2016 International Conference on Environment, Climate Change and Sustainable Development (ECCSD 2016)
ISBN: 978-1-60595-358-8

Performance Experimental Study of Environment Friendly Refrigerant R32 Enhanced Vapor Injection Heat Pump Water Heater

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Keywords: Environment friendly refrigerant R32, Enhanced vapor injection system, Heat pump water heater, Performance test, Comparative analysis.

Abstract. In this paper R32 and R410A were filled into the two-stage compression system with an enhanced vapor injection device so as to carry out some experimental studies and test of the performance. The results show that when being used in the air-source heat pump water heater with the enhanced vapor injection device, R32 has better operating effect and higher COP. Therefore, environment friendly refrigerant R32 can effectively improve the poor heating capacity of the air-source heat pump water heater under the low-temperature working conditions.

Introduction

Relative to other water heaters, the air-source heat pump water heater has some advantages[1], such as good safety for use, energy saving, good economy, wide application scope, and so on. The temperature in northern China is lower, which would affect the heat pump operation, more concretely, (1) The suction specific volume of refrigerants increases, and working medium circulation decreases. (2) Suction pressure decreases, and the pressure ratio increases. (3) The discharge temperature of compressors is too high. (4) The evaporator surface frosts, and then the heat exchange efficiency decreases. With the deterioration of outdoor environment conditions, the discharge temperature of compressor gradually increases, which would result in the decrease of the systematic overall performance. More seriously, the compressor would run under overload[2, 3]. For the problems mentioned above, Scholars at home and abroad have carried out relevant research, and has achieved the results of the stage, and it played a good role in promoting the development of heat pump water heater[4, 5]. Nowadays, people pay more attention to environmental issues, R32 is a low GWP refrigerant, its lower flammability limit is high, flame propagation velocity is slow and combustion heat released after combustion is small, so it is the safest refrigerant of the alternative refrigerants of R410A[6]. According to the relevant standards and regulations in China, a set of feasible test scheme for the operating energy efficiency characteristic of heat pump water heater unit was proposed. The performance test of heat pump water heater was carried out by the construction of the test experiment table. The common problems in the operating process of air-source heat pump water heater were theoretically analyzed, and the enhanced vapor injection technology scheme with R32 working medium was put forward. Moreover, the feasibility of this technology scheme was analyzed. The operating state parameters of air-source heat pump hot water system with working mediums of R410A and R32 under different environment conditions were tested, respectively. The experimental data were arranged, and the influence of each parameter of two-stage enhanced vapor injection heat pump water heater on the system performance was analyzed. All of these were worth using for reference for system optimization. At present, the air-source heat pump water heater has not been widely popularized in China because that many technological difficulties have still not been overcome.

Principle of Enhanced Vapor Injection Experiment System

This study adopted a circular manner of throttling in two sides and incomplete cooling in the middle. Furthermore, the function of flash evaporator was similar to that of intercooler, which play a role of refilling and enthalpy increasing as well as lowering the discharge temperature of compressors. It would not only improve the efficiency of the compressor but also improve the low-temperature adaptability of the heat pump units that both the two-stage compression and enhanced vapor injection were used in the rolling rotor compressor. So this has an important significance for the promotion and application of heat pump water heater in northern cold region. Figures 1 and 2 were the flow diagram and $\lg P-h$ diagram of two-stage compression cycle of enhanced vapor injection.

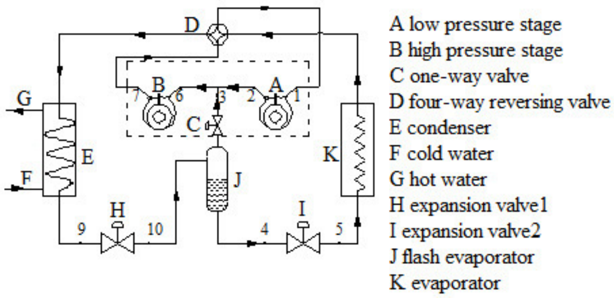

Figure 1. Flow diagram.

