Performance Test and Energy Saving Analysis of a Heat Pipe Dehumidifier

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Abstract: Heat pipe technology applied to ventilation, dryness, and cooling and heating radiator in a building is introduced in this paper. A new kind of heat pipe dehumidifier is designed and tested. The energy-saving ratio with the heat pipe dehumidifier ranges from 11.81% to 30.34% compared with the normal dehumidifier, according to the performance testing. The dehumidification capacity and the surface cooler power increases, but the energy saving ratio is reduced with the increase of air relative humidity, dry bulb temperature and air quantity.

Key words: heat pipe; dehumidifier; energy saving HVAC

1. HEAT PIPE APPLICATION IN BUILDING ENERGY SAVING

Boiling and condensation have a high efficiency of heat transfer with latent heat exchange. Liquid working fluid boiling in one side (evaporation side) of a closed pipe and condensates in other side (condensation side), which causes the heat be transferred from one side to another, and this closed pipe is called heat pipe[1]. Because both boiling and condensation are take place at the same time in the pipe, the temperature in the pipe basically is at the saturation temperature of working fluid, the axial temperature difference along heat pipe is very small and the heat transfer capability is very large, so heat pipe is also called a super heat conducting element. Also the fluid, no matter cooled or heated, always flows in the outside of heat pipe, the heat transfer surface can be spread easily, so the heat transfer efficiency is high and the flow resistance is small. Also both the cooled and heated fluids can be forced to flow in separated channels, there is no leakage between the two fluids. The heat pipe can also make the heat be transferred conversely to suit for the heat transfer requirement at different cases. The heat pipe fresh air exchanger can be efficiently used for ventilation in some large public cases, such as mall or subway to recover the heat (cold) from outlet air with a very small temperature difference to reduce the heat (cold) loss.

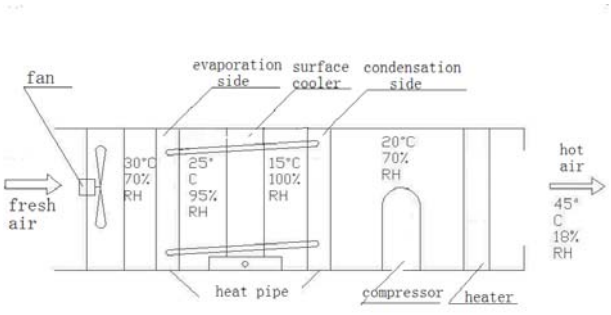
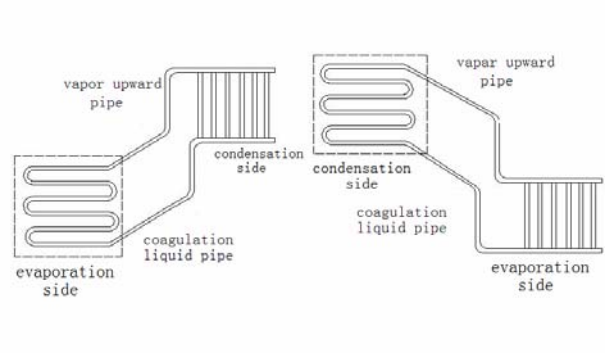


Fig.1 Heat pipe dehumidifier and dryer

Heat pipe is used in dehumidifying system as figure1[2]. High temperature wet air first passes through the evaporation side of heat pipe to reduce the temperature, then cooled by the surface cooler for cooling and dehumidify, then heated through the condensation side of the heat pipe, and finally passes through the electric heater to be heated till to the needed temperature. Heat pipe dehumidifier utilizes the sensible heat and the latent heat of the high wet air to heat the dry air, which can improve the air quality and lower the power of the system. In the process of dehumidification, the pre-cool improves surface cooler's ability in dehumidification, and reduces refrigeration requirement, so a small refrigeration compressor can be chosen. The heat pipe dehumidification system also have a function of

automatic adjustment, especially for air drying in moist days, the wetter the air is, the higher the system efficient is, the energy saving effect will be more obvious[3].

