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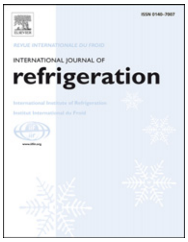

Experimental performance study of a small wall room air conditioner retrofitted with R290 and R1270

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ABSTRACT

An original R22 wall room air conditioner with a cooling capacity of 2.4 kW and energy efficiency ratio (EER) of 3.2 is retrofitted with a compressor of a 20% larger displacement to charge R290 and R1270 for performance experiments. The results show that for R1270, only adopting a same kind mineral lubricant of higher viscosity would supply 2.4% higher cooling capacity and 0.8% higher EER than those of the original R22 system under normal condition, and for R290, adopting the larger displacement compressor simultaneously would also obtain better performance. Alternative systems all have higher increase rate and greater increment in both cooling capacity and EER than the original R22 system when outdoor temperature decreases. The R1270 system has great increase in cooling capacity and negligible decrease in EER. Refrigerant charge distribution is also investigated and it indicates that the charge within both heat exchangers and compressor ought to be reduced.

Etude expérimentale sur un petit conditionneur d'air individuel converti au R290 et au R1270

Mots clés : R290 ; R1270 ; Conditionneur d'air individuel ; Performance ; Distribution de la charge

1. Introduction

Owing to the negative environmental impact of R22, which is widely used in heating, ventilation and air conditioning (HVAC) nowadays, a series of Montreal Protocol contracting meetings have decided to rank R22 into the phase out list, and there has been an accelerated hydrochlorofluorocarbon (HCFC) phase out plan approved by the Montreal Protocol parties (UNEP, 2007). Therefore, it is urgent to search for proper alternatives to R22. In early years, some countries insisted on using R410A, R407C and other hydrofluorocarbons (HFCs), which don't deplete the stratospheric ozone, however, have equivalent or even higher global warming potential (GWP) than R22 (GWP for the time horizon of 100 years: 2000 for R410A, 1700 for R407C and 1780 for R22 (Calm and Domanski, 2004)), and are hence regulated under the Kyoto

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Nomenclature

A	area, m^2
DBT	dry bulb temperature, °C
EER	energy efficiency ratio
GWP	global warming potential
HC	hydrocarbon
HCFC	hydrochlorofluorocarbon
HFC	hydrofluorocarbon
HVAC	heating, ventilating and air conditioning
LFL	lower flammable limit, kg m^{-3}
ODP	ozone depletion potential
SEER	seasonal energy efficiency ratio
WBT	wet bulb temperature, °C

Protocol. There have been researches accomplished by several influential agencies, claiming that the projected HFC emissions would be 9–45% of projected global CO_2 emissions in 2050 if HFCs, mainly R410A and R407C, were not restricted in use, which would undoubtedly aggravate the greenhouse effect badly (Velders et al., 2009). The international societies have already agreed unanimously that HFCs couldn't be a long term choice, and through continuous and deep consideration, now, people's interest has been focused on hydrocarbons (HCs), especially on R290 and R1270.

As natural substances, R290 and R1270 have zero ozone depletion potential (ODP) and negligible GWP, doing no harm to the environment (Calm and Domanski, 2004). Moreover, they have favorable characteristics as refrigerants from the point of view of both thermodynamic and transport properties. Furthermore, many experiments indicate that R290 and R1270 offer equivalent or even better performance than R22. In addition, R290 and R1270 have extensive sources and low cost, and are perfectly compatible with the lubricants and materials commonly being used in HVAC (Granryd, 2001). The only problem with R290 and R1270 is that their high flammability would induce dangerous incidents if not properly handled, just as all other flammable substances, for which the international societies always take their use seriously while once prohibiting any use (Corberan et al., 2008b). However, seeking environmental friendly refrigerants is a trend now, and R290 and R1270 have eventually been back to people's view thanks to public growing environmental awareness.

R290 and R1270 have been successfully used as substitutes to R22 in heat pumps in Europe and some Asian countries, where the risk associated with their high flammability is under good control and the performance is satisfying (Palm, 2008). Fernando et al. (2004) used R290 in a water-to-water heat pump with a heating capacity of 5 kW and determined the optimum charge with the use of mini-channel aluminum heat exchangers at 200 g without any loss in EER. Hoehne and Hrnjak (2004) carried out charge studies to R290 in a heat pump with a heating capacity of 1–1.5 kW and discovered that refrigerant lay most in compressor, and then in condenser and evaporator. Park and Jung (2007, 2008) and Park et al. (2010) adopted R290, R1270 and other pure HCs and their mixtures as refrigerants in an original R22 heat pump with a heating capacity of 3.5 kW while taking water/ethylene glycol as the secondary fluid for heat exchangers. They found that for both R290 and R1270, EER was up to 11.5% higher and discharge temperature and refrigerant charge were largely reduced when compared to R22 in all tests. They also found that the R290 system showed up to 8.2% lower capacity under normal condition and 5% higher capacity under extremely cold condition, and R1270 system showed higher capacity under all conditions with respect to the R22 system.

