6	0.31	5.11	0.37	4.27
01-Sep	09:00	09:30	45	4.83	3.54	1.6	0.33	4.83	0.41	3.81
01-Sep	21:00	21:30	45	5.66	4.42	1.6	0.32	4.99	0.34	4.61
26-Aug	14:00	14:30	45	5.84	4.69	1.6	0.33	4.85	0.33	4.74
26-Aug	09:00	09:30	45	6.03	5.11	1.6	0.33	4.85	0.41	3.88
26-Aug	13:30	14:00	45	6.06	4.92	1.6	0.29	5.39	0.32	4.92
01-Sep	09:30	10:00	45	6.16	4.54	1.6	0.32	4.95	0.38	4.13
01-Sep	20:30	21:00	45	6.26	4.59	1.6	0.33	4.85	0.42	3.75
26-Aug	09:30	10:00	45	6.64	5.47	1.6	0.29	5.37	0.38	4.19
26-Aug	10:00	10:30	45	6.95	5.91	1.6	0.33	4.77	0.41	3.84
26-Aug	13:00	13:30	45	7.97	6.98	1.6	0.31	5.16	0.42	3.79
26-Aug	10:30	11:00	45	8.13	6.80	1.6	0.34	4.67	0.34	4.64
26-Aug	12:30	13:00	45	8.73	7.35	1.6	0.34	4.58	0.42	3.81
26-Aug	12:00	12:30	45	9.00	7.64	1.6	0.35	4.55	0.42	3.76
26-Aug	11:30	12:00	45	9.07	7.73	1.6	0.34	4.59	0.38	4.14
26-Aug	11:00	11:30	45	9.24	7.88	1.6	0.34	4.60	0.35	4.56
27-Aug	17:00	17:30	45	0.25	-0.34	1.6	0.23	6.92	0.32	5.07
27-Aug	15:30	16:00	45	0.75	0.10	1.6	0.25	6.43	0.31	5.27
27-Aug	13:30	14:00	45	0.76	-0.19	1.6	0.25	6.42	0.28	5.82
27-Aug	16:00	16:30	45	0.77	0.18	1.6	0.27	6.06	0.32	5.07
27-Aug	16:30	17:00	45	0.77	0.22	1.6	0.24	6.73	0.28	5.70
27-Aug	14:00	14:30	45	0.83	0.25	1.6	0.22	7.50	0.28	5.75
27-Aug	15:00	15:30	45	1.01	0.40	1.6	0.23	6.98	0.32	5.12
27-Aug	14:30	15:00	45	1.07	0.48	1.6	0.23	7.05	0.28	5.83
25-Aug	19:30	20:00	70	2.21	2.80	2.5	0.52	4.71	0.65	3.81
25-Aug	19:00	19:30	70	2.53	2.96	2.5	0.41	6.04	0.65	3.79
25-Aug	11:30	12:00	70	4.03	3.53	2.5	0.56	4.40	0.66	3.75

