

A new solar vapor jet refrigeration system with light funnel congregating and high temperature storing energy

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ABSTRACT: the vapor jet refrigeration system which uses thermal effect of the solar energy gets the attention because of its simple structure, environmentally friendly characteristic and easy maintaining. This paper develops a new type of refrigeration system with solar funnel high temperature congregating and storing energy. The operation parameters of the whole system have been calculated. The result shows that the new system proposed can provide refrigeration capacity for individual user in the fine weathers thank to its high solar collecting efficiency and high heat collection temperature. It has a promising application.

Keyword: solar energy; light funnel assembling energy; solar vapor jet refrigeration

1. INTRODUCTION

Using solar energy to drive a vapor jet refrigeration system, or an absorption refrigeration system and adsorption refrigeration system has been widely got attention and has gained certain effects. In the early researches, the solar absorption refrigeration system was the study focus for many researchers, and got a relatively mature development. Many demonstration projects have been set up. The solar solid adsorption refrigeration system has also broken through some new technology recently years. Many new products have been made. However, both of them have complicated structures. Their working medium has causticity. Their

efficiency would be decrease for a long time use. Therefore, vapor jet refrigeration gets more and more attention.

Comparing with the traditional electric drive compressing refrigeration system, vapor jet refrigeration system has its unique advantages ^[1]:

- (1) Ejector doesn't have any move part, and its structure is simple, its operation is reliable.
- (2) Ejector use low quality thermal energy as its power. So the system would consume little electricity and could use solar energy.
- (3) The environmental friendly working medium such as water could be used as the freezing medium.

- (4) The ejector has a simple structure and easy to combine with other system to form a hybrid one, which can enhance the system efficiency while it doesn't need to add the system complexity.

Because of the above advantages of the vapor jet refrigeration, using solar energy in a vapor jet refrigeration system have a double significance of energy saving and environment protection. Many researchers have studied on this kind of system in this field for long time. Nguyen(2001) have ever made a vapor jet refrigeration system using water as the freezing medium. The simulation result showed that the whole day *COP* of the system could be 0.2~0.3^[2]. Zhangbo(2006) have also experimentally studied the performance of the jet refrigeration system. The result indicated that the system's *COP* was up to about 0.20^[3, 4]. Moreover, many researchers have ever brought forward such systems as pressure enforce jet refrigeration system, hybrid jet system and compound jet system. The operation performance of these kind of system have a rise in certain extent. Dorantes(1996) simulated the situation that jet-compression hybrid refrigeration system got a 0.34 *COP* under the real weather in Mexico using R142b as freezing medium^[5].

On the basis of the research results, it is not difficult to find that the solar vapor jet

refrigeration system could not take full use because of the low temperature of the solar heating system. A new vapor jet refrigeration system with a solar funnel collecting the sun's energy has been designed which can get a high temperature operation condition. The experimental result indicated that this new solar collection system can get a 350°C temperature. In this paper, the funnel-shape solar heat collecting system was combined with the vapor jet refrigeration system, and the operation parameters were designed and calculated.

2. THE SOLAR VAPOR JET REFRIGERATION SYSTEM WITH LIGHT FUNNEL CONGREGATING AND HIGH TEMPERATURE STORING ENERGY

2.1 The structure of the system

The structure schematic of the new type solar vapor jet refrigeration system is shown in Fig.1. It is composed of three parts: sun light collection system, heat storage system and vapor generation and jetting system. The light collection system has the shape of a funnel linked to an automatic tracking system. Heat storage system is composed of a heat storage tank and heat storage material (phase change material). The vapor jetting system is composed of an ejector, evaporator, condenser and working medium pump.

