

Theoretical heating coefficient of a heat pump water heater with heat recovery applied in household bathing room

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Abstract: Presents the components and flow diagram of a heat pump water heater with heat reclaim applied In household bathing room, analyzes its characteristics from thermodynamical principle, calculates its theoretical heating coefficient under different operating conditions. The result shows that the maximum value of its heating coefficient is 12.9 under a typical operating condition.

Keywords: bathing room; heat-reclaim; heat pump; flow diagram; COP

1. Introduction

In most conditions, the excess heat of exhaust water, discharged from household bathing room and drained directly, is not utilized, which causes greater heat loss for its higher temperature. For this reason, it is suggested that a heat pump, which takes exhaust water as low temperature heat source, should be used to reclaim its exhaust heat and to produce sanitary hot water for bating room. In this way, we name the above-mentioned heat pump as "heat pump water heater applied in household bathing room with heat recovery" (briefly name it HPWH below).

2. Components and operation

Basic flow diagram of HPWH is shown in Fig.1. The main components of the system are four parts (similar to electrical heat pump, including compressor, condenser, throttle valve, evaporator) and secondary equipments (including: accessorial electrical element, water collector and filter, bathing settings, piping fittings),

Operation running of HPWH is similar to common electrical heat pump. Refrigerant absorbs firstly heat from the exhaust water discharged from household bathing room in evaporator, then is compressed in compressor, and finally release its heat in condenser to heat tap water to the required temperature for bashing. In condenser, refrigerant is condensed into saturated liquid, and then its pressure and temperature are lowered in throttle valve. And it flows into evaporator to absorb heat and change itself into saturated vapor, thus a circulation is completed. At the same time, tap water absorb heat

in condenser and its temperature increases to certain value(about 40 °C), and then flows into water-sprayer for the use of bathing. The water used during bathing is collected in the water filter and collector, and then flows into evaporator to release its excess heat, sequencely drained by drainpipe.

Before start-up of HPWH for bathing, Refrigerant can only absorbs heat from the water remained in condenser, because there is not higher-temperature water discharged from the bathing room to be used as low temperature source. When its temperature drops down from normal temperature to about zero, accessorial electrical element may be used to heat directly bathing water for a short time, and after the beginning of bathing it will stop automatically because exhaust water from bathing room can be used as its low temperature source.

3. Theoretical heating coefficient

In order to simplify its analysis and computation of heating coefficient ε_h , secondary factors, such as sub-cooling, superheating in vapor suction, and so on etc. are neglected, and $\varepsilon_{h,th}$ is calculated according to theoretical circulation of HPWH, which is shown in T-S and lgp-h figure as Fig.2.

In fig.2, line 4-5 stands for throttling process of refrigerant, during which its enthalpy keeps constant and its temperature and pressure drop synchronously, and then it flows into two-phase region; line 5-1 stands for evaporating process of refrigerant, during which it absorbs heat from the exhaust water from bathing room; line 1-2 stands for constant-entropy compressing process; line 2-3-4 stands for condensing process, including cooling process (line

2-3) and saturated-condensing process (line3-4). Refrigerant liberates its thermal energy and potential heat respectively under higher and saturated temperature respectively in line 2-3 and line 3-4. From here we see that the compression work and the heat, which is absorbed by refrigerant from exhaust water, are transferred together into the bathing water to be heated.

During operation of HPWH, the temperature of the water collected from bathing room is relevant to many factors, such as bathing water consumption, temperature of bathing water before its spraying, spraying style, bathing room temperature, bathing room area, wall structure, etc. And their quantificational correlation is expected to be

determined by experiment.

The hypotheses below are adopted to simplify the computation process of theoretical-heating coefficient $\varepsilon_{h,th}$ of HPWH:

- 1) Condensing temperature is 50°C , according with the required temperature for bathing;
- 2) Evaporating temperature is 10°C lower than that of exhaust water from bathing room(i.e. The temperature difference is 10°C in the evaporator, and condensing temperature is constant);
- 3) Refrigerant is Freon R22.

From the conditions mentioned-above and the theoretical circulation as shown in Fig.2, the change in $\varepsilon_{h,th}$ with the temperature of exhaust water from bathing room is gained, as shown in Fig.3.