22-Aug	18:30	19:00	70	4.47	3.75	2.5	0.53	4.63	0.65	3.79
22-Aug	16:30	17:00	70	4.49	3.85	2.5	0.53	4.68	0.60	4.08
22-Aug	18:00	18:30	70	4.51	3.74	2.5	0.53	4.63	0.71	3.44
22-Aug	17:30	18:00	70	4.51	3.88	2.5	0.53	4.61	0.73	3.39
01-Sep	11:00	11:30	70	4.55	4.65	2.5	0.48	5.13	0.63	3.90
22-Aug	17:00	17:30	70	4.62	3.95	2.5	0.53	4.64	0.65	3.79
01-Sep	19:00	19:30	70	4.85	4.94	2.5	0.53	4.65	0.58	4.23
01-Sep	18:30	19:00	70	4.99	4.93	2.5	0.44	5.53	0.65	3.76
01-Sep	10:30	11:00	70	4.99	4.45	2.5	0.52	4.77	0.74	3.33
01-Sep	11:30	12:00	70	5.32	5.27	2.5	0.53	4.63	0.67	3.65
22-Aug	16:00	16:30	70	6.31	5.83	2.5	0.56	4.42	0.71	3.47
22-Aug	14:30	15:00	70	6.53	6.05	2.5	0.56	4.38	0.72	3.41
22-Aug	15:30	16:00	70	6.67	6.34	2.5	0.56	4.40	0.81	3.05
22-Aug	12:30	13:00	70	6.79	6.75	2.5	0.56	4.36	0.76	3.24
22-Aug	15:00	15:30	70	6.88	6.55	2.5	0.56	4.39	0.68	3.64
22-Aug	14:00	14:30	70	7.01	6.70	2.5	0.56	4.37	0.78	3.17
22-Aug	12:00	12:30	70	7.06	7.02	2.5	0.57	4.35	0.69	3.56
22-Aug	13:00	13:30	70	7.44	7.13	2.5	0.57	4.34	0.77	3.21
22-Aug	13:30	14:00	70	7.59	7.35	2.5	0.57	4.31	0.70	3.54
28-Aug	14:30	15:00	70	-2.96	-2.55	2.5	0.33	7.51	0.48	5.26
28-Aug	16:30	17:00	70	-2.94	-2.55	2.5	0.33	7.49	0.55	4.58
28-Aug	16:00	16:30	70	-2.83	-2.33	2.5	0.34	7.46	0.55	4.57
28-Aug	15:00	15:30	70	-2.74	-2.29	2.5	0.34	7.47	0.45	5.58
28-Aug	15:30	16:00	70	-2.62	-2.16	2.5	0.34	7.46	0.48	5.20
23-Aug	15:00	15:30	95	0.01	0.62	3.3	0.69	4.83	0.84	3.95
23-Aug	14:00	14:30	95	0.07	0.45	3.3	0.73	4.54	0.83	4.00
23-Aug	18:30	19:00	95	0.07	0.64	3.3	0.73	4.59	0.83	4.00
23-Aug	17:30	18:00	95	0.47	1.21	3.3	0.76	4.38	0.92	3.63
23-Aug	15:30	16:00	95	0.52	1.48	3.3	0.70	4.79	0.83	4.03
23-Aug	16:00	16:30	95	0.53	1.32	3.3	0.70	4.75	0.94	3.56
23-Aug	17:00	17:30	95	0.84	1.81	3.3	0.71	4.70	0.88	3.79
23-Aug	16:30	17:00	95	1.03	1.89	3.3	0.78	4.27	0.95	3.50
02-Sep	10:00	10:30	95	1.05	3.40	3.3	0.90	3.69	1.14	2.92
02-Sep	10:30	11:00	95	1.59	3.96	3.3	0.91	3.67	1.15	2.91
02-Sep	11:00	11:30	95	2.18	4.58	3.3	0.91	3.65	1.15	2.90
02-Sep	18:30	19:00	95	2.41	4.13	3.3	0.89	3.75	1.02	3.28
02-Sep	18:00	18:30	95	2.63	4.30	3.3	0.89	3.73	1.02	3.28
02-Sep	11:30	12:00	95	2.65	5.13	3.3	0.92	3.63	1.16	2.87
25-Aug	17:00	17:30	95	2.70	4.18	3.3	0.89	3.76	0.97	3.44
02-Sep	17:30	18:00	95	2.78	4.72	3.3	0.90	3.69	1.03	3.25
25-Aug	17:30	18:00	95	2.88	3.96	3.3	0.88	3.80	0.97	3.43
02-Sep	12:00	12:30	95	3.15	5.67	3.3	0.93	3.60	1.16	2.87
02-Sep	17:00	17:30	95	3.16	5.10	3.3	0.91	3.66	1.04	3.22
02-Sep	16:30	17:00	95	3.29	5.59	3.3	0.92	3.64	1.15	2.91
02-Sep	16:00	16:30	95	3.35	5.55	3.3	0.92	3.63	1.04	3.21
02-Sep	12:30	13:00	95	3.39	6.10	3.3	0.93	3.58	1.18	2.84
02-Sep	14:30	15:00	95	3.72	6.36	3.3	0.93	3.58	1.17	2.86
02-Sep	15:30	16:00	95	3.73	6.39	3.3	0.93	3.59	1.16	2.87
02-Sep	13:00	13:30	95	3.93	6.50	3.3	0.94	3.56	1.18	2.84
02-Sep	15:00	15:30	95	3.95	6.58	3.3	0.93	3.57	1.17	2.86
02-Sep	14:00	14:30	95	4.11	6.71	3.3	0.94	3.56	1.17	2.85
25-Aug	13:00	13:30	95	4.19	4.98	3.3	0.89	3.76	0.98	3.41