For air conditioners, Devotta et al. (2005) measured the performance of a R22 window air conditioner with a capacity of 5.13 kW, EER of less than 2.5, and heat exchangers of 10 mm tubes and found that the R290 system showed 6.6% and 9.7% lower in cooling capacity, respectively, and 7.9% and 2.8% higher in EER, respectively, under lower and higher operating conditions when compared to the R22 system. Padalkar et al. (2010) retrofitted the 5.13 kW capacity split air conditioner to charge with R290, and reported that the larger condenser supplied 1.6% lower cooling capacity and 10% higher EER with respect to the original R22 system, and the higher capacity compressor improved cooling capacity by 2.8% and reduced EER by 1.1%. Zhou and Zhang (2010) tested R290 in a split air conditioner which had a capacity of 3.2 kW, an EER of 2.4 and 9.53 mm smooth tubes for the condenser and 7 mm internally spiral groove tubes for the evaporator, and stated that the R290 system had 4.7–6.7% lower cooling capacity and 8.5% higher EER when compared to the R22 system. Teng et al. (2012) experimentally investigated the performance of a 2 kW capacity window air conditioner using R290 as a substitute to R22 under various refrigerant charge and outdoor temperatures (26, 29, 32 °C). The results showed that the optimum charge for R290 is 50–55% of that for R22, and the EER of R290 increased by up to 20% with the outdoor temperature.

The above studies indicate that R290 and R1270 can be used in heat pumps and air conditioning systems with equivalent or even better performance, providing good guidance and reference for their application in room air conditioners which are widely used in households and offices.

The technology progress has promoted the efficiency improvement of air conditioners. Now, for a split air conditioner with a capacity of 4.5–7.1 kW, EER ought to be no less than 3.1, and for that with a capacity of less than 4.5 kW, EER ought to be above 3.2. Most of the existing studies are focused on air conditioners of low EER; however, the structure, cycle parameters and energy loss distribution of air conditioners of high EER are different from the ones of low EER. On the other hand, small air conditioners with capacities of less than 3.6 kW are commonly used in East and Southeast Asia, for which it is probably possible to satisfy the safety requirements of EN 378 criterion, etc. However, available researches on the split air conditioners of high EER and with capacities of the above range are relatively few. In this study, a small R22 wall room air conditioner with a capacity of 2.4 kW and an EER of 3.2 is proposed to retrofit with a compressor of a larger displacement. The performance is experimentally investigated when adopting R290 and R1270 as alternatives to R22.

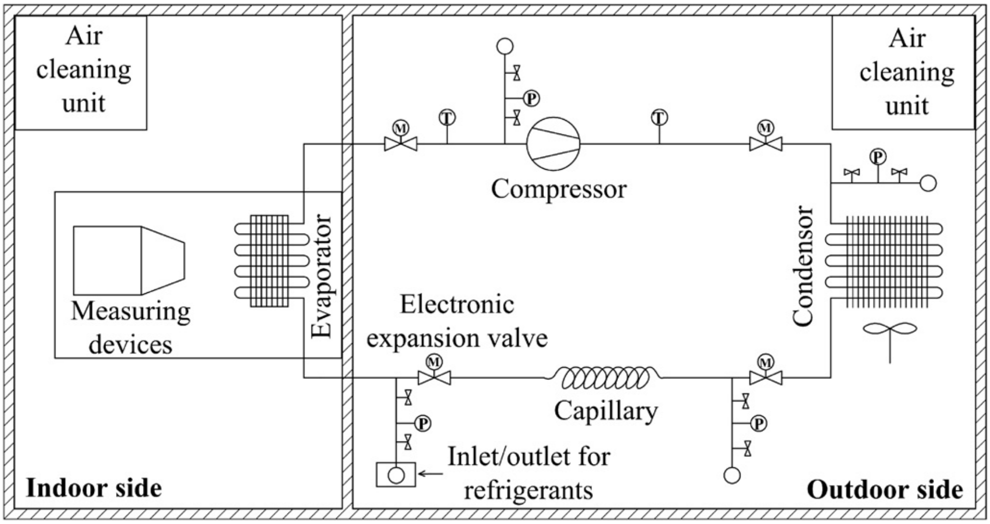

Fig. 1 – Schematic diagram of the test rig.