Heat pipe has an ability of converse heat transfer, which can meet the requirement of heating and cooling in different seasons. A loop heat pipe heating (or cooling) radiator system to save the building energy and promote comfortable sense has been proposed as figure 2. The heating (or cooling)



(a) Heating (b) Cooling

Fig.2 A loop heat pipe radiator for heating and cooling

radiator system has some characteristics as follows: 1) The heat pipe is in vacuum state, working fluid can be in the saturation of the environmental temperature to meet the requirements of heating and cooling at the low temperature difference; 2) The heat is transferred by evaporation and condensation, the system has a high heat transfer coefficient and the heat transfer efficient is high; 3) Working fluid quantity in the system is very small, there will be little impact on the environment in the case of leakage; 4) Working fluid is always in the obturation condition in heat pipe, it is difficult for the fluid to be deteriorated and dirty; 5) The evaporating vapor and condensing fluid can be flow back by gravity or capillary action, there is no need of an assistant pump using, so it will not consume the extra power; 6) It is flexible to adjust the heat transfer surface about the evaporation side and the condensation side of the heat pipe, which will be meet the heating and cooling requirement of different building; 7)It is better to optimize building configuration because the heat source and the cold source can be placed far away from building. Therefore a loop heat pipe radiator has a huge applied value and a high potential in heating (cooling) radiator of building.

2. HEAT PIPE DEHUMIDIFIER PERFORMANCE TEST AND ANALYSIS

2.1 Experiment system and parameters

The layout of heat pipe dehumidifier test system and the measurement points is shown in figure 3 and the

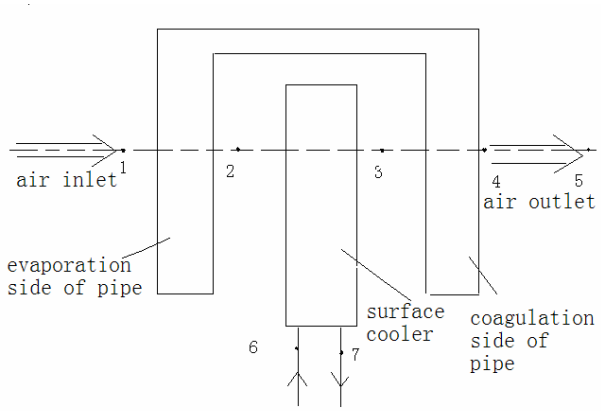


Fig.3 Layout of heat pipe dehumidifier test system and measurement points

1 air inlet 2 forward of surface cooler
3 backward of surface cooler
4 backward of heat pipe evaporation side
5 air outlet 6 frozen water inlet
7 frozen water outlet

spot photo is shown as figure 4.

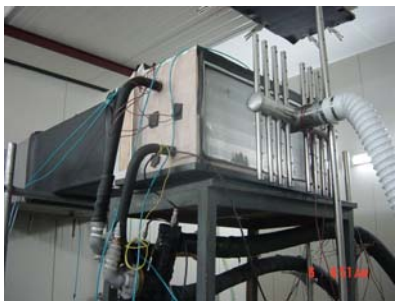


Fig .4 Photo of heat pipe dehumidifier and test system

The air parameter range provided by the test system is: room temperature -15~55℃, relative humidity 10%~95%, air quantity 350~20000 m^3/h, system refrigerating power 8~90kw. The heat pipe dehumidifier is tested at different air quantity, different dry bulb temperature and different wet bulb temperature (relative humidity). The working