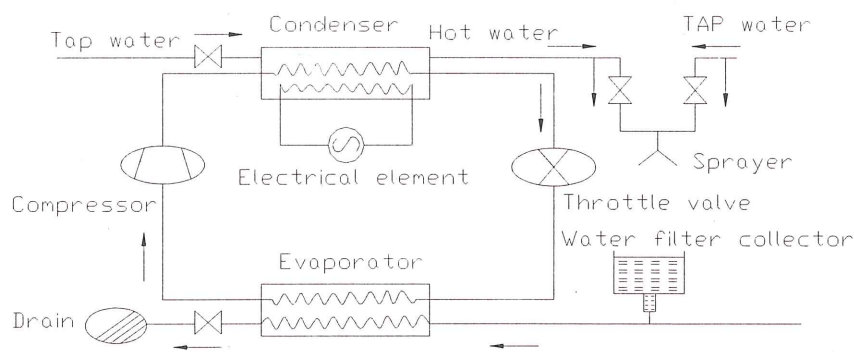


Fig.1 Flow diagram of HPWH

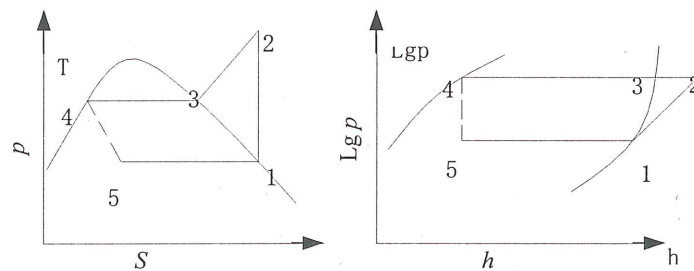


Fig.2 T-S and $\lg p$ -h of HPWH

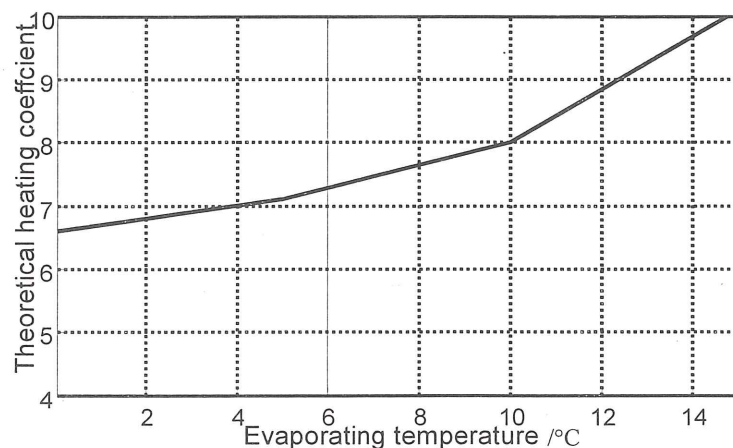


Fig.3 Heating coefficient of HPWH

In Fig.3, $\varepsilon_{h,th}$ of HPWH increases from 5.6 to 15.2 when the temperature of exhaust water from bathing room ranges from 5°C to 35°C. Really, the range of temperature variation of the exhaust water is very small. Author measured the temperature of exhaust water from a bathing room (3m²) in a resident house in southern China and found that its temperature varies from some 28°C to 36°C, mostly being about 30°C. Consequently it is considered as the typical value of the temperature of exhaust water from a bathing room, and its corresponding $\varepsilon_{h,th}$ of HPWH is 12.9. However the heating coefficient of conventional household electrical water heater is only 0.95-0.98, adopting its mean value as 0.96. Thus it can be seen that $\varepsilon_{h,th}$ of HPWH is 13.4 times, compared with that of the electrical water heater.

HPWH takes the exhaust water discharged from bathing room, which has higher temperature, as its low temperature source, so its $\varepsilon_{h,th}$ is as high as 12.9, which is much higher than that of a common heat pump.

As for the correlation of real heating coefficient of HPWH (ε_h) and operating parameters, such as condensing temperature, evaporating temperature, etc. is to be decided by a series of experiments later.

4. Conclusion and discussion

The HPWH presented in this paper is really a water-source heat pump (WSHP), which takes exhaust water discharged from bathing room as its low temperature source. Theoretical computation shows that $\varepsilon_{h,th}$ of HPWH is 13.4 times than that of common water heater, so using a HPWH to replace a common water heater to produce hot water for a bathing room may make users' electricity consumption and operation cost much lower. As for the increase in first-cost of HPWH, it can be compensated by energy-conservation. So its research and application should be performed well to speed its spread.

It should be pointed out that the real heating coefficient of HPWH is to be decided by a series of experiments.

References

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