This study also carries out refrigerant charge distribution tests. The results could contribute to the application of R290 and R1270 in room air conditioners.

2. Experimental setup and procedures

2.1. Exprimental setup

An original R22 wall room air conditioner, whose charge is 1150 g, capacity 2.4 kW and EER 3.2, is adopted as a baseline and retrofitted to charge with R290 and R1270. The original R22 air conditioner mainly contains a rotary compressor typed with PH150X1C-8FTD3, a condenser, an evaporator and capillary, as shown in Fig. 1. The capillary tube is Φ1.5 mm × 650 mm. The specifications of heat exchangers are presented in Table 1.The displacement of the original compressor is 150 cm^3. Besides, a compressor of a displacement of 180 cm^3, which is typed with PH180X1C-8FTD3, is used in this study to further assess the performance of R290 and R1270, which has the same structure parameters as the original other than bigger eccentricity of crank shaft. The specifications of the compressors are presented in Table 2.

To investigate the performance, cooling capacity and power consumption tests are necessary. The experiments are conducted by means of air-enthalpy test method in a psychrometric chamber according to Chinese Standard GB/T 7725, 2004 Room Air Conditioners. The psychrometric chamber consists of the indoor side and outdoor side, as shown in Fig. 1. The conditions of air in both sides are precisely adjustable in the form of dry bulb temperature/wet bulb temperatures (DBT/WBT) to exactly satisfy the strict requirements of temperatures and other needs in experiments. The air temperature is maintained within ±0.2 K and measured by dry bulb and wet bulb thermometers with the accuracy of ±0.1 K. Furthermore, some data, e.g. air flow rate, could be achieved by the apparatus equipped within the psychrometric chamber inherently. The air flow is measured by a nozzle flow meter with an accuracy of 1% FS.

Table 1 – Dimensions of heat exchangers.

Parameters	Heat exchangers	
	Evaporator	Condenser
Size (mm)	630 × 340 × 26	760 × 500 × 28
Tube type	Rifled U-tube	Rifled U-tube
Number of U-tubes	12	24
Total tube length (mm)	19,176	39,966
Tube outside diameter (mm)	7.00	7.00
Average inside diameter (mm)	6.14	6.14
Fin geometry	Louver	Louver
Fin spacing (mm)	1.2/1.4	1.2/1.4
Tooth depth (mm)	0.18	0.18
Number of teeth	50	50
Helix angle (°)	18	18
Apex angle (°)	40	40

Table 2 – Specifications of compressors.

Parameters	Compressors	
	PH150X1C-8FTD3	PH180X1C-8FTD3
Cylinder diameter (mm)	43	43
Cylinder height (mm)	30	30
Crank shaft eccentricity (mm)	4.015	4.965
Stroke volume (cm^3)	14.75	17.80
Relative clearance volume (%)	2.2	1.8
Motor efficiency (%)	81	83

The air conditioner is featured with necessary instruments. Some certain pressure transducers and T-type thermocouples are fixed at proper sites to measure the pressure and temperature of the refrigerants and air. The accuracy of pressure transducers is ±0.25%FS and the accuracy of thermocouples is ±0.5 K. Additionally, an electrical power analyzer with an accuracy of ±0.5% is adopted to record the energy consumption. The uncertainties of cooling capacity and EER are, respectively, 1.53% and 3.27%.

For the sake of study of system performance at various charges, a set of precise charging tool is used throughout all the experiments, which includes a weighing machine with an accuracy of ±1 g. With the help of this very equipment, it is feasible to make sure that the exact amount of refrigerant is charged into the system every time. Four electronic expansion valves as well as inlets/outlets for refrigerant are installed between the four main components of the air conditioner in order to carry out charge distribution tests, as shown in Fig. 1.

The refrigerants used in the experiments have good purity of higher than 99%. Considering that the viscosity of the lubricant used for R22 is relatively too low to be suitable for HCs, a same kind mineral oil of higher viscosity is selected as the lubricant for R290 and R1270.

It can never be too serious to take all the safety issues into account because of the high flammability of HCs. Relevant precautions are adopted in the experiments, e.g. tube connections and joints are brazed and electrical components are sealed, etc. More importantly, several Searchpoint optima pluses made by Honeywell are reasonably installed in the psychrometric chamber as alarming devices in case of unexpected leakage to reduce the risk as much as possible.

