# MULTI-OBJECTIVE PARTICLE SWARM OPTIMIZATION ALGORITHM FOR DATA ACQUISITION AND SYSTEM CHARACTERISTICS RESEARCH OF PHASE CHANGE THERMAL STORAGE HEAT PUMP WATER HEATERS

by

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Original scientific paper
https://doi.org/10.2298/TSCI2402469C

*In order to understand the multi-objective particle swarm optimization algorithm for data collection and system characteristics research of heat pump water heaters, the author proposes a multi-objective particle swarm optimization algorithm for data collection and system characteristics research of phase change thermal storage heat pump water heaters. The author first introduced the working principle of the phase change heat storage heat pump water heater, and then conducted a comparative experimental study on the performance of two types of heat pump water heater systems using pure paraffin phase change heat storage and water storage. They compared and analyzed the heat storage process, condensation heat recovery rate of the heat storage box, and comprehensive energy efficiency coefficient of the system under the refrigeration and heat recovery mode of the two types of heat pump water heater systems, on this basis, measures were proposed to improve the performance of pure paraffin phase change thermal storage hot water systems. At long last, the examination of exploratory information shows that the Rx of the water warm capacity framework is around 6% higher than that of the stage change warm capacity framework, and the framework COPt is likewise 20% higher than that of the stage change warm capacity framework, from this, it tends to be seen that the stage change heat capacity box has unfortunate intensity move proficiency, prompting a lessening in the presentation of the intensity siphon water radiator framework. Contrasted and customary water stockpiling heat siphon boiling water frameworks, unadulterated paraffin stage change capacity heat siphon high temp water frameworks lessen the volume of the intensity stockpiling tank, and the framework works somewhat flawlessly during the intensity stockpiling process. However, the system's overall energy efficiency is impacted by the heat storage tank's poor heat exchange effect and relatively low condensation heat recovery rate. The intensity move of the intensity stockpiling box can be upgraded by finning the winding curls in the intensity stockpiling box, embedding aluminum foil, adding extended graphite, and different measures to further develop the buildup heat recuperation rate, subsequently working on the general execution of the framework.*

Key words*: heat pump water heater, data collection, thermal storage*

## Introduction

Stage change warm capacity heat siphon water radiator is another sort of intensity recuperation framework, which has been generally endlessly concentrated on lately because of its benefits of high effectiveness, energy protection, and natural neighborliness. In the stage

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change process, the stage change material retains the hot star and deliveries heat in the exothermic cycle, to understand the recuperation and usage of energy. Because of the issues in information assortment and framework qualities examination of stage change heat capacity heat siphon water radiators, the writer has planned an information assortment framework in light of multi-objective molecule swarm improvement calculation, the framework measures and gathers boundaries like temperature, meteor, and strain in the stage change warm capacity heat siphon water radiator through information assortment hubs. The primary parameters that need to be collected for the phase change heat storage heat pump water heater are blower speed, blower power, water tank temperature, water tank level, and different boundaries. To all the more likely gather these boundaries, planning an information assortment system is important. Among them, the siphon speed, siphon power, and water tank temperature are the primary boundaries of the assortment framework. Through these parameters, the thermal star and temperature generated during the operation of the unit can be obtained. After collecting these data, the operating status of the system can be obtained. The water level and temperature of the water tank are the results of the three-state transformation of water, gas, and solid in the phase-change thermal storage heat pump water heater, and are two parameters that are often used in practical life. Therefore, it is necessary to collect these two parameters.

