Experimental Study Comparing the Efficiency of Heat Pump Hot Water Using Refrigerant R32 and Refrigerant R410A

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Abstract: ***The paper presents the research results of experimental heat pump hot water (HPHW) using new refrigerant R32, more friendly to the alternative environment for hot water supply heat pump systems using the current R410A on the market. Experimental results show that the new refrigerant pump system R32 has a lower CO_2 emission factor than the system using R410A refrigerant. Hot water heating time of R32 heat pump system is 25.86 minutes shorter than the system using R410A medium with 27.78 minutes with hot water temperature required to reach 50 °C***

Keywords: heat pump; hot water; refrigerant R32; refrigerant R410A; CO_2 emission

1. Introduction

Currently, the demand for hot water use in industry as well as in living in households is increasing. The production of hot water has been using a variety of methods such as resistors, solar energy, solar power combined with heat pumps, in which the method of using heat pumps to heat hot water is of interest head. However, the current major challenge of heat pump systems is safe and environmentally friendly. With the commonly used media for previous heat pump systems such as R22, R134a, R407C and recently R410A have been banned or are completely eliminated in existing heat pump or air conditioning systems due to the index Ozone Depleting Potential (ODP) and high Global Warming Potential index (GWP), not environmentally friendly. With the top priority being environmentally friendly, the search for new refrigerants has been interested and researched by scientists. Stratospheric ozone depletion, as well as atmospheric greenhouse effect due to refrigerant emissions, have led to drastic changes in the refrigerant and air conditioning technology since the beginning of the 90s, This is especially true for the area of commercial refrigerant and A/C plants with their wide range of applications. Until a few years ago the main refrigerant used for these systems were ozone depleting types, namely R12, R22, and R502; for special applications R114, R12B1, R13B1, R13, and R503 were used [1]. Boccardi [2] studied the CO_2 application to replace traditional HFCs. Based on the advantages of non-ODP CO_2 and extremely low GWP index, use an ejector device to reduce throttle losses and increase system efficiency to about 30% (based on ejector efficiency and regulator system operating conditions). The article offers heat pump test models using multi-level ejector device with CO_2 under experimental and analytical conditions, showing COP index of heat pump using multi-level ejector is effective in heat capacity and injection performance. According Kim [3] showed some disadvantages of a single-stage heat pump and studied the application of multi-level heat pump system to replace a one-level heat pump system. In this article, the AWHP (air to water heat pump) system is tested and researched. The high and low cycles of the system used R404A and R410A substrates to match. In this paper, the optimal intermediate temperature for AWHP systems is empirically studied. Based on the analysis of the total minimum compression capacity of the system and the numerical method of predicting the achieved experimental results, the difference between high-temperature condensate and low-pressure evaporation is explained... Wanjiru [4] has integrated systems to make hot water supply pumps with renewable energy sources to ensure efficient and stable energy efficiency to reduce electricity costs and greenhouse emissions. The article introduces an optimal control strategy for HPWH activities, significantly reducing energy costs for users. Liu [5] proposed a heat pump transformer system in combination with H2O / LiBr to run on average heat waste to provide two useful heat types. The article is based on the law of energy conservation and mass conservation and phase balance, they have developed a computational model to investigate the performance of combined heat pump transformer (CHPT) heat pump systems. ECOP index increased with absorbent at high pressure, low-pressure absorber and reduced with evaporation temperature and steam temperature. AccordingJu [6] conducted an experimental study to evaluate the effectiveness of hot water supply heat pump systems for households using R744 / R290 mixtures to replace R22 refrigerants. While Lee [7] presented an experimental study of the thermodynamic properties of refrigerant R32 / R152a used for water heat pump systems. The study has determined that the ratio of unburnt mixes and COP coefficients of this heat pump system is 15.8% higher than those using R22 media. Jingyong [8] has stimulated the operating characteristics of a dual-heating hot water heat pump system. The study proposed a dual heat pump with air evaporator connected in parallel and operated simultaneously to recover the amount of solar energy used for the heat pump system. On that basis, the effects of solar radiation, ambient temperature, and packaging factors are discussed. Loi [9]claimed that the parameters of a heat pump system. The paper states the applicability of alternative heat pumps for traditional water heating and heating equipment for electricity, gas or domestic oil. family and in business. If replacing traditional water heating and heating equipment sets with heat pumps, energy savings, and CO_2 emissions can be reduced to 60%.