2.2. *Experimental procedures*

The original R22 room air conditioner is used as the baseline and retrofitted with R290 and R1270. To assess the performance of the air conditioner with different refrigerants, experiments are carried out under both normal condition and conditions of various outdoor temperatures. The indoor and outdoor DBT/WBT is 27/19 °C and 35/24 °C for the normal condition. For the conditions of various outdoor temperatures, the indoor DBT/WBT is kept as constant as 27/19 °C, and the outdoor DBT/WBT are 29/24 °C, 32/24 °C, 38/24 °C, 40/24 °C, respectively. All the data are recorded for 7 times at an interval of 5 min to obtain the average value after confirming the steady running state of air conditioner for 1 h.

The experimental procedures are as follows. Above all, the performance of the original R22 air conditioner with R22 of 1150 g is recorded under both normal condition and conditions of various outdoor temperatures to be recognized as the baseline. In the second stage, after accomplishing the experiments with R22, the original air conditioner is recycled out of R22 as well as its lubricant, and then charged with R290 and R1270, respectively, as well as the new lubricant, following conventional procedures. The performance of the air conditioner is first assessed at different charges to determine the optimum charge under normal condition, and then assessed at the optimum charge under conditions of various outdoor temperatures. The new lubricant for R290 and R1270 is charged at the same amount in weight as that for R22 throughout all the experiments. In the third stage, the original air conditioner is retrofitted with the compressor of a displacement of 180 cm^3. Its performance with R290 and R1270 is respectively assessed in the same way as in the second stage. In the final stage, the experimental data are analyzed.

In order to facilitate description, the following naming is adopted.

System I: The original air conditioner charged with R22
System II: The original air conditioner charged with R290 and a same kind mineral lubricant of higher viscosity
System III: The original air conditioner charged with R1270 and a same kind mineral lubricant of higher viscosity
System IV: The original air conditioner retrofitted with a compressor of a 20% larger displacement and charged with R290 and the lubricant of higher viscosity
System V: The original air conditioner retrofitted with a compressor of a 20% larger displacement and charged with R1270 and the lubricant of higher viscosity.

3. Experimental results and discussion

3.1. *Various charges*

Figs. 2–4 present the experimental results with various charges for R290 and R1270.

It can be seen from Fig. 2 that the cooling capacity first increases, but then decreases as refrigerant charge increases for both R290 and R1270. Meanwhile, Fig. 3 shows that power consumption is always rising slightly with refrigerant charge. Fig. 4 presents that EER has the same variation with charge as cooling capacity. The results indicate that there must be an optimum charge for every system, at which the performance would be best. The optimum charge and corresponding performance of systems for R290 and R1270 and their comparison to the original R22 system are listed in Table 3.

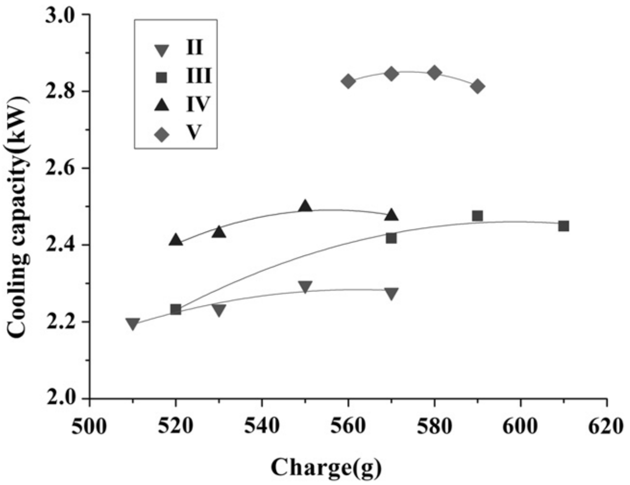

Fig. 2 – Cooling capacity at various charges under normal condition.

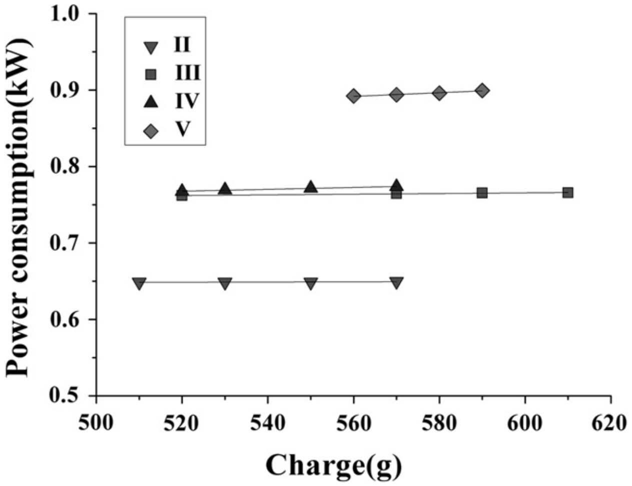

Fig. 3 – Power consumption at various charges under normal condition.