02-Sep	13:30	14:00	95	4.32	6.89	3.3	0.94	3.55	1.18	2.83
23-Aug	09:00	09:30	95	4.45	4.67	3.3	0.87	3.84	0.99	3.38
23-Aug	10:00	10:30	95	4.58	6.12	3.3	0.91	3.65	1.01	3.32
01-Sep	16:30	17:00	95	4.69	6.03	3.3	0.92	3.61	1.05	3.18
01-Sep	17:00	17:30	95	4.80	5.57	3.3	0.91	3.65	0.92	3.61
25-Aug	13:30	14:00	95	4.81	5.69	3.3	0.89	3.76	1.01	3.29
23-Aug	09:30	10:00	95	5.23	5.60	3.3	0.88	3.78	1.00	3.36
23-Aug	10:30	11:00	95	5.41	6.89	3.3	0.92	3.62	1.12	2.97
01-Sep	12:30	13:00	95	5.67	6.19	3.3	0.92	3.62	0.94	3.55
23-Aug	13:30	14:00	95	5.86	6.35	3.3	0.90	3.69	1.00	3.33
23-Aug	11:00	11:30	95	6.24	7.57	3.3	0.93	3.60	1.14	2.94
23-Aug	13:00	13:30	95	6.61	7.21	3.3	0.92	3.61	1.02	3.26
23-Aug	11:30	12:00	95	6.63	7.92	3.3	0.93	3.60	1.14	2.92
23-Aug	12:00	12:30	95	6.75	7.55	3.3	0.93	3.59	1.07	3.12
01-Sep	13:00	13:30	95	6.77	6.88	3.3	0.93	3.58	1.07	3.12
23-Aug	12:30	13:00	95	6.85	7.76	3.3	0.93	3.58	1.14	2.92

3.3.1 Power of The Air Conditioners

From Table 2, it is seen that the common range of outside-inside temperature difference under different part load conditions was about 0K to 7K. The change in power of the non-inverter and inverter ACs at part load values of 45%, 70% and 95% due to this temperature difference is illustrated in Figure 2. For both ACs, the power is observed to increase with an increase in the temperature difference and also with increase in part load ratios. It appears that these experimental observations are agreed well with theoretical principles of air conditioning systems.

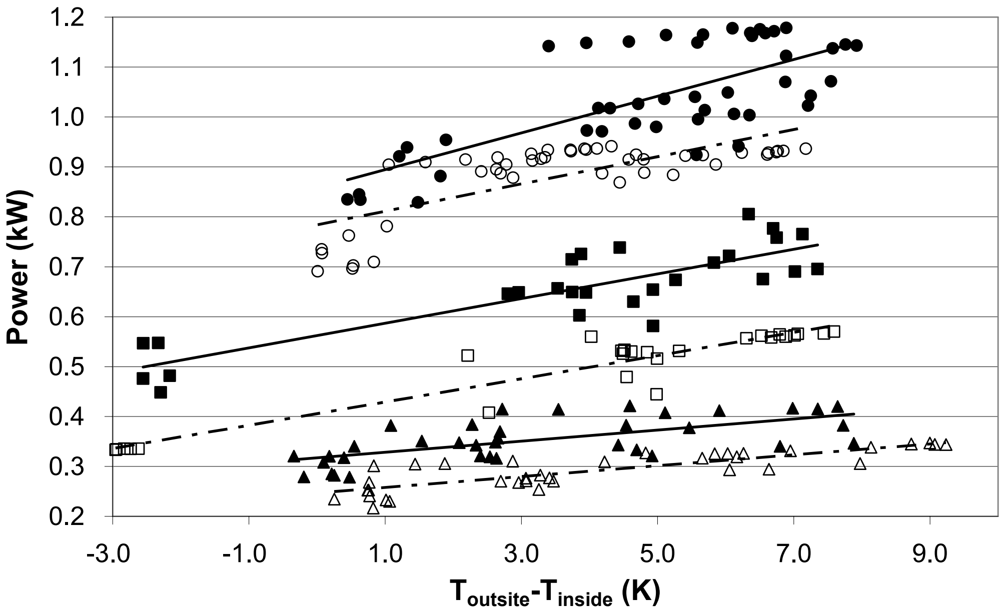

Figure 2: Effect of temperature differences on the power of the inverter AC at part load ratios of ○ 95%, □ 70% and Δ 45% (-------), and that of the non-inverter AC at part load ratios of ● 95%, ■ 70%, and ▲ 45% (—)