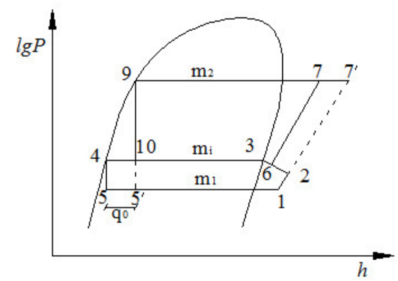

Figure 2. $\lg P-h$ diagram.

Experiment Test and Data Analysis

According to the principle of air source heat pump water heater system, we have further improved and designed the system, make it to meet our experimental conditions and experimental purposes. According to the actual situation we constructed a two-stage compression system with an enhanced vapor injection device. Figure 3 is the Schematic diagram of experimental device.

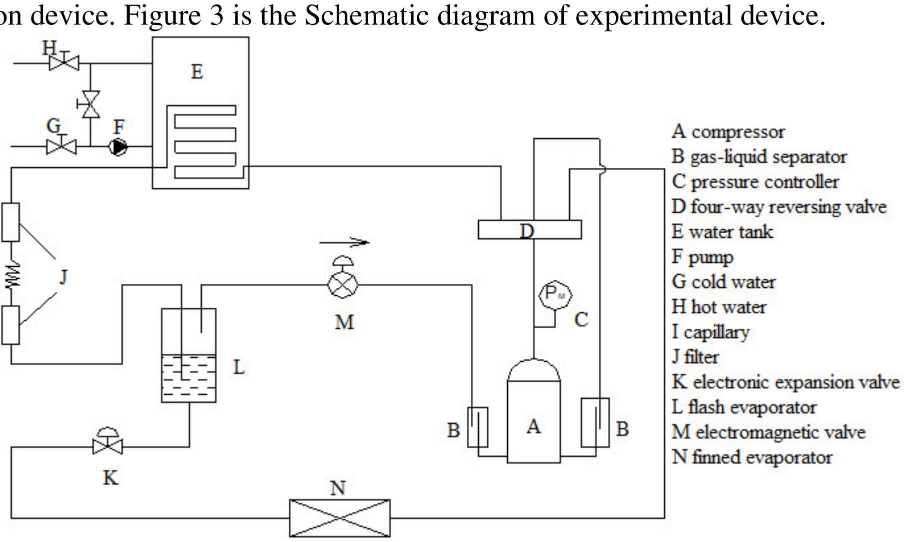

Figure 3. Schematic diagram of experimental device.

Effect of Refrigerant Charge Amounts on the Performance of the System

The charge amount of refrigerant in the air-source heat pump system would result in the great influence on each state parameters of the system, such as suction and discharge temperatures of a compressor as well as suction and discharge pressures, power consumption of a system, heating time of hot water under the same working conditions, performance coefficient COP of a system, and so on. In order to study the influence of charge amount on the performance parameters of units, two kinds of refrigerants R32 and R410A were chosen for the charge amount experiment. This can not only study the influence of charge amount on the heat pump system performance but also contrastively analyze the operating parameters of two kinds of refrigerants under the same working condition. This study selected the nominal condition (dry-bulb temperature 20 °C, wet-bulb temperature 15 °C, inlet water temperature 15 °C, and outlet water temperature 55 °C) in GB/T 23173-2008 to carry out the test of relevant experiments. Then the test results were analyzed and contrasted in detail.

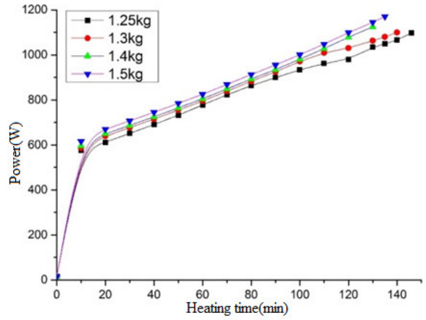

Figure 4. R410A system.

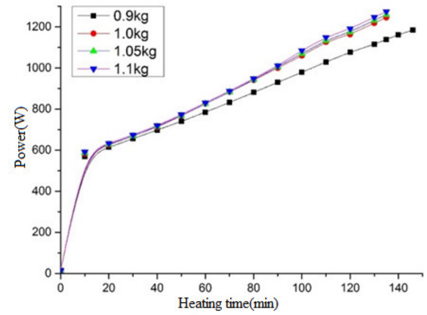

Figure 5. R32 system.