It can be seen from Table 3 that the optimum charges optimized by cooling capacity and EER are 550 g and 590 g, respectively, for R290 and R1270 without changing the compressor, which are more or less half of that for R22. It is notable that both the cooling capacity and EER at the optimum charge are highest because the variation rate of the cooling capacity is higher than the slight increase rate of the power consumption. The results are consistent with those of other studies (Zhou and Zhang, 2010; Teng et al., 2012) and can be reasonably explained by the nearly half lower density of R290 and R1270. It is interesting that the use of the compressor of a larger displacement wouldn't make any influence on the optimum charge of R290 and reduce that of R1270 from 590 g to 570 g. The reason for the unique phenomena is not sure, but we guess that it can be ascribed to the lower specific volumetric capacity and better heat transfer properties of R290 even if the compressor of a larger displacement increases the refrigerant flow rate. For R290, the optimum charge with the original compressor, 550 g, may be just perfect when a larger displacement compressor is used. However, for R1270, which offers a specific volumetric capacity very close to that of R22, the loads of heat exchangers at the charge of 590 g may be overwhelmed when the compressor of a larger displacement is adopted, and therefore, the optimum charge is reduced by 20 g. And it is also notable that the two compressors have the same structure parameters except the crank shaft eccentricity, which means that increasing the displacement, consequently the refrigerant flow rate, is achieved by employing a compressor of a bigger crank shaft eccentricity instead of a bigger size. Therefore, the use of the compressor of the larger displacement would never make any charge increase in the compressor itself. And this makes it possible to decrease the refrigerant charge in the entire air conditioner system if useful measures are adopted.

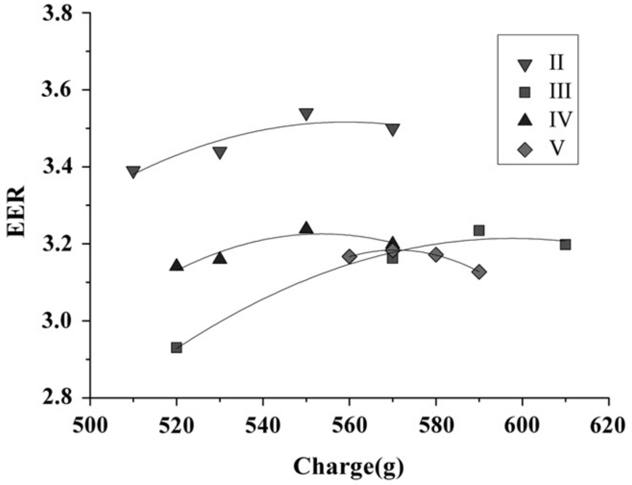

Fig. 4 – EER at various charges under normal condition.

The data in Table 3 also indicate that only adopting a same kind mineral lubricant of higher viscosity could offer higher cooling capacity and EER for R1270 with respect to R22, and much higher EER but relatively lower cooling capacity for R290. It is generally known that using R290 as a drop-in substitute to R22 in air conditioners and heat pumps would result in decrease in cooling capacity and increase in EER (Granryd, 2001). It can be recognized that the lower cooling capacity attributes to smaller specific volumetric capacity of R290 and the higher EER results from better thermodynamic properties of R290 (Corberan et al., 2008a). Besides, we guess that the less heat transfer load in heat exchangers due to lower cooling capacity also contributes to higher EER for R290. Therefore, it is valuable to observe the performance for R290 by using a compressor of a larger displacement, which would increase refrigerant flow rate and heat transfer load in heat exchangers while keeping the heat exchangers unchanged and hence could check out whether the properties of R290 are better or not. And it would provide further performance comparison among R290, R1270 and R22 as well. Considered that R290 offers 15% lower specific volumetric capacity than R22 and better heat transfer properties (Granryd, 2001), it is reasonable to choose a compressor of a displacement of 180 cm^3, 20% larger than the original compressor of 150 cm^3. It is notable that Padalkar et al. (2010) retrofitted a 5.13 kW capacity R22 split air conditioner with a 10% higher capacity compressor to charge with R290, and reported that the higher capacity compressor did supply 2.8% higher cooling capacity but 1.1% lower EER with respect to the original R22 system. The results in Table 3 show that adopting a compressor of a 20% larger displacement could help increase both cooling capacity and EER for R290, and largely increase cooling capacity while keeping equivalent EER for R1270 when compared to the original R22 system, which therefore demonstrates that the properties of R290 and R1270 are really better.