For each part load ratio of 45%, 70% and 95%, comparison in power between the non-inverter and inverter ACs was made with 4 values of averaged temperature difference i.e 1, 3, 5 and 7 K, as given in Table 3 and also illustrated in Figures 3 and 4.

Table 3: Comparison in power between the non-inverter and inverter ACs

ΔT [K]	Part load ratio [%]	Power of the inverter AC [kW] (1)	Power of the non-inverter AC, [kW] (2)	(2) – (1) [kW]	{(2) – (1)} / (2) [%]
1	45	0.258	0.328	0.071	21.5
3	45	0.280	0.351	0.071	20.3
5	45	0.301	0.373	0.071	19.2
7	45	0.323	0.395	0.072	18.2
1	70	0.429	0.587	0.158	26.9
3	70	0.475	0.636	0.161	25.3
5	70	0.522	0.686	0.164	23.9
7	70	0.568	0.735	0.167	22.7
1	95	0.811	0.894	0.083	9.3
3	95	0.866	0.968	0.102	10.6
5	95	0.920	1.042	0.121	11.6
7	95	0.975	1.115	0.140	12.6

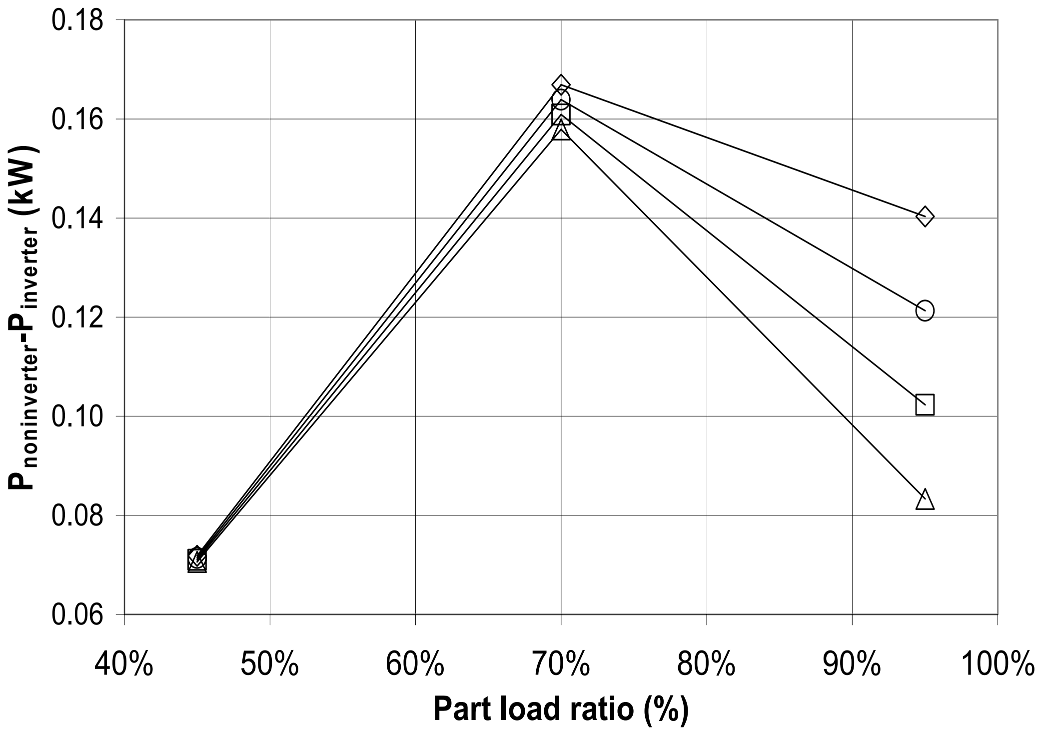

Figure 3: Effect of part load ratio on the absolute power difference between the non-inverter and inverter ACs at various outside-inside temperature differences of Δ 1K, □ 3K, ○ 5K, and ◊ 7K

