Liquid Desiccant Air Conditioning System with Centralized Regenerator

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Abstract.

In conventional air conditioning system for comfort or process application, chilled water is handled to a very low temperature in order to meet the dehumidifying demand. The (coefficient of performance) COP of the chiller is decreased. Liquid-desiccant air conditioners (LDACs) are important alternative to conventional equipment. They can dehumidify by absorbing moisture directly rather than by cooling the air below its dew point and at the same time, can improve the indoor air quality(IAQ). LDAC avoid CFCs and HCFCs by using nontoxic salt solution as the primary working fluid. In this paper, A simple style of LDAC with a centralized regenerator is introduced. Simple performance analysis was performed with consideration of different out door air conditions.

Introduction

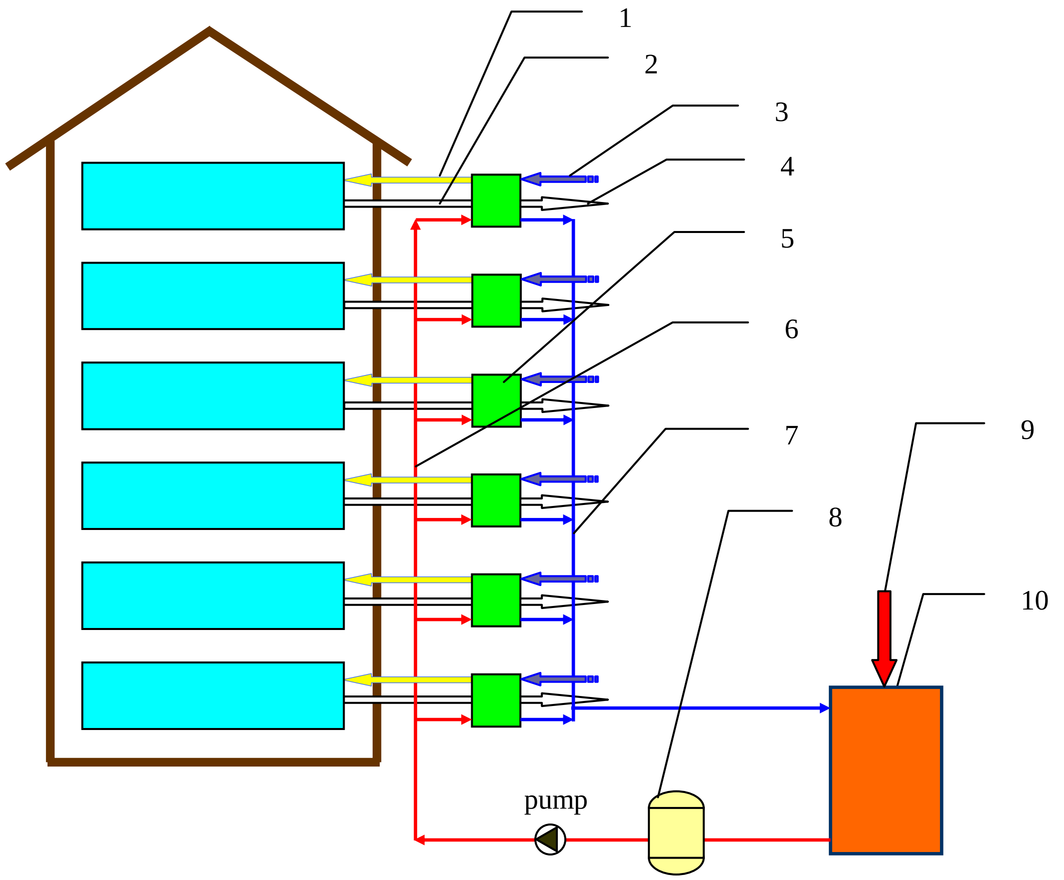
Liquid desiccant air conditioning (LDAC) systems are an important alternative to the conventional system[1,2]. Such systems have many characteristics:

1. Ability to realize independent humidity control, having a high efficiency as well as meeting comfortable demand.
2. Thermally driven by low temperature heat source such as the waste heat produced by cogeneration.
3. Avoid CFC, HCFC or Ammonia by using nontoxic salt solution.
4. Can sterilize the air by spraying and improve the indoor air quality (IAQ).
5. Much cheaper equipment cost than the conventional system.
6. Convenience to match the regeneration heat supply with the latent load by energy storage.

In china, some large cities had begun to build district combined heating, cooling and power systems[3] to cope with the cities' energy crises and pollution problems. In such system, how to use the low temperature hot water of the power plant in refrigeration is very important. One of the choices is to use absorption chiller. But the heat source temperature is so low (70-90^{o}C) that the absorption chiller only have the COP(coefficient of performance) of 0.3-0.4 if a double –stage absorption cycle be used. Then the liquid desiccant air conditioning system is a better choice because it has a higher COP under low driven temperature.