Besides, the results show that the use of the compressor of a larger displacement leads to increase in cooling capacity by 8.9% and 15% for R290 and R1270, respectively, but decrease in EER by 8.5% and 1.6% due to 18.9% and 16.8% higher power consumption when compared the cases without changing the compressor. In addition, the cooling capacity for R1270 is 13.9% higher than that for R290 and EER is only 1.7% lower when the compressor of a larger displacement is used. Overall, R1270 offers great increase in cooling capacity with little

Table 3 – Optimum charge and performance for systems under normal condition.

System	Cooling capacity		Power consumption		EER		Charge (g)
	Value (kW)	Diff. (%)	Value (kW)	Diff. (%)	Value	Diff. (%)	
I	2.4165	–	0.7531	–	3.209	–	1150
II	2.2948	−5	0.6487	−13.9	3.54	10.3	550
III	2.4752	2.4	0.7654	1.6	3.234	0.8	590
IV	2.4981	3.4	0.7716	2.5	3.238	0.9	550
V	2.8455	17.8	0.8904	18.2	3.183	−0.8	570

loss in EER. Considering that the charges are almost the same for R290 and R1270, meaning that R1270 has an 11.1% higher cooling capacity per unit mass refrigerant of 5 W g^{-1} with respect to 4.5 W g^{-1} for R290, and the lower flammable limits (LFL) of R290 and R1270 are nearly equal (0.038 kg m^{-3} for R290 and 0.040 kg m^{-3} for R1270 (BOC-CARE refrigerant, 2007)), therefore, the performance for R1270 is better than that for R290 when taking safety issues into account.

Additionally, because the length of capillary has a great influence on the system performance, optimization tests are carried out. The performance of the air conditioner is recorded and compared at the optimum charge for both R290 and R1270 when the length of capillary is properly increased and shortened based on the original length of capillary in the R22 system. The results indicate that the cooling capacity and EER with the changes of the length of capillary are worse for both R290 and R1270, which demonstrates the original length of capillary is suitable, needing no modifications. However, the exact reason remains unknown.

3.2. *Various outdoor temperatures*

Figs. 5–7 present the system performance under various outdoor temperatures for R22, R290 and R1270.

It can be easily seen from Fig. 5 that the R290 and R1270 systems all show a higher increase rate as the outdoor temperature decreases when compared to the original R22 system. Adopting R290 as a drop-in substitute to R22 in the original system leads to lower cooling capacity under all conditions, and using R1270 with the compressor of a larger displacement results in greater increment in cooling capacity, with a maximum of up to 580 W at 29/24 °C. For the other two cases, the cooling capacity shows the same trend that it is higher than that of the original system when outdoor temperature is relatively low and lower when outdoor temperature is relatively high.

Fig. 6 shows that all the five systems have almost the same increase rate in power consumption with the increase of outdoor temperature. Fig. 7 indicates that the four alternative systems all have the same higher increase rate in EER with the decrease of outdoor temperature with respect to the original R22 system. It is presented that EER is higher for R290 as a drop-in substitute to R22 than that for R22 under all conditions with a maximum of 0.5 at 29/24 °C. For the other three cases, EER is slightly higher than that for R22 when outdoor temperature is relatively low, and is slightly lower with an almost same scale when outdoor temperature is relatively high. In a word, the alternative systems all have higher EER at relatively low outdoor temperature and greater increment in EER as outdoor temperature decreases from 40/24 °C to 29/24 °C, which would help improve the Seasonal Energy Efficiency Ratio (SEER) and hence be good for energy saving.

Furthermore, it can be known from Figs. 5–7 that the performances are different between after and before the use of the compressor of a larger displacement. For R290,

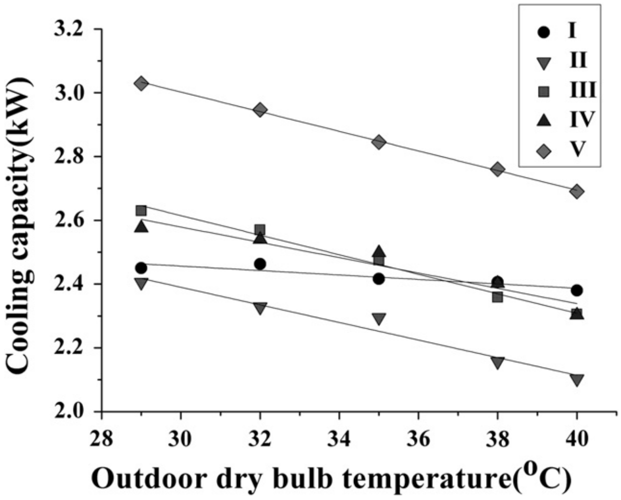

Fig. 5 – Cooling capacity at various outdoor DBT.