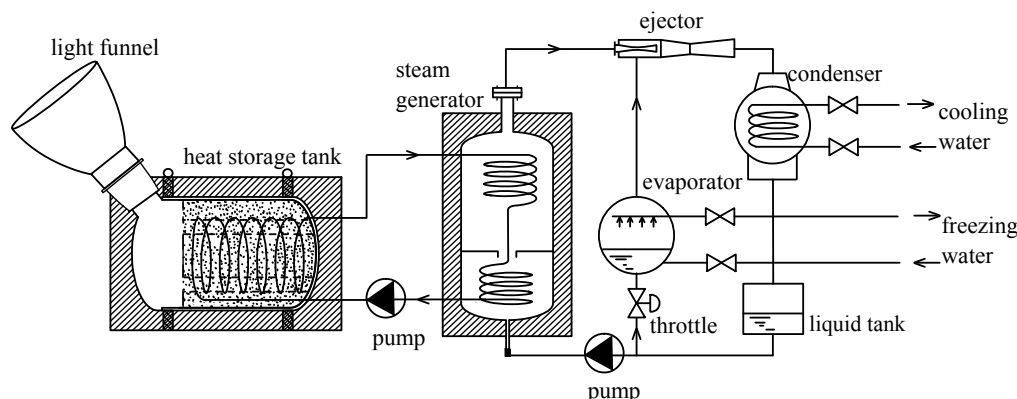


Fig.1: Structure schematic of the new solar vapor jet refrigeration system.

2.2 The working principle of the heat storage and refrigeration of the system

The funnel-shaped solar concentrator collects the solar energy and stores it into the heat storage tank via the light guide channel and promote the inside temperature of the tank. The heat conduction oil exchanges the heat energy via the heat conduction coil inside the heat storage tank and then transmits the heat energy to the evaporator. High temperature and high pressure working vapor has been produced inside the evaporator. The working vapor swells adiabatically via the reducing-and-divergent nozzle and has a very high speed and big kinetic energy when it reaches the outlet. So there is a very low pressure inside the suction chamber. The low pressure gaseous freezing medium in the evaporator will be sucked into the suction chamber of the ejector so that the low pressure in the evaporating chamber is kept and the continuous refrigeration is accomplished. Afterward, the high speed working vapor together with the low pressure cold vapor in the suction chamber go into mix chamber. The two vapors in the mix chamber exchange the energy to each other. Their flow speeds become even gradually and then reach into the diffusion chamber. With the gradual reduction of the flow speed of the vapor stream in the diffusion chamber, the kinetic energy of the stream turns into the pressure energy. The pressure of the vapor stream rises and is up to condensation pressure when it reaches the outlet. After the pressure to be enhanced the mix vapor enters the condenser and becomes liquid with the freezing medium cooling it. Some of it, as freezing medium, enters the evaporator via expansion valve. The others go back to the vapor generator via a working medium pump.

3. THE THERMODYNAMIC CALCULATION OF THE NEW SOLAR VAPOR JET REFRIGERATION SYSTEM

3.1 The theory circulation of the vapor jet refrigeration

In the tephigram, the theory circulation of the vapor jet refrigeration is shown in Fig.3. The points in the Fig.3 correspond to the designated points.

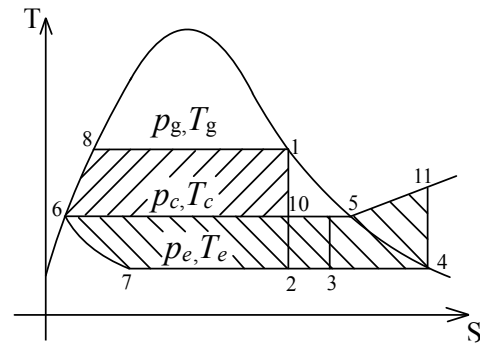


Fig.3: The vapor jet refrigeration circulation on the tephigram.

If supposing the compression process in the ejector is divided into 2→10 for working vapor and 4→11 for cold vapor, two circulations are conducted in the vapor jet refrigerator: normal thermal circulation 1→10→6→8→9→1 and adverse refrigeration circulation 4→11→5→6→7→4.

Under the ideal condition, the efficiency of the jet refrigeration system is

$$\begin{aligned} COP_i &= Q_e / Q_g \\ &= T_e / T_g \times (T_g - T_c) / (T_c - T_e) \\ &= (1 - T_c / T_g) [T_e / (T_c - T_e)] \end{aligned}$$

The above equation indicates that in the normal condition the standard to select the circulation temperature is that the temperature in the evaporator and generator should be as high as possible and the one in the condenser should be as low as possible in order to get the high COP .