In order to address the asynchrony between the supply and demand of traditional domestic hot water in terms of time and quantity, people use energy storage equipment for heat storage to provide domestic hot water. The water storage heat pump water heater has problems such as large system volume and high input power, while the phase change heat pump water heater system not only solves the problem of asynchronous hot water supply time and quantity, but also reduces the volume of the heat storage tank, which can be flexibly arranged, helping to improve its energy-saving potential. The PCM is widely used in thermal storage applications and building energy-saving fields due to its high thermal storage density, stable performance, and phase change process approaching constant temperature. A new type of phase change energy storage heat pump water heater developed by scholars has been tested and found to have a system power consumption of 2000 W under summer operating conditions, a useful energy efficiency ratio of around 3.5, and a water heater that can produce 125 L of 47.6 °C hot water after two hours of heating. In the natural blend of stage change heat capacity and intensity siphon innovation, it is shown that the warming productivity of the stage change heat capacity preheating heat siphon water warmer is higher than that of the customary intensity siphon water radiator, and the intensity move attributes of the intensity stockpiling gadget are hypothetically broke down and tentatively examined. In order to improve the heat transfer efficiency of its heat storage and exothermic process, the author suggests including a variety of metal rings in the PCM. As of now, the examination extent of numerous homegrown researchers is just in the intensity move execution of stage change heat capacity, and there is not a lot of exploration on the effect of stage change heat capacity on the exhibition of the whole intensity siphon water warmer framework. It is as yet worth further hypothetical examination and exploratory exploration. The author investigated the effect of phase change heat storage boxes on the performance of heat pump water heater systems as well as the heat exchange effect of the heat storage boxes. The author used phase change heat storage materials for condensation heat recovery in heat pump air conditioning systems to produce domestic hot water. Based on experimental testing, the efficiency ratio of condensation heat recovery, temperature, and system cooling energy efficiency ratio (EER) were obtained comprehensive energy efficiency coefficient (COPt), based on the performance comparison with traditional water storage heat pump water heater systems (hereinafter referred to as water storage systems), the author proposes measures to improve the performance of phase change heat pump water heater systems (hereinafter referred to as phase change heat storage systems) [1, 2].

## Literature review

A heat pump water heater is a device that uses the principle of a heat pump to extract heat from a low temperature medium to produce hot water. In the early days of the invention of the heat pump, people began to try to use the heat pump to make hot water. During the WWII, Made in USA made about 10000 distillation heat pumps, providing drinking water for millions of people, but the widespread use of heat pump water heaters was after WWII. Many scholars have conducted professional research on heat pump water heaters. Zavrel *et al*. [3] studied the operating characteristics of R23 and R407C in heat pump water heaters, and found that the power consumption of heat pump water heaters using R407C is significantly higher than that using R23. At the same time, when water is discharged at high temperature, the heating efficiency of R407C is higher than that of R23. Especially when the evaporator dedicated to R407C is configured, its heating efficiency will be 22% higher than that of R23 system, and the power consumption of water heating will also increase by 5% [4]. Mahendra *et al.* [5] conducted comparative tests on air source heat pump water heaters using R134a, R147a, and R23 on a performance testing platform for air conditioners under various typical operating conditions. The analysis of the measured parameters shows that the suction and exhaust pressures of R417a and R134a are better than those of R23, which is beneficial for the operation of the heat pump water heater unit and R134a has a lower COP than R417a in a room temperature environment below 7 °C. Borodulin and Nizovtsev [6] studied the operating characteristics of small heat pump water heaters using capillary tubes of different lengths under different operating conditions, starting from throttling devices. The experiments showed that when the temperature of the heat source was too high, the capillary tube was the main limiting factor for the low heating efficiency of the heat pump.

Compared with ordinary heat exchange equipment and sensible heat storage equipment, phase change heat exchange equipment has the prominent feature of arranging fluid pipe-lines in the heat exchange equipment while also arranging PCM. According to the characteristics of phase change heat transfer, the PCM and fluid heat transfer process gradually increase the heat transfer resistance on the phase change material side due to the continuous phase change of the PCM, when the PCM layer undergoes complete phase change, the effective heat transfer area of the system gradually decreases, leading to a change in the temperature on the fluid side. Therefore, adopting effective heat transfer enhancement techniques and designing efficient heat storage and exchange equipment are the key to improving the latent heat storage efficiency.

## Methods

### *Heat pump water heater system test bench*

This system is composed of a heat pump air conditioner and a phase change heat storage box. The entire system can achieve functions such as separate refrigeration, separate heating, separate hot water production (independent heat recovery), and simultaneous refrigeration and heat recovery, the experimental content was conducted in both refrigeration and heat recovery mode. The phase change heat exchanger is a shell and tube type heat exchanger, which is filled with pure PCM through the refrigerant inside and outside. The heating water pipe and refrigerant copper pipe are arranged in parallel in a spiral shape. System workflow: The high temperature and high pressure superheated steam generated by the compressor undergoes heat exchange with the PCM through a phase change heat storage box, releasing sensible heat and becoming a high temperature and high pressure saturated gas. After further heat exchange through the condenser, it becomes a high temperature and high pressure supercooled liquid. After being throttled by a throttling device, it enters the heat exchanger inside the chamber to exchange heat and become a low temperature and low pressure gas, and then returns to the compressor. During the circulation process, high temperature and high pressure gas continuously flows through the phase change box to transfer heat to the PCM and heat it [7, 8]. As shown in fig. 1.