Vinh [10] has designed and built a heat pump system using hot air units. The paper presents the design, fabrication, and testing of heat pump water heaters using R22 and air-conditioner in Vietnam climate conditions. The paper compares the efficiency of the heat pump model using R404A medium with R22 medium.Hung [11]indicated the energy saving program for heat pump systems and gave new directions to the heat pump system. The paper presents working principles, methods for evaluating energy efficiency and the ability to use heat pump effectively in the national economy to save primary energy. An [12]showed the construction of a household heat pump with R404A refrigerant and the results showed that the heat pump system is capable of providing 50 liters of hot water with a power consumption of 0.272 kWh. for 1 kWh of heating water, about 27% of the electricity consumed by resistive hot water production equipment has the same capacity. According to Shigeharu [13], the new R32 / R1234ze solvent mixture used for hot water heat pump was also studied to compare the coefficient of COP heat pump in Japanese weather conditions. Liu [14] launched a hot water heat pump system that uses solar storage devices to thaw ice at night. Experiments carried out in the lab give results that the system has a COP of nearly 82% compared to traditional heat pump systems. The system uses primary solar heat, suitable for cold and wet winter areas. Xiaolong [15] have launched a new step-by-step automatic heat pump cycle with solar power assisted SAHPC (solar-assisted auto-cascade heat pump cycle) using R32 / R290's zeotropic mixture. Mathematical models were developed based on this model and compared with the conventional heat cycle of a conventional air-source heat pump cycle (CAHPC). In the SAHPC system, use a CHEX (cascade heat exchanger) flow heat exchanger in combination with phase shifters to improve the overall system performance and provide the system's automatic jump cycle. The paper shows that the model using the azeotropic mixture of R32 / R290 significantly improves COP and thermal capacity, about 4.23 - 9.5% and 4.37 - 9.68%. There is also a study of the combination of water and LiBr mixture. The influence of thermodynamic properties of refrigerant R744 and R410A on COP coefficients of hot water supply heat pumps was assessed by Jin [16].

With the current demand for hot water in Vietnam is increasing due to the growth of construction and service sectors. Current heat pump systems in the market mostly use R410A refrigerant. With a high GPW, the current trend is to eliminate the use of R410A refrigerant from heat pump systems. The paper presents an experimental study on hot water supply heat pump using a new refrigerant R32 which can be widely applied in hot water supply in Vietnam.

2. Theoretical basis

The Global Warming Potential (GWP) of R410A refrigerant is 2090, higher than the new R32 refrigerant of 675. This suggests that the environment-friendly nature of R32 refrigerant is much better than R410A refrigerant. Figure 1 shows the GWP index and CO_2 emission index of R22, R410A, and R32 media. From here, it can be seen that the search for a new environment-friendly refrigerant for hot water supply heat pump system is an urgent issue.

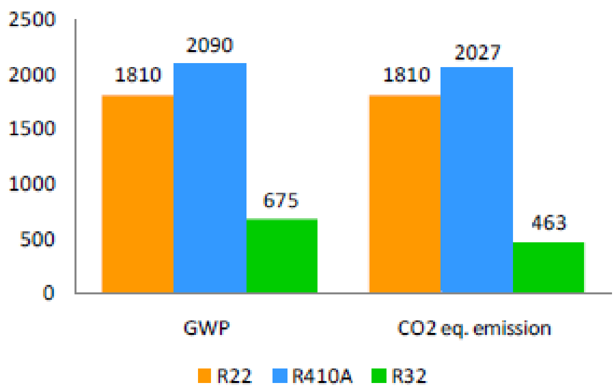

Figure 1: The Global Warming Potential (GWP) and CO_2 emission of R22, R410A and R32
[Source: GWP Values according to IPCC 4th Assessment Report]

The hot water (condensation) side has a temperature of 50 ° C out of the outdoor unit as required, the compressor capacity is 1 Hp. The contents to be calculated for the hot water pumping cycle are: Design of water heating system using R410A refrigerant and new refrigerant R32 (design of outdoor unit, water tank, hot water supply pump)