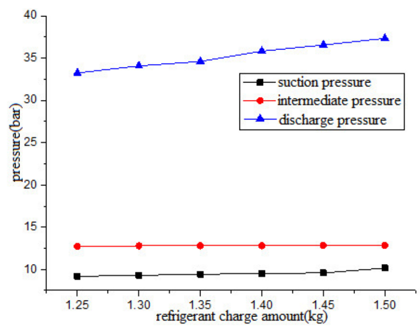

Figure 6. R410A system.

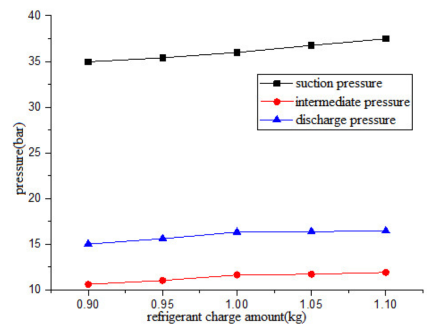

Figure 7. R32 system.

Figures 4 and 5 showed the changing curves between systematic power consumption and the charge amounts of refrigerants. It can be clearly observed that the power constantly increased with the time, moreover, the input power of the R32 system was higher, which was because that unit theory compression work of the R32 system was greater than that of the R410A system.

Figures 6 and 7 showed that the discharge pressure of the compressor increases with the refrigerant charge amount, while intermediate pressure and the suction pressure have little change. It is mainly because of the increase of the refrigerant charge amount, the refrigerant in the condenser is more and more, the condensation pressure is increased, and the discharge pressure of the compressor is increased.

In order to determine the optimal charge amount scope of the system, the method of combining theory with experiment was used to determine the optimal charge amount of the system. Firstly, the theoretical analysis method was used to determine a general scope of charge amount according to the systematic performance parameters. Then the refrigerant was replenished in 50g within this scope. The COP of units with various charge amount was tested under standard conditions, respectively, as well as the curve graph was drawn. Finally, the optimal charge amount was determined.

The computational formula of heat pump performance coefficient COP was as follows.

$$U = V / H \tag{1}$$

$$Q = 1.163 \times U \times (T_2 - T_1) / 1000 \tag{2}$$

$$COP = Q / P \tag{3}$$

where U-water heating ability, L/h; *V*- heated water volume, *L*; *H*- heating time, *h*; Q-heating capacity of heat pump, kW; T_1-inlet water temperature, °C; T_2-outlet water temperature, °C; P-heating power consumption of heat pump, kW.

It is finally determined by the method of combining theoretical calculation with experiment that the optimal charge amount of the system with R410A was 1.4kg and the optimal charge amount of the system with R32 was 1.05kg under the nominal condition. Figure 4 and Figure 5 show the different COP with different refrigerant charge amounts.

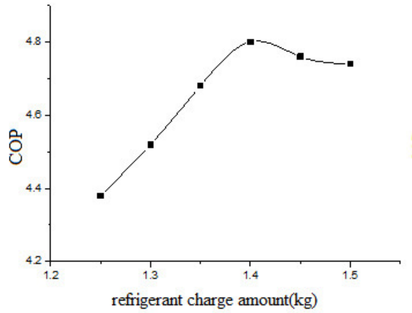

Figure 8. R410A system.

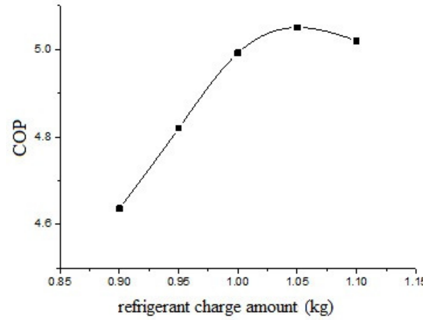

Figure 9. R32 system.

