Experimental Investigation on the Operation Performance of A Liquid Desiccant Air-conditioning System[1]

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Abstract: A large share of energy consumption is taken by an air-conditioning system. It worsens the electricity load of the power network. Therefore, more and more scholars are paying attention to research on new types of air-conditioning systems that are energy-saving and environment-friendly. A liquid desiccant air conditioning system is among them, as it has a tremendous ability for power storage and low requirements for heat resources. Heat with low temperatures, such as excess heat, waste heat, and solar power, is suitable for the liquid desiccant air-conditioning system. The feasibility and economical efficiency of the system are studied in this experimental research. The result shows that when the temperature of the regeneration is about 80℃, the thermodynamic coefficient of the system is about 0.6, and the supply air temperature of the air-conditioning system remains stable at 21℃, the air-conditioning system can meet human comfort levels.

Keywords: The liquid desiccants air-conditioning system; waste energy applying; experiment; performance analysis

1. INTRODUCTION

Currently, a large share of the energy consumption is taken by conventional air-conditioning system in summer. In 2003, it is indicted in the analysis report of the power market in our country by the state power network corporation that the power consumption proportion used for the load of air-conditioning system in the power networks of east China, south China and middle China has overtopped 30%. It is considered as a urgent job to develop a new, energy-saving air-conditioning system. Liquid desiccant air-conditioning system is able to use the low worth heat source with temperature about 80 , which can be waste heat, excess heat from industry, and the reproducible and clean power included solar energy etc.. Moreover, the liquid desiccant air-conditioning system has the ability to reserve heat energy as chemical energy, which is more efficient than common heat-reserving material－ice by 4 to 6 times. So the liquid desiccant air-conditioning system is increasingly accepted by people.

Recently years, both domestic and overseas experts do a large scale of studies for the liquid desiccant air-conditioning system, and obtain many valuable productions. But these productions are mainly the study of theory model, numerical simulation and the performance analysis of the single dehumidifier unit or regenerator unit, such as H.M.Factor、P.Gandhidasan had made numeral studies of heat and mass transfer in the liquid desiccant system[1] [2], Öberg et al constructed a experiment set include dehumidifier and regenerator to research the influencing factors for the operation of dehumidifier and regenerator[3], but there are only few words about the practice work performances of the whole liquid desiccant air-conditioning system. With a whole liquid desiccant air conditioning system, the paper

1 Supported by key project of Ministry of Science and Technology of China (2005BA908B27), special project of Shanghai World's Fair (05dz05827), key project of Shanghai Municipal Education Committee (T0503)

investigates the practice performances of the system which works in a stabilization condition.

2. LIQUID DESICCANT AIR CONDITIONING SYSTEM

A liquid desiccant air conditioning system consists of dehumidifier, evaporate cooler, solution cooler, solution heater, regenerator, storage heater and water tank for store energy and so on. A schematic description is given in Fig.1. The exchange of heat and mass is processed between handled air (ambient air of the installation or return air of air-conditioning room) and liquid desiccant in the dehumidifier (state 1). The handled air is dehumidified by liquid desiccant and then the dry air is sent into the evaporate cooler (state 2), going through the humidifying in a constant enthalpy process, its temperature falling down to the supply air temperature required by the air conditioning system along with its humidity increasing. At the same time, the desiccant solution goes also through two circle processes, which are dehumidifying circle and regenerating circle. In the dehumidifying circle, solution pump (state 5) firstly sent the highly concentrated desiccant solution to the solution cooler (state 3) to depress its temperature, then into the dehumidifier (state 1). There, the vapor pressure of the low temperature concentrated solution is less than that of the handled air, and the desiccant solution absorbs the vapor of the handled air, so that the air is dried and the dehumidify process is completed. After absorbing the vapor, the desiccant solution becomes into thin solution. Since the dehumidify process should go on continuously, it is necessary to regenerate the diluted desiccant solution. Thus, the thin solution is pumped into the solution heater (state 6) by the solution pump (state 5) and heated in it. Then the heated solution is sent to the regenerator (state 7), where the hot thin solution contacts with the fresh air from the environment. Here the face vapor pressure of the heated thin solution is higher than that of the air used for regenerating solution, the import air used for regenerating will take away the steam from the thin solution evaporating to make the thin solution get concentration and regeneration.

3. EXPERIMENT STUDY DESCRIPTION

In the experiment system given by Fig.1, the devices of dehumidifier and regenerator have the similar structure form, parked type tower structure. The characteristic of the padding filling in these towers is that surface area ratio is 350m^2/m^3, the average equivalent diameter is 0.01m and the height is 1.0m.