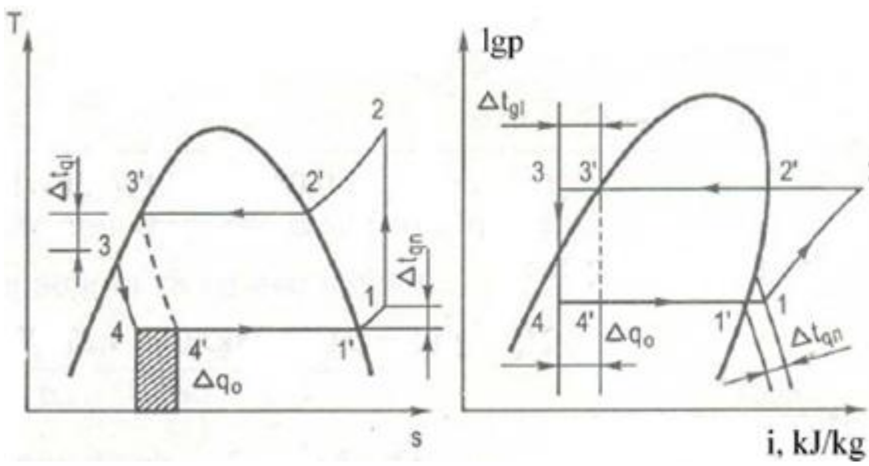

Figure 2: lg p – h and T – s diagram for heat pump cycle

As following the documents above, it is possible to calculate specific quantities for the cyclic process on the following formulas:

$$q_o = h_{1'} - h_4 , (kJ/kg) \quad (1)$$

$$q_k = h_2 - h_3 , (kJ/kg) \quad (2)$$

$$l = h_2 - h_1 , (kJ/kg) \quad (3)$$

$$Q_k = m.q_k , kW \quad (4)$$

Condenser heat ex-changer area:

$$F_k = \frac{Q_k}{k_k \times \Delta t_{tb}} , m^2 \quad (5)$$

In which Q_k: heat capacity of the outdoor unit, W; k_k: heat transfer coefficient, W / m^2K; F_k: heat exchange surface area, m^2; ; Δt_{tb}: average logarithmic temperature, K

The COP coefficient of a hot water supply heat pump is the ratio of heat transfer energy to water and total power consumption for a compressor (Pe) and calculated as follows:

$$COP = \frac{Q_k}{P_e} \quad (6)$$

3. Experiments

3.1 Experimental setup

Two models of the experimental system of hot water supply heat pump with the hot water temperature of 50 ° C, a model using a new refrigerant R32 compared with a heat pump system using refrigerant R410A. The system uses a 1 Hp compressor. The evaporator of the heat pump system is selected from the standard indoor unit air conditioner RAC (Room Air Conditioner). The outdoor unit of the heat pump system with the task of heating the hot water is selected as a copper coil and is inserted in the water supply pipeline. The system is equipped with an additional water pump that regulates feedwater flow and continuously supplies water to the system. The pipelines are 10mm thick insulated to reduce heat loss.