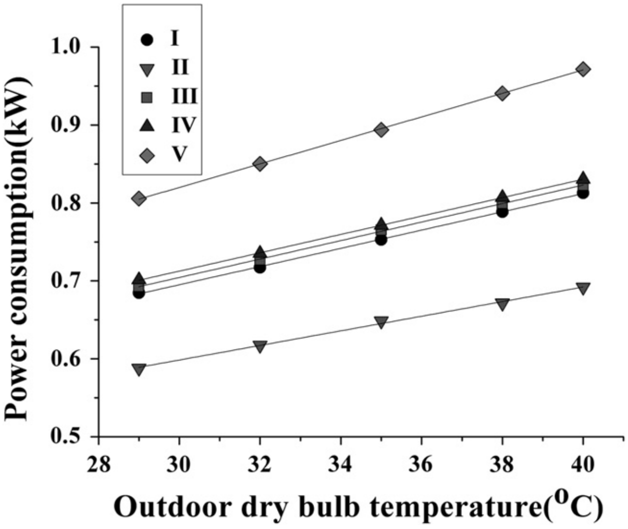

Fig. 6 – Power consumption at various outdoor DBT.

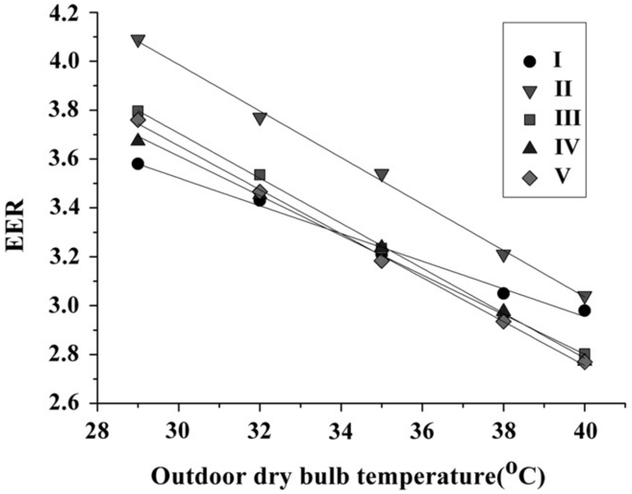

Fig. 7 – EER at various outdoor DBT.

although cooling capacity increases approximately by 200 W (or 7.1–11.4%), EER decreases by 0.23–0.42 (or 7.3–10.2%). For R1270, cooling capacity increases by about 400 W (or 14.7–17%) while EER almost remains the same. Additionally, the cooling capacity for R1270 is higher by 288–453 W (or 13.9–17.6%) than those for R290 when the compressor of a larger displacement is used, and EER is almost the same for both R290 and R1270. On the whole, R1270 has great increase in cooling capacity and little loss in EER under all the various conditions when using the compressor of a larger displacement, which is the same as the case under normal condition and further proves that it's better to adopt R1270 as the refrigerant when the compressor of a larger displacement is used.

4. Charge distribution tests

The international societies have been taking the use of flammable refrigerants seriously and have established some criteria which severely limit their use. Among all the criteria, EN 378 made by the European Committee for Standardization (CEN) and DIS ISO 5149 made by the International Standardization Organization (ISO) are most famous and widely accepted (Corberan et al., 2008b). Public worry about the risk due to the flammability of R290 and R1270 attributes largely to the overcharge. Kataoka et al. (2000) once developed a method to calculate allowable charge for flammable refrigerants, which is suitable for the criteria including EN 378 and DIS ISO 7149. It can be used in this study to calculate the allowable refrigerant charge for each system. The results are listed in Table 4, and the comparison between allowable charge and practical charge is presented as well.

Table 4 – Allowable charge and the comparison to practical charge.

System	Cooling capacity (kW)	Calculating A[a] (m^2)	Allowable charge (g)	Practical charge (g)
II	2.2948	11.47	256	550
III	2.7452	12.38	286	590
IV	2.4981	12.49	267	550
V	2.8455	14.23	307	570

a A = Cooling capacity/Cooling needs. The cooling needs is assumed as 200 W m^{-2}.