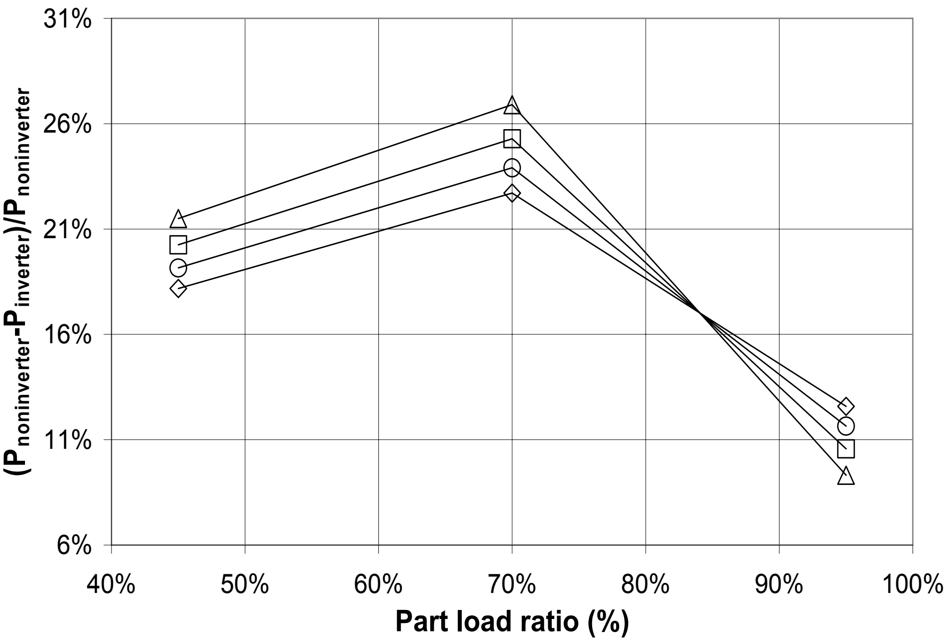

Figure 4: Effect of part load ratio on the relative power difference between the non-inverter and inverter ACs at various outside-inside temperature differences of Δ 1K, □ 3K, ○ 5K, and ◊ 7K

Figures 3 and 4 show that the inverter AC is mostly effective in energy consumption reduction at a part load ratio of 70%. The results are agreed well with the experimental observations by Yu and Chan (Yu and Chan 2007).

3.3.2 Coefficient of Performance of The Air Conditioners

From Table 2, it is also found the change in COP of the non-inverter and inverter ACs at part load ratios of 45%, 70% and 95% due to variation of the difference between indoor and outdoor temperatures. At a part load ratio of 45% for both ACs, the COP is observed to decrease with an increase in the temperature difference, as seen in Figure 5. Similar trends could be obtained for 70% and 95% part load ratios (Pham et al. 2010).