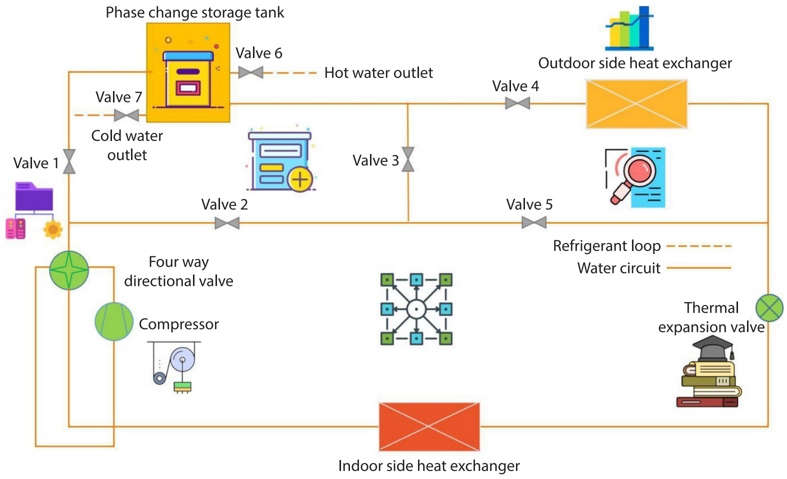


**Figure 1. Principle of phase change heat storage heat pump water heater system**

For the heat pump water heater system, the main parameters to be tested are the temperature inside the heat storage box, system evaporation temperature and condensation temperature, system suction and exhaust pressure, compressor power, refrigerant flow rate*, etc.* Under two working conditions of water storage and phase change heat storage, the COP of EER and heat storage box *R* of the system can be calculated from the test results of these parameters. See tab. 1 for the test device.

**Table 1. Testing device level accuracy**

| Device name | Specification form | Accuracy | Range |
|---|---|---|---|
| Temperature measuring device | Thermocouple | 0.6 level | –10-360 °C |
| Side pressure device | Pressure transmitter | 0.3 level | 0-2.6 MPa |
| Power measurement device | Power transmitter | 0.3 level | 0-870 W |
| Volume flow measurement device | Turbine flow transmitter | 0.6 level | 0-7 $m^3$ per hour |
| Mass-flow measurement device | Coriolis mass-flow meter | 0.3 level | 0-520 kg per hour |

## *System performance parameters*

The presentation boundaries of the intensity siphon water warmer are for the most part reflected in *R* and blower power utilization. The trial activity is in the refrigeration and intensity recuperation mode, and the principal execution boundary tried is the intensity stockpiling box *R*, which is the proportion of intensity recuperation add up to buildup heat discharge. The calculation formula is shown:

$$R_x = \frac{Q_r}{Q_{er}} \times 100\% \tag{1}$$

where $R_x$ is the condensation heat recovery rate, $Q_r$ [W] – the condensation heat recovery amount, $Q_{er}$ [W] – the amount of condensation heat released, and $Q_{er}$ – composed of compressor power consumption and cooling capacity under nominal operating conditions.

The $Q_r$ calculation formula for the water thermal storage system:

$$Q_r = c_P m \Delta t \tag{2}$$

where $c_p$ [kJkg$^{-1}$°C$^{-1}$] is the specific heat capacity of water, $m$ [kg] – the mass of water, and $\Delta t$ [°C] – the temperature difference between the inlet and outlet of the water tank. The $Q_r$ calculation formula for phase change heat storage systems:

$$Q_r = m\left(\lambda + c_P \Delta t\right) \tag{3}$$

where $c_p$ [kJkg$^{-1}$°C$^{-1}$] is the specific heat capacity of paraffin, $m$ [kg] – the mass of paraffin, $\lambda$ [kJkg$^{-1}$] – the enthalpy change of solution of paraffin, and $\Delta t$ [°C] – the temperature difference of paraffin thermal storage.