Effect of Environmental Conditions on the Performance of the System

Environmental condition was the main factor to affect the operating performance of units and was the key in the air-source heat pump test. The variable testing condition experiment for the system was carried out under the optimal charge amount. Furthermore, the testing conditions to be selected in this experiment were shown in Table 1 according to the experimental conditions of heat pump hot water device in the GB/T 23173-2008.

Table 1. Experiment conditions.

Testing condition	Air side		Water side	
	Dry-bulb temperature / °C	Wet-bulb temperature / °C	Inlet water temperature / °C	Outlet water temperature / °C
high-temperature operating condition	35	24	20	55
nominal condition	20	15	15	55
minimum operating condition	7	6	9	55
low-temperature operating condition	-7	-8	9	55

The following is the experimental analysis.

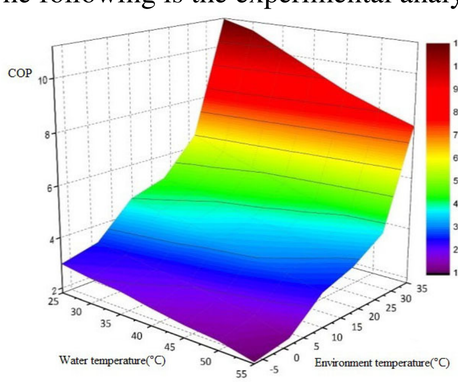

Figure 10. R410A system.

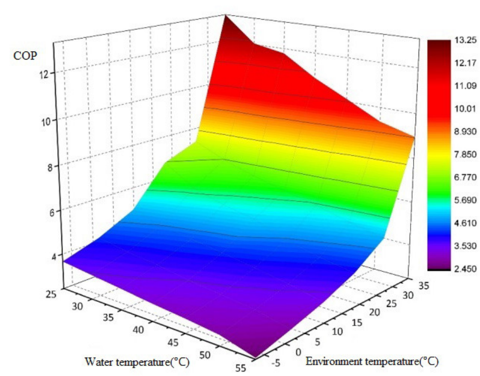

Figure 11. R32 system.

Figure 10 and Figure 11 are the water temperature-environment temperature-COP curved surface diagrams of the R410A and the R32 systems, respectively.It can be clearly observed in Figure 8 and 9 that the influence of environment temperature on COP continuously decreased as well as the room for increase of COP was smaller in a scope of higher water temperature. Hence, the COP of heat pump system should be increased during the first half of heating process. The influence of water temperature on COP was basically consistent in different environment temperatures. The lowest point and highest point of COP in Figure 10 and 11 corresponded to the lowest point of environment temperature and the highest point of water temperature as well as the highest point of environment temperature and the lowest point of water temperature, respectively. So in order to solve the heat pump applicability, the operating performance of heat pump at a low temperature should be increased from the lowest point of COP. It can also be seen in Figure 8 and 9 that the COP of the R32 system was higher than that of the R410A system under all the testing conditions. Hence, environment friendly refrigerant R32 has a great potential to replace R410A.

Summary

After analyzing the experimental data, we can conclude that:

(1) It was concluded by the comparison between the heat pump systems with R410A and R32 that COP of the R32 system was 4.2% higher than that of the R410A system under the optimal charge amount of nominal condition, but the charge amount of the R32 system decreased by about 25%.

(2) The operating performance of heat pump water heater can be obviously improved by the use of enhanced vapor injection technology at a low temperature. When the enhanced vapor injection technology combined with the advantages of the R32, the performance of air-source heat pump water heater at a low temperature can be significantly improved.

(3) Under the same working conditions, the power of the R32 heat pump system was slightly higher than that of the R410A heat pump system, namely, the difference between the two was small. Moreover, the heating capacity of the R32 system was higher than that of the R410A system, as well as the attenuation amplitude of heating capacity of the R32 system was smaller with the increase of water temperature. This showed that the heat exchange efficiency and COP of the R32 heat pump system were higher than those of the R410A heat pump system.

Therefore,the application of R32 with vapor injection device of air source heat pump water heater with good running effect and higher COP, can effectively improve the problem of the air source heat pump water heater that the heating capacity is poor under low temperature conditions.

Acknowledgments

This work was financially supported by the Innovation Program of College student on Shanghai Higher Education Commission.

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