The section dimension of the evaporative cooler is 0.09m^2, the average equivalent diameter of the wet film is 0.01m, the length of the wet film is 0.15m and the surface area ratio of the wet film is 350m^2/m^3.

The heat exchange quantity of the solution cooler can be adjusted in the bound of 0 ~ 12 kW.

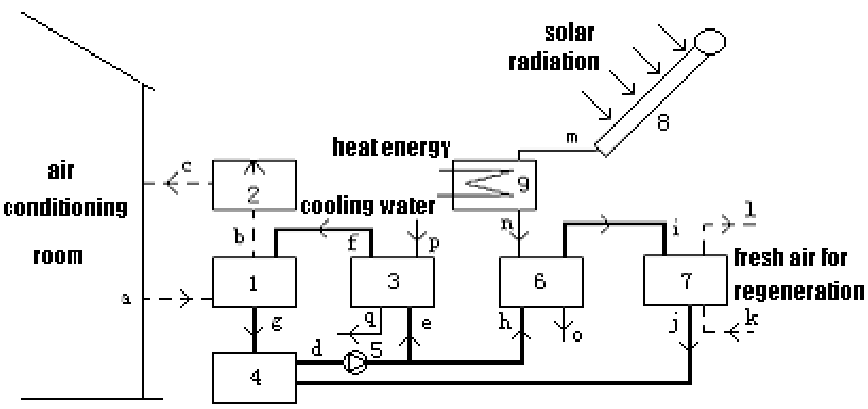

Fig.1 Schematic description of the liquid desiccant air conditioning system

1-Dehumidifier 2-Evaporative cooler 3-Solution cooler 4-Solution storage tank 5-Solution pump

6-Solution heater 7-Solution regenerator 8-Solar energy collector 9-Storage energy water tank

Theheating quantity of the solution heater can be adjusted in the bound of 0 ~ 18 kW.

Based on the results of the single device experiment, the optimal function parameters of the dehumidifier and regenerator are selected. For the dehumidifier, the inlet temperature, flux and concentration of solution are 30 , 900L/h and 40%, while the inlet temperature, humidity and flux of handled air are 35 , 20g/kgDA and 40%. For the regenerator, the inlet temperature, flux and concentration of solution are 60 , 320L/h and 40%, while the inlet temperature and humidity of ambient air used for regenerating are 35 and 15g/kgDA. The whole liquid desiccant air conditioning system works with the parameters listed upwards. After the system enters stability state, the work data of the system are mensurated and used to research the one another relation of the refrigeration capacity betweem the solution concentration, the temperature of heat source, and the waste work etc.

In the experiment study, the system parameter test content involves the temperature and humidity of the environment air, the temperature of the cooling water entering and venting the system, the temperature, humidity, quantity of the air current of entering and venting the dehumidifier and the regenerator, the solution temperature, flux, concentration of entering and venting the parked towers, the heating and cooling quantities of the system, the waste work of fans and pumps.

The temperature test point is 15 points and T type thermocouple (0.3mm) is used for temperature test element. The temperature meterage includes the test of dry bulb temperature and wet bulb temperature. With the dry bulb temperature and wet bulb temperature of every test point, the humidity of this point may be obtained by calculating the humidity content. The temperature measure consists of the test of dry bulb and wet bulb temperature of the ambient air, the temperature of the air and the solution of entering and venting the parked towers, and the temperature of the solution in the storage tank, the temperature of the cooling water at the inlet and outlet of solution cooler, the temperature of the hot water at the inlet and outlet of solution heater. The humidity gotten by calculation with dry bulb and wet bulb temperature of every point includes the humidity of ambient air, the humidity of the air at the inlet and outlet of the dehumidifier and regenerator.

The test of air current employs pitometer to measure air flow rate in every point in the towers and the ducts. And the rotameter is employed to the test of water and the brine flux. The first step of the test on the concentration of the solution is to measure the density of the solution, then at the concentration-density chart the solution concentration can be looked up with the obtained density. The data collector is employed to log the real time value of each parameter, such as temperature, flow quantity and electric current, voltage etc.. The solution concentration and the pressure value of air current through the towers are measured and noted manually. The collection and analysis program of experiment data is workout with VB. All data would display at the computer interface and be stored in the computer databank.