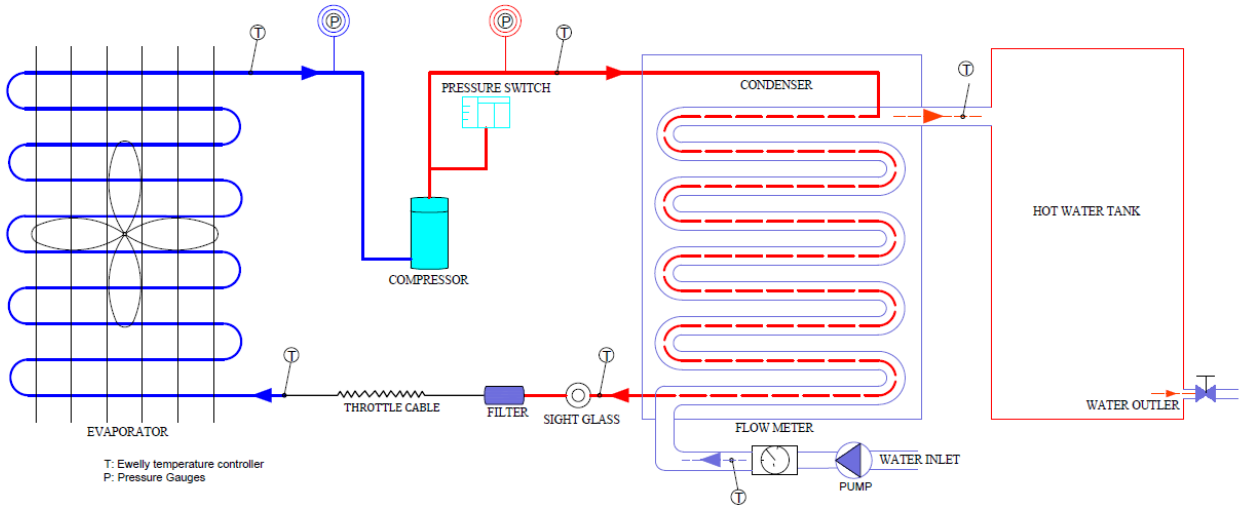

Figure 2: Schematic diagram of a test rig of instant heat pump system

3.2 Measurements method

The parameters to be recorded during the measurement process include: the temperature of the incoming water, the temperature of the hot water after being heated, measured by two temperature sensors of the Ewelly controller (± 0.5 ° accuracy C) placed at the inlet of the water pump (before entering the heating device) and the output of the heating device; Two pressure gauges HT60-30BS (precision level: 2) are attached to the suction head and push-pull head of the compressor to determine the Pk condensing pressure and Po evaporation pressure of the heat pump system. There is also a temperature sensor of the Ewelly controller (accuracy of ± 0.5 ° C) to determine the environment. The water flow rate can be changed by the flow regulator and measured by the LZM-15Z flowmeter (accuracy: ± 2%). The power dissipation of the device (compressor) is measured by a power meter PZEM - 061 (accuracy: ± 1%) Wh to determine the power consumption of the system.

3.3 Operating principle of heat pump system

The operating principleof the hot water supply pump is as follows: when the system is operating, the feed water will be pumped in the opposite direction with the refrigerant into the outdoor unit, receiving the heat released by the condensate refrigerant and then entering the tank hot water. The system is equipped with a float valve to stop the system when the water in the tank is full to blame the water out when there is no need to use hot. High-pressure relays in the system are installed to protect the system when high-voltage incidents occur. The feed water pump can adjust the intake water flow through the flow regulator.

To determine the COP of the system, the measured values are collected regularly after each 5-minute interval. When performing the experiment, the water pump pumped water into the heat ex-changer (outdoor unit), the cooling fan worked, after 3 minutes the compressor started working. Carry out the values of temperature, pressure, flow, power consumption at each time 5 minutes apart until the hot water in the tank reaches 75 liters/minute, the float valve interrupts the heat pump system, proceeds rinse the water in the tub, continue the experiment. The measured data from the experiment are saved in the Excel file to perform calculations, analysis, and evaluation.

4. Results and Discussions

In this study, the comparison of the performance of the heat pump system using the new refrigerant R32 with refrigerant R410A was tested according to the change in water flow rate, input water temperature,

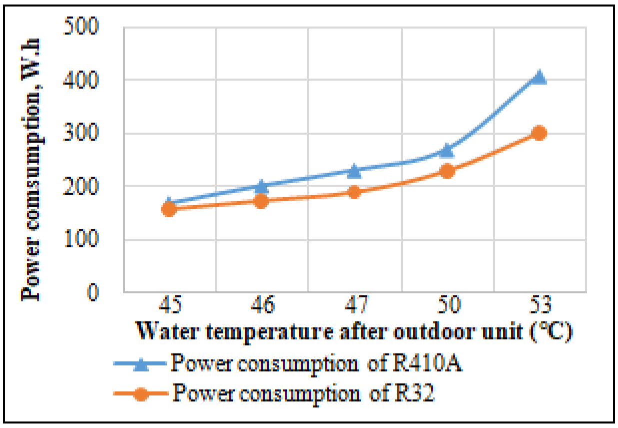

Figure 4: Power consumption of heat pump system using refrigerant R32 and refrigerant R410A

Figure 4 shows the power consumption of the hot water supply heat pump system. Hill with the new R32 refrigerant heat pump system shows that the operating cost of electricity is much lower than that of R410A refrigerant heat pump system. At the hot water temperature out of the condenser reaches 50 ° C, the energy consumption of the hot water supply heat pump system uses refrigerant R410A reaching 271 Wh while the new refrigerant heat pump system R32 only costs 231 Wh This shows that the operating cost of hot water supply heat pump system using R32 refrigerant is lower than that of R410A refrigerant. Consistent with current energy saving requirements.