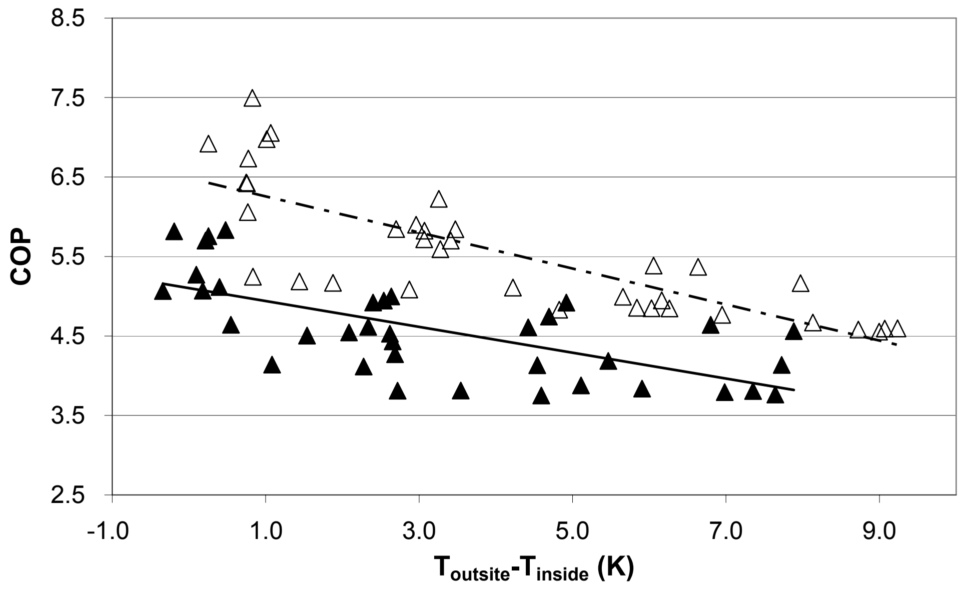

Figure 5: Effect of temperature difference on the COP of the inverter AC (Δ,---) and that of the non-inverter AC (▲, —) at a part load of 45%

The comparison in COP between the non-inverter and inverter ACs was made under different part load ratios with the same values of averaged temperature difference i.e 1, 3, 5 and 7 K. The calculated data are given in Table 4 and are also represented in Figures 6 and 7.

Table 4: Comparison in COP between the non-inverter and inverter ACs

ΔT [K]	Part load ratio [%]	COP of the inverter AC [-] (1)	COP of the non-inverter AC [-] (2)	(1) – (2) [-]	{(1) – (2)} / (2) [%]
1	45	6.26	4.94	1.32	26.7
3	45	5.80	4.61	1.19	25.8
5	45	5.35	4.29	1.06	24.7
7	45	4.89	3.96	0.93	23.5
1	70	6.09	4.35	1.74	40.1
3	70	5.45	3.99	1.46	36.6
5	70	4.81	3.63	1.18	32.5
7	70	4.17	3.27	0.90	27.5
1	95	4.17	3.75	0.43	11.4
3	95	3.90	3.49	0.41	11.6
5	95	3.63	3.24	0.39	11.9
7	95%	3.35	2.99	0.37	12.2%

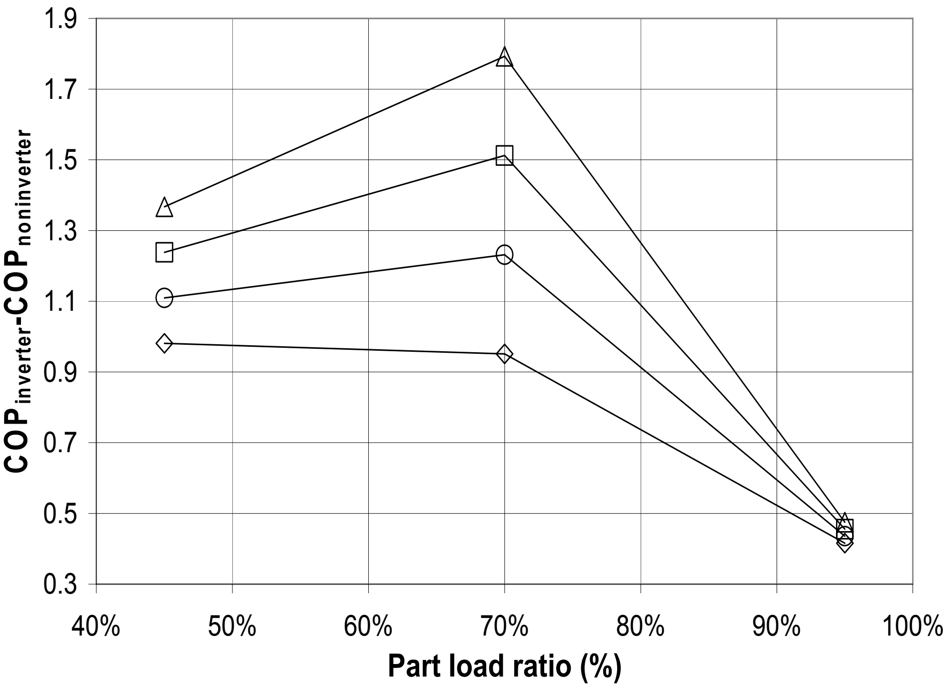

Figure 6: Effect of part load ratio on the absolute COP difference between the inverter and non-inverter ACs at various outside-inside temperature differences of Δ 1K, □ 3K, ○ 5K, and ◊ 7K