### *Data analysis*

By comparing traditional water heat storage and phase change heat storage experiments, the relationship between the internal temperature of the heat storage box, system suction and exhaust pressure, refrigerant condensation temperature, and evaporation temperature over time is obtained. Figures 2 and 3 show the variation curves of exhaust pressure and suction pressure over time for phase change heat storage and traditional water heat storage systems. From the comparison between figs. 2 and 3, it can be seen that the exhaust pressure of the phase change heat storage system in fig. 2 gradually increases before 95 minutes, and the fluctuation of this value is relatively small during the subsequent experimental process. However, in fig. 3, the exhaust pressure of the water storage system changes significantly and continuously increases over time, while the suction pressure has no obvious trend of change. From the data displayed in the fig. 3, it can be seen that the average exhaust pressure of the phase change heat storage system is below 2.6 MPa, and the average suction pressure is around 0.7 MPa. The suction pressure of the water storage system is around 0.5 MPa, and the exhaust pressure

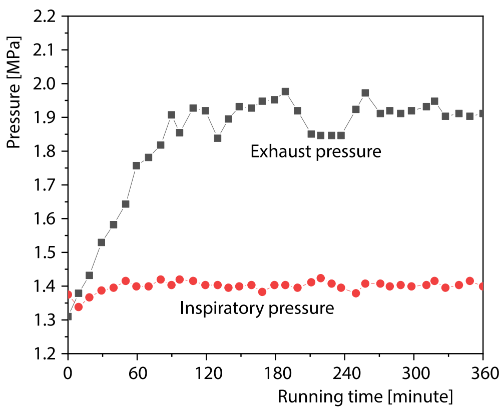


**Figure 2. Changes in exhaust pressure and suction pressure of phase change heat storage system**

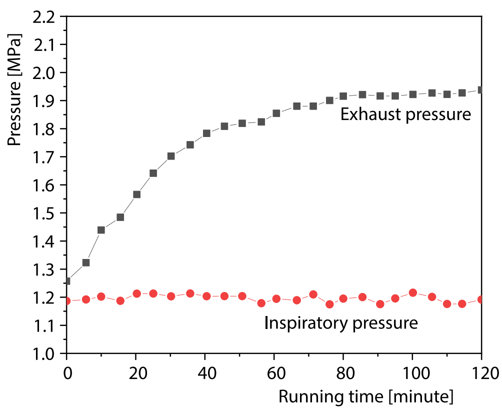


**Figure 3. Changes in exhaust pressure and suction pressure of the water thermal storage system**

increases from 1.3-2.1 MPa after 2.6 hours, gradually approaching the compressor shutdown protection value (2.6 MPa). The difference between the exhaust pressure of the water thermal storage system and the exhaust pressure of the phase change thermal storage system gradually decreases from the initial 0.8 MPa to the final compressor shutdown, indicating that the phase change thermal storage system operates more smoothly than the water thermal storage system.

The initial increase in exhaust pressure of the phase change heat storage heat pump water heater system is due to the single-phase heat exchange between solid paraffin and copper pipes at the beginning of the experiment. The temperature rise of solid paraffin reduces the heat exchange effect of the condenser, leading to an increase in exhaust pressure. After reaching the phase change temperature, paraffin begins to phase change heat storage, and the temperature remains approximately unchanged, resulting in less fluctuation in the system's condensation pressure, this is the reason why the exhaust pressure tends to stabilize after 95 minutes. So during the entire system operation, there is little fluctuation in the exhaust pressure and suction pressure values, with an average exhaust pressure of 1.92 MPa and an average suction pressure of 0.58 MPa.

In the traditional water storage heat pump water heater system, the exhaust pressure changes significantly. In light of the connection between buildup temperature and dissipation temperature over the long haul in fig. 4, it tends to be seen that because of the enormous temperature contrast in heat trade among water and refrigerant in the intensity stockpiling box toward the start of the analysis, the buildup temperature and strain are moderately low, as the water temperature expands, the intensity move limit on the water side debilitates, and more buildup heat is step by step moved by the outside heat exchanger. The exhaust pressure rises and the growth rate of condensation pressure and temperature slows down as the water temperature rises to approximately 50 °C. The development rate keeps on diminishing until the blower stops for insurance. The indoor temperature stays consistent, so the blower vanishing temperature and tension stay steady.