3.2 The parameter circulation of the solar vapor jet refrigeration

The new solar refrigeration system uses polyols solid-solid phase change Materials to store energy, whose phase change temperature is 188 °C, the density is $\rho=1440\text{kg/m}^3$ and energy storage density is $\rho_e=323\text{kJ/kg}$. Supposing the power of the pump in the system is 75 W. Reserve thermal efficiency is set to $\eta_s=90\%$, set the efficiency of light funnel is set to $\eta_c=50\%$ ^[6], the efficiency of steam generator for the $\eta_g=95\%$. The maximum radius of the light funnel is $r=1.5\text{m}$.

If the power of the refrigeration system is 0.7kw, the system will work 12 hours a day, the intensity of solar radiation is 900w/m^2 and daily solar radiation time is eight hours. According to the literature [3], when the refrigeration system operating parameters take the numerical shown in Table 1, the system can achieve the value of *COP* 0.45, as a conservative estimate, *COP* calculated for this refrigeration system is taken 0.4.

Table I: The operation parameters of the new solar refrigeration system.

Evaporator temperature/ T_e	12°C
Condenser temperature/ T_c	35°C
Vapor generator temperature/ T_g	164°C
Working vapor pressure/ P	0.7MPa

Accordingly, the calculation of the total refrigeration power per day is 30.24MJ.

The total heat energy requirement provided by the steam generator is about

$$Q_g = \frac{Q_e}{COP_r} = \frac{30.24}{0.4} = 75.6 \text{ MJ}$$

The total energy provided by the thermal storage tank is about

$$Q_s = \frac{Q_g}{\eta_g} = \frac{75.6}{0.95} = 79.57 \text{ MJ}$$

The total energy stored by the thermal storage tank is that

$$Q_c = \frac{Q_s}{\eta_s} = \frac{79.57}{0.9} = 88.41 \text{ MJ}$$

The total energy collected by the collector is

$$Q = \frac{Q_c}{\eta_c} = \frac{88.41}{0.5} = 176.82 \text{ MJ}$$

Collect-area is as follows

$$S = Q / (900 \times 3600 \times 8) = 6.82 \text{ m}^2$$

Needed to set the number of concentrators is,

$$n = \frac{S}{\pi r^2} = \frac{6.82}{3.14 \times 1.5^2} = 0.96 \approx 1$$

Phase change materials needed for the quality,

$$m = \frac{Q}{\rho_e} = \frac{176.82}{0.323} = 547.43 \text{ kg}$$

Phase change materials needed for the size

$$V = \frac{m}{\rho} = \frac{547.43}{1440} = 0.38 \text{ m}^3$$

The above calculation shows the application of the new type of refrigeration system with solar funnel high temperature congregating and storing energy, if the day by 30.24MJ of refrigeration capacity, the diameter of 3m of the new focusing type light funnel is needed only one and energy storage materials is needed only 0.38m^3 .

4. CONCLUSION

In a refrigeration system which uses thermal effect of the solar energy, the vapor

jet refrigeration system gets the attention because of its simple structure, environment friendly characteristic and easy maintaining. But this vapor jet refrigeration system is inefficient, which is an important reason to restrict the development of the system. And the low temperature from solar concentrator is the one of the most important reasons to make this vapor jet refrigeration system have a low efficiency. The new type of solar funnel high temperature congregating and

With the funnel-shaped collector high temperature collection heat technology and the development of storage heat technology, the solar vapor jet refrigeration system will

storing energy technology, which developed in this paper, can solve the problem.

Through the calculation above, we can conclude that combine this new type of solar funnel high temperature congregating and storing energy system with the vapor jet refrigeration system can provide power for 0.7 kW refrigeration system running half-day. This can service for the small users to provide adequate refrigeration power, for example, we can use it in remote parts of the be used in a broader field.

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