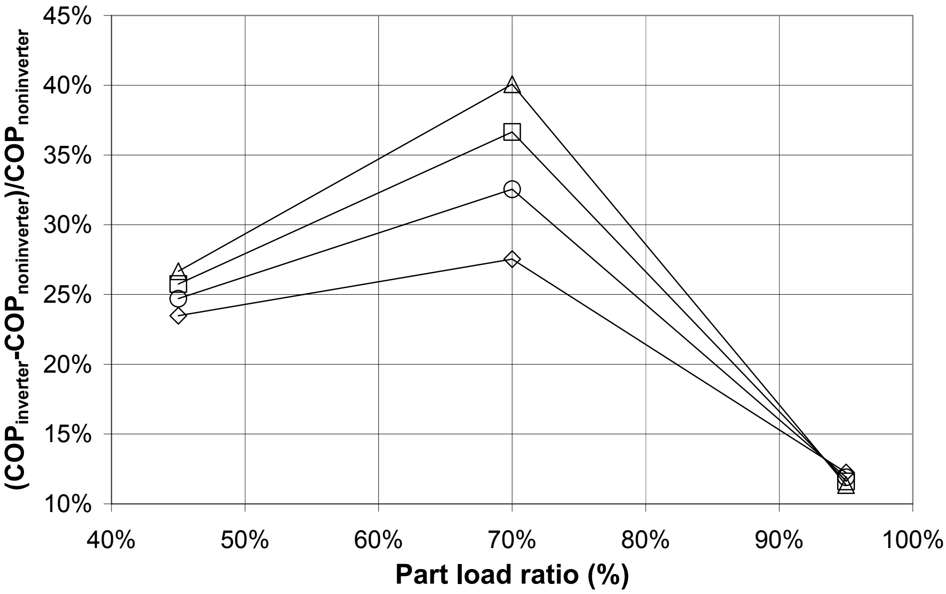

Figure 7: Effect of part load ratio on the relative COP difference between the inverter and non-inverter ACs at various outside-inside temperature differences of ∆ 1K, □ 3K, ○ 5K, and ◊ 7K

From Figures 6 and 7, it is seen that the COP differences reach the highest values at a part load ratio of 70%. It also appears that the effect of the outside-inside temperature difference on the COP differences is clearly recognized at part load ratios of 45% and 70%.

4 CONCLUSIONS

A simple and affordable laboratory set-up for comparing the energy performance of non-inverter and inverter ACs having the same rated capacity of 12000 BTU/hr was developed. The tests of set-up insulation, air tightness as well as of humidifiers were conducted and the obtained results reflected that the developed set-up was really good for the comparison study.

The power of the inverter and non-inverter ACs was found in the order of from 0.26kW to 0.97kW and from 0.33kW to 1.12kW, respectively at part load ratios of 45%, 70% and 95% and with outside-inside temperature differences ranging from 1K to 7K. The experimental results show that the inverter AC consumed from 9.3% to 26.9% less electricity compared to the non-inverter AC under the same operating conditions. It is also seen that using inverter AC was most effective in term of energy saving at a part load ratio of 70%.

The COP of the inverter and non-inverter ACs was estimated to be from 3.4 to 6.3 and from 3.0 to 4.9, respectively at part load ratios of 45%, 70% and 95% and with the temperature differences ranging from 1K to 7K. The COP of the inverter AC was found to be from 11.4% to 40.1% higher than that of the non-inverter one under the same working conditions. The highest value was obtained at a part load of 70% while the lowest was received at a part load ratio of 95%.

With the above results, a further investigation at other intermediate part load ratios is encouraged. Finally, in an attempt to promote energy efficiency products for CO_2 emission reduction in developing countries, it is expected that the developed laboratory set-up would be potentially employed to introduce other high energy efficiency residential electrical appliances by comparing their energy performances with that of low energy efficiency ones which are currently being in use in these countries.

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