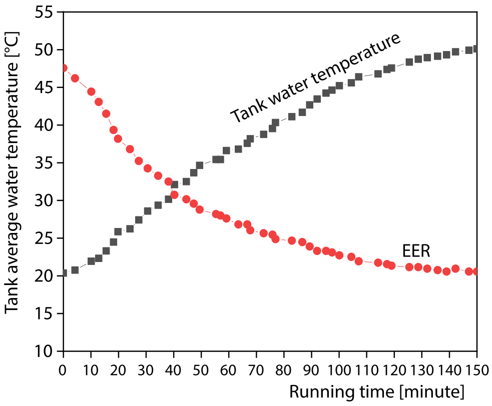


**Figure 4. Water temperature and EER variation diagram of water tank**

From fig. 4, it can be seen that the rate of increase in water temperature gradually decreases over time, and by 160 minutes, the temperature tends to 50 °C, while the EER continues to decrease over time, ultimately reaching around 2.6. Due to the continuous increase in condensation temperature on the condensation side, the compressor has a certain compression volume, and the exhaust pressure continues to rise, resulting in a decrease in refrigerant flow rate and corresponding reduction in cooling capacity in the system. The input power continues to increase, and the refrigeration EER of the system decreases with the increase of water temperature. Figures 5 and 6 show the variation curves of COPt and *Rx* over time for phase change thermal storage systems and water thermal storage systems.

The system shown in fig. 5 runs smoothly throughout the entire operation process, with minimal fluctuations in COP and *RQ*. As shown in fig. 6, the COP and *R* of the water storage system gradually decrease over time. This is because the condensation temperature increases, the compressor compression volume is constant, and the refrigerant flow rate decreases, resulting in a decrease in the system's heating capacity. The increase in exhaust temperature increases the system's power consumption. As the exhaust temperature of the system increases, the heat leakage between the compressor exhaust port and the expansion valve increases, causing a decrease in *R*. Compared to the two, the *Rx* of the water thermal storage system is about 6% higher than that of the phase change thermal storage system, and the system COPt is also 20% higher than that of the phase change thermal storage system. This shows that the heat exchange effect of the phase change thermal storage box is poor, leading to a decrease in the performance of the heat pump water heater system [9-11].

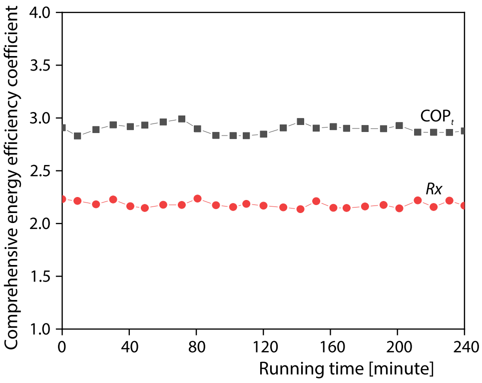


**Figure 5. Change diagram of COPt and *Rx* in phase change heat storage system**

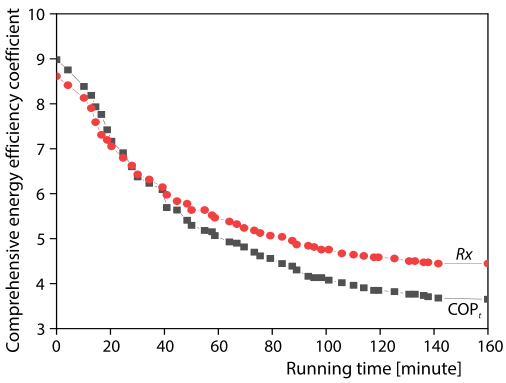


**Figure 6. Changes in COPt and *Rx* of the water thermal storage system**

## Conclusions

The author conducted experimental tests on the performance of pure paraffin phase change heat storage and water storage heat pump water heater systems, analyzed the pure PCM heat storage process and system comprehensive performance, and compared them with traditional water storage systems. The conclusions are as follows.

- The suction and exhaust pressure of a phase change heat storage system is less affected by condensation temperature and evaporation temperature than that of a water storage system, and its operating state is stable, which is conducive to controlling parameters such as indoor and outdoor simulated side temperatures during the experimental process.
- The phase change heat storage system's heat storage box has a poor internal heat transfer situation, resulting in a significant decrease in *Rx* and a poor recovery effect. The intensity move and energy stockpiling impacts of stage change materials significantly affect framework execution. Subsequently, heat move is fortified by finning the twisting curl or embedding aluminum foil, adding materials, for example, extended graphite, to abbreviate the intensity stockpiling time and work on the general execution of the framework, in this way further developing energy use effectiveness.

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Paper submitted: May 18, 2023
Paper revised: August 23, 2023
Paper accepted: September 25, 2023