4. EXPERIMENT RESULT AND DATA ANALYSIS

The chief work of experiment of the liquid desiccant air conditioning system is to test whether all work conditions of the system is match and the one another relations of the solution concentration, temperature of heat source and refrigeration capacity, energy consumption is harmony. The precondition of study is that the system must run under steadily, especially the solution concentration must be steady. In the experiment process, the system applied a series of means to keep the refrigeration capacity steady, namely, at first adjusting the portion work condition of dehumidify and humidify to make these conditions steady and steadying the parameter of the air current entering the system, then adjusting the temperature and flow quantity of regeneration solution to make the refrigeration capacity steady after the state of air steam entering into the towers steadying. At that time the variety of solution concentration in the regenerator and dehumidifier becomes equilibrated. Whether the variety of solution concentration is equilibrated or not can be estimated by checking whether the unit time mass transfer quantity in the regenerator and dehumidifier is equipotent. The temperature and flow quantity of regeneration solution are the adjusting shifts to realize solution concentration steady.

When the experiment start, first as per design require we adjust air temperature, humidity and flow quantity, solution flow quantity of entering into regenerator and humidifier, then open the solution heater to heat regeneration solution with 80℃ hot water and make the system run. Observing the unit time vapor transformation in the regenerator and dehumidifier, we found that with the temperature raise the variety of steam held by the solution gradually cuts down to zero, indeed to negative value. Meanwhile, the steam quantity taken away from the solution by regeneration air is more than the steam quantity absorbed from the handled air by the solution. The temperature of heat source using for solution concentrating in the system confirms the inspissation's direction. When the heat quantity to regenerating solution decrease and the temperature of regeneration solution fall down to about 65℃, the variety of vapor held by the solution still is negative, about -1800g/h. Decreasing the hot water volume continuously, namely reducing the heat quantity to regeneration solution makes the temperature of solution steady about 61℃, here the variety of steam held by the solution fluctuate near zero. The balance of the vapor absorption and desorption of solution would be reached. The liquid desiccant air conditioning system can run steadily. When the system run stably, the process parameters are listed as follows, the air inlet temperature is 35℃, the air inlet humidity is 20g/kgDA, the flow quantity of dehumidified air is 386m^3/h, the flow quantity of regenerating air is 360m^3/h, the temperature of desiccant solution is 30℃, the solution concentration is 40%, the solution flow quantity in dehumidifier is 950L/h, the solution flow quantity in regenerator is about 300 L/h, the temperature of water used for humidifying is 15℃. The varying curves of portion experiment parameters determined under stably work condition shows at Fig.2 to Fig.5.

Fig.2 Vapor variety of the system going through the circle of dehumidifying and regenerating (g/h)