It can be seen from Table 4 that the practical charge for each air conditioner system in this study is far more than the allowable charge and therefore cannot meet the criteria. In fact, the optimum R290 charge in a 5 kW water-to-water heat pump was only 200 g by applying mini-channel aluminum heat exchangers (Fernando et al., 2004). It is no doubt that the HC refrigerant charge in the air conditioners must be reduced to the allowed value to win practical application as in heat pumps.

The charge distribution tests would be of great use for reducing the overcharged refrigerants in systems. Considered that charge is almost not changed with the use of the compressor of a larger displacement and the two compressors are of the same structure parameters only except the eccentricity of crank shaft, it is reasonable to perform charge distribution tests only on R290 and R1270 systems without changing the compressor.

4.1. *Testing method*

The charge distribution tests are carried out with a set of recovery equipment for refrigerants, which comprises a vacuum container and connecting hose. The vacuum container has a large volume of 40 L to guarantee the test accuracy. Besides, the equipment is featured with devices to measure the pressure and temperature.

After running steadily for 1 h, the air conditioner system is shut down and the four electronic expansion valves (see Section 2.1 and Fig. 1) are closed simultaneously. The refrigerant is hence trapped within the four components: the evaporator, compressor, condenser and liquid line pipes (capillary included), separately. For each separated component, the refrigerant charge is estimated as follows. The connecting hose of the recovery equipment is discharged out of air and then used to connect the vacuum container and the separated component by the inlet/outlet for refrigerant, as shown in Fig. 1. Therefore, the separated component and vacuum container are connected together to form a single volume. And then the recovery process begins. It can be considered that the refrigerant is recovered thoroughly when the pressure in the single volume decreases to below 0.05 MPa and then the pressure and temperature are

Table 5 – Charge distribution in systems with R290 and R1270.

Systems	Measured charge (g)			
	Condenser	Compressor	Evaluator	Liquid line
II	350	98	69	33
III	376	105	74	35

recorded. Density or specific volume of the refrigerant can be obtained according to the data recorded, and hence, the charge within the separated component can be calculated due to the known volume of the vacuum container, connecting hose and the component itself.

4.2. *Results and discussion*

The results of charge distribution tests for R290 and R1270 are listed in Table 5.

It can be seen from Table 5 that the charge distributions are almost the same for R290 and R1270. The charge is most within the condenser, up to 63%, and then within the compressor, about 18%. The overall charge distributions here are consistent with the calculating one by Corberan et al. (2008a), and the experimental ones by Fernando et al. (2004) and Hoehne and Hrnjak (2004) in heat pumps, both indicating that most of the refrigerant was in the condenser and compressor. It is noteworthy that the R290 charge in the compressor here is much lower than those by Fernando et al. (2004) and Hoehne and Hrnjak (2004) in heat pumps. It may attribute to the different running conditions of the air conditioner and heat pump, and as well as, perhaps more importantly, the use of different lubricant oils, for the solubility of R290 in different lubricants are different.

It is clear that efforts ought to be made first to largely reduce the charge within the heat exchangers, especially the condenser. Meanwhile, the charge within the compressor is 98 g and 105 g, respectively, for R290 and R1270, which are equivalent to 38.3% and 36.7% of the allowable charge shown in Table 5. Therefore, it is necessary to reduce the charges within the compressor and liquid line pipes at the same time in order to meet the EN 378, etc. Obviously, how to reduce the charge deserves deep consideration and it is our job to put forward measures in the next step.

5. Conclusions

In this study, an original R22 wall room air conditioner with a cooling capacity of 2.4 kW and EER of 3.2 is retrofitted with R290 and R1270. Based on the experimental performance investigation as well as charge distribution tests, the following conclusions could be drawn.

Only using a same kind mineral lubricant of higher viscosity would offer R1270 2.4% higher cooling capacity and 0.8% higher EER, and adopting a compressor of a 20% larger displacement simultaneously would also supply better performance for R290.

The alternative systems all have higher increase rate and greater increment in cooling capacity and EER with the decrease of outdoor temperature when compared to original R22 system, which would be good for SEER and energy saving.

Taken safety issues into account, R1270 system with the compressor of a larger displacement has better performance with negligible loss in EER and great increase (13.9–17.6%) in cooling capacity (or 11.1% in cooling capacity per unit mass refrigerant) when compared to R290 system.

The optimum charge optimized by performance is far beyond that regulated by EN 378, etc, and is most within condenser (63%) and compressor (18%). The charge within the compressor accounts for 36.7–38.3% of the allowable charge. Therefore, it is necessary to reduce the charge not only within heat exchangers but also within compressor and liquid line pipes.

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