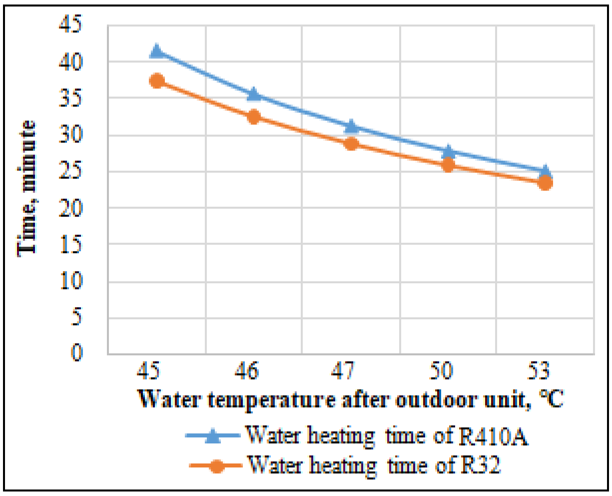

Figure 5: Hot water heating time corresponding to hot water temperature out of an outdoor unit of new refrigerant pump system R32 and refrigerant R410A

Figure 5 shows that in addition to the power consumption of the hot water heat pump system using a new refrigerant R32 lower than the system using R410A solvent, the system uses R32 for hot water heating time as required. better. At a water temperature of 50 ° C, the heating time of the heat pump system using the new refrigerant R32 is 25.86 minutes while the system uses R410A, the time lasts up to 27.78 minutes.

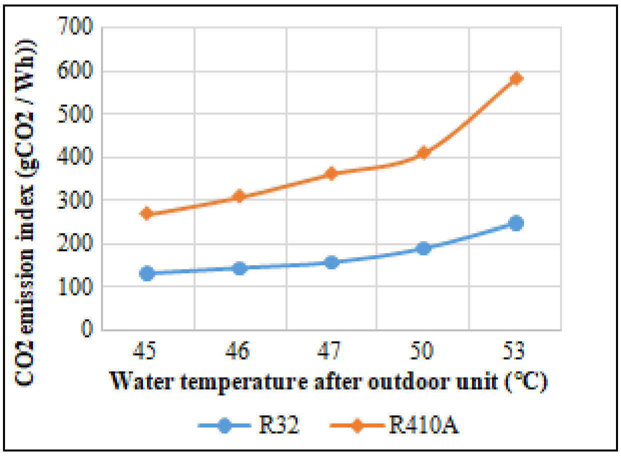

Figure 6: CO_2 emission index of hot water supply heat pump system

Figure 6 shows the CO_2 emission index of hot water supply heat pump system using R410A refrigerant higher than the new R32 refrigerant system. At the same time, it is shown that the hot water temperature when rising out of the system increases the power consumption, making the CO_2 emission index increase.

5. Conclusions

In this study, comparing the efficiency of hot water supply pumps using R410A refrigerant with new refrigerant R32 can be found:

1) The power consumption of the hot water supply heat pump system depends on the required hot water temperature. When the hot water temperature comes out of the high outdoor unit, the compressor consumes higher power, the compressor increases. At the required water temperature of 50 ° C, the power consumption of the heat pump using the new refrigerant R32 is 231 W.h while the R410A heat pump consumes more power than 271 W.
2) With variable water flow at the test times, the hot water supply heat pump system uses a new refrigerant R32 which has a shorter heating time than the heat pump system using R410A solvent. In response to the exit water temperature of 50 ° C, the water flows into the outdoor unit of the heat pump system uses a new refrigerant R32 of 2.3 liters/minute, while of the R410A refrigerant system is 2.1 liters/minute.
3) Because the new refrigerant R32 has higher condensing pressure than R410A refrigerant, it is not feasible to apply in a static type hot water supply system (outdoor unit soaked in hot water tank); instead, the system will design water forcibly moving through a cage-type outdoor unit.

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