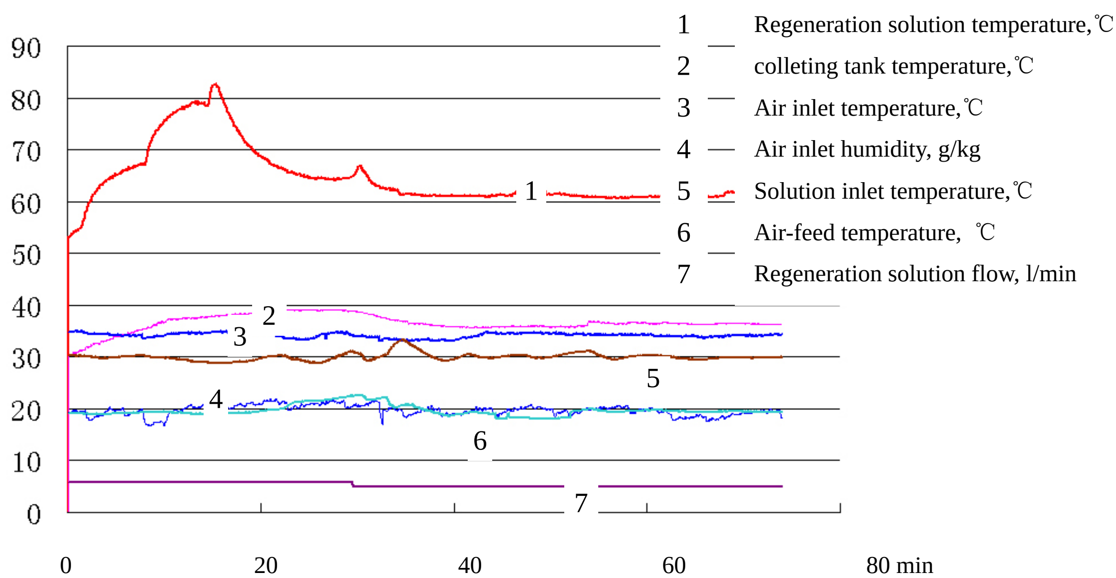

Fig.3 Value variety of portion test parameter in the system

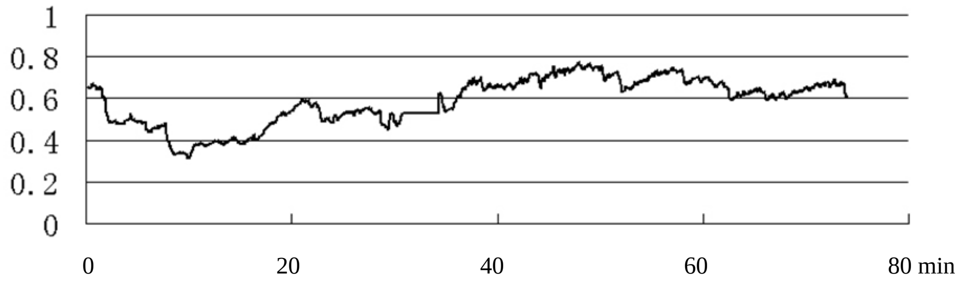

Fig. 4 Value variety of the system heat efficiency (kW/kW)

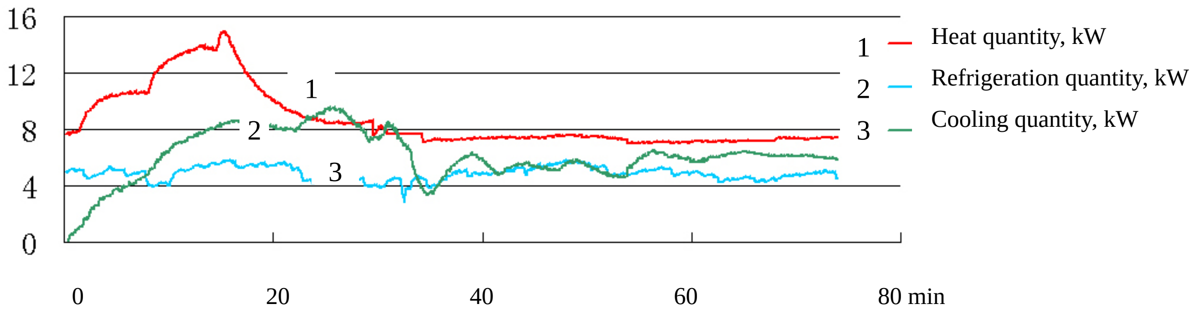

Fig. 5 Value variety of heat quantity, refrigeration quantity and cooling quantity of the system

These experiment data show when the temperature of heat source is 80℃ and the inlet solution temperature of regenerator steady at 61℃ and other system parameters steady at enactment condition, thus the liquid desiccant air conditioning system will run stably. At the time the temperature of supply air, namely the temperature of the air humidified, is about 20℃. The temperature can meet the supply air temperature need of air conditioning system. When the temperature of supply air steady at 20℃ and the heat quantity of heat source steady at 7.5 kilowatt, the refrigeration capacity of the system may be about 5 kilowatt, and the system heat efficiency fluctuate near 0.6. A mass of solution heat is carried away by the regeneration air which is imported from ambient. The cooling capacity is at 6.5 kilowatt, about 1.3 times as the refrigeration capacity. Compared with other refrigeration means driven by heat, cooling capacity of the system is obviously lesser.

These experiment result show when the liquid desiccant air conditioning system arrive at the stable state, the proportion of the solution current between in the dehumidifier and in the regenerator is not 1:1. In this experiment, when the proportion of the solution current between in the dehumidifier and in the regenerator is 3:1, the system goes to steady. If the driving heat source happen to change or the temperature limit condition required by the supply air differs, the proportion of the circulation solution current in the dehumidifier and the regenerator also differ so that the system is at stable state.

When the temperature of driven heat source is 80℃, the system heat efficiency of refrigeration is about 0.6. This shows that the system has better thermodynamic performance. The liquid desiccant air conditioning system use 80℃ heat source for driving heat source. So the generic industry excess heat and waste heat, and the reproducible energy sources such as solar energy etc can all be used for driving heat source. In the place where can provide with waste heat, terrestrial heat and solar energy the desiccant air conditioning system may be applied widely. That has vast space of saving energy and activity social and economic signification.

5. CONCLUSION

Under proper work conditions, the liquid desiccant air conditioning system can provide 20℃ supply air temperature for the air conditioning room. The temperature can meet the need of general comfortable air conditioning. So the liquid desiccant air conditioning system possesses the feasibility of application.

Utilizing 80℃ heat source, the liquid desiccant air conditioning system can supply suitable air temperature and refrigeration capacity required by air conditioning system. The system has better thermodynamic performance and locates higher level of efficiency among the similar air conditioning systems driven by low grand heat source.

As the liquid desiccant air conditioning system is driven by low grand heat source in the place with excess heat, waste heat and terrestrial heat, solar energy etc reproducible energy sources, the application foreground of the system is prosperous, and the system can be extended and has a great economic value.

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