Tab.1 Experiment working conditions and calculating parameters

Sequence number	Item	symbol	Working condition 1	Working condition 2	Working condition 3	Working condition 4	Working condition 5	Working condition 6	Working condition 7
1	Air flux, m^3/h	Q	2160	2186	2187	2216	1514	1077	1061
2	Air inlet dry bulb temperature, ^0C	Tg1	32.053	24.005	19.971	31.492	31.486	31.387	31.507
3	Air inlet relative humidity,%	Φ1	85.04	69.91	69.23	59.96	59.66	60.57	72.29
4	Air inlet humidity content, g/kg.dry air	D1	25.93	13.07	10.08	17.48	17.49	17.56	21.22
5	Dehumidifying capacity, kg/h	Dd	26.60	9.034	4.95	14.45	12.37	10.47	13.91
6	Surface cooler power, kW	Pl2	24.87	12.08	7.95	18.88	14.89	11.99	14.27
7	Surface cooler power without heat pipe, kW	Plw	28.20	16.474	11.412	24.704	19.894	16.887	19.094
8	Heat pipe saving power, kw	Ph	3.33	4.394	3.462	5.824	5.004	4.897	4.824
9	Energy saving ratio, %	H2	11.81	26.67	30.34	23.58	25.15	29.00	25.26

conditions and the calculating results about the parameters, such as, dehumidifying capacity, surface cooler power, heat pipe saving power and energy saving ratio are listed table 1.

2.2 Analysis of experiment result

The air parameters in the dehumidifier at different points are shown in figure 5. Point 1 is the state of high temperature wet air, point 2 is low temperature wet air after pre-cooling in evaporation side of heat pipe, point 3 is low temperature dry air after passing through surface cooler to low temperature and dehumidification, point 4 is dry air after passing through heat pipe condensation side to increase temperature. Heat pipe be used in the dehumidifier can pre-cooling the high temperature wet air and reheat low temperature dry air, 1-2 and 3-4 show the processes and the energy saving ratio. Point 5 is air condition point after low temperature and dehumidification in the same power condition of surface cooler with heat pipe, it can be indicated that point 4 has a higher air temperature and a lower relative humidity than point 5.

The test indicates that:

1) Heat pipe has a good operating effect, the air temperature has a great change after passing through heat pipe evaporation and condensation side, the energy saving effect is marked. The surface cooler power with using heat pipe has been greatly reduced,

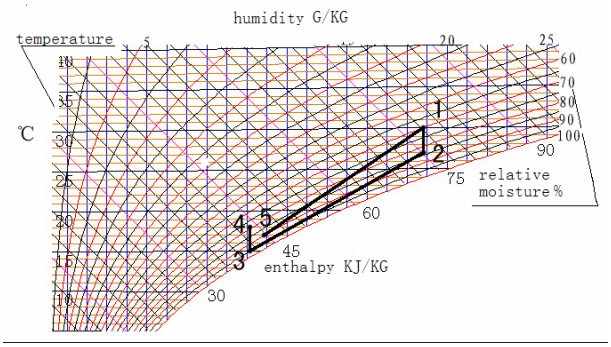


Fig.5 humidity enthalpy chart of air parameter in heat pipe dehumidifier

the energy saving ratio of heat pipe is range from 11.81% to 30.34%.

2) Along with the increase of air relative humidity (working condition 1 and 4, working condition 6 and 7), the dehumidification capacity and surface cooler power increase, but the energy saving ratio of heat pipe dehumidifier is reduced.

3) Under condition of the same relative humidity, dehumidification capacity and surface cooler power decrease along with the decrease of dry bulb temperature (working condition 2 and 3), but the energy saving ratio of heat pipe dehumidifier increase.

4) Under condition of the same air's dry and wet bulb temperature, dehumidification capacity and surface cooler power reduce along with the reducing of air quantity (working condition 4, 5 and 6), but the energy saving ratio increases.

5) The flow resistant and pressure difference are small when the air passes through the heat pipe evaporation side and condensation side.

3. RESULTS

Heat pipe dehumidifier performance has been tested in this paper, it shows that the air temperature changes greatly when the air passes through heat pipe evaporation side and condensation side and the heat pipe dehumidifier has a good operating effect. The surface cooler power reduced greatly with the using of heat pipe. The dehumidification capacity and surface cooler power as well as the energy saving ratio decrease along with the increase of relative humidity, and the dehumidification capacity and surface cooler power reduce alone with the reducing of dry bulb temperature and air quantity. The energy saving ratio by using the heat pipe are tested range from 11.81% to 30.34%.

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