System Description of LDAC with Centralized Regenerator

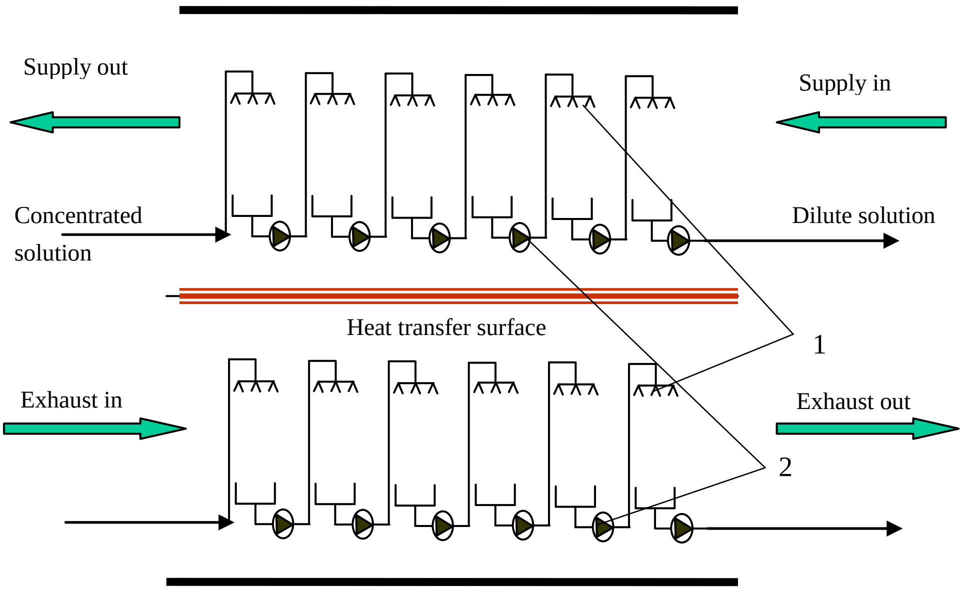
The liquid desiccant air conditioning system can be divided into two parts: the air handling part and the regeneration part. In order to have higher regeneration efficiency, the regenerator should be centralized[4,5] and should be designed as multi-effect. The desiccant solution should be circulated from the regenerator to each air handling modules by plastic pipes. A receiver is introduced in the desiccant solution loop as the energy storage facility. The whole system should be described as follows:



1 supply out 2 exhaust in 3 supply in 4 exhaust out 5 air handling module 6 concentrated desiccant solution 7 dilute desiccant solution8 receiver 9 heat source 10 regenerator

Figure 1 system of LDAC with a centralized regenerator

There are two air-flows flow through the air handling module (see figure 2), the supply air and the exhaust air. The supply air is dehumidified by the desiccant solution and is cooled by the exhaust air. And the exhaust air is saturated by direct evaporation in order to have a larger cooling capacity. The dehumidification process and the cooling process are staged in order to lower the irreversible loss of heat and mass transfer. In figure 2, different stages have different temperatures or concentrations.



1 sprayer 2 pump

Figure 2 The air handling module

What happens in the air handling module (see figure 3) is very complex. The evaporation process of the exhaust air cools the dehumidifying process of supply air. So the dehumidifying process can happen in a certain or slightly decrease temperature, and that is very important for the performance of the system. The dry supply air could be cooled by indirect evaporative cooler and supplied in to the air conditioning space.

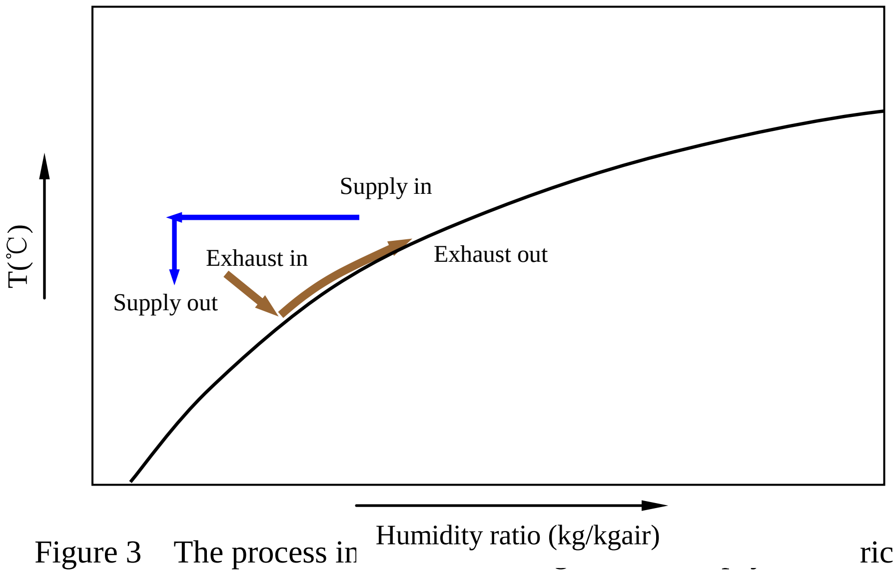


Figure 3 The process in ric chart

Such system can act only as latent load absorber and some cooling method to cope with sensible load is needed. Under this condition, the temperature of the cooling medium will be higher than the conventional system because of it need not to cooled air below its dew point. So some high temperature cooling sources such as ground water or cooling methods such as indirect evaporation cooling can be used.

In winter such system can work at heating mode. The solution works as heating medium instead of dehumidification medium. After being heated in the regenerator, the solution heats the supply air by spraying. And this mode can take some favorable advantages such as the equipment is frost-proof and sometime acts as humidifier.

The performance analysis of LDAC

The performance of LDAC including the performance of the regenerator and the performance of air handling module, which are independent. As for the performance of the regenerator, this paper gives an empirical coefficient. At a regeneration temperature of 80°C, the effect coefficient (the latent heat of evaporation divided by the total heat supply) of the regenerator is about 0.7.

As for the air handling module, the performance analysis is performed under the conditions as follows:

1. The temperature difference of heat exchanger is given
2. The outdoor condition is set to the IIR outdoor condition: dry bulb temperature is 35°C and relative humidity is 40%;
3. The temperature of the air conditioning space is 26°C and the relative humidity is 50%;
4. The heat capacity of the desiccant solution is omitted;

The definition of the COP of LDAC is: $COP_{liquid} = \frac{\Delta i}{Q}$, Δi is the difference of enthalpy of supply in and supply out, (kJ/kgair); Q is the regeneration heat,(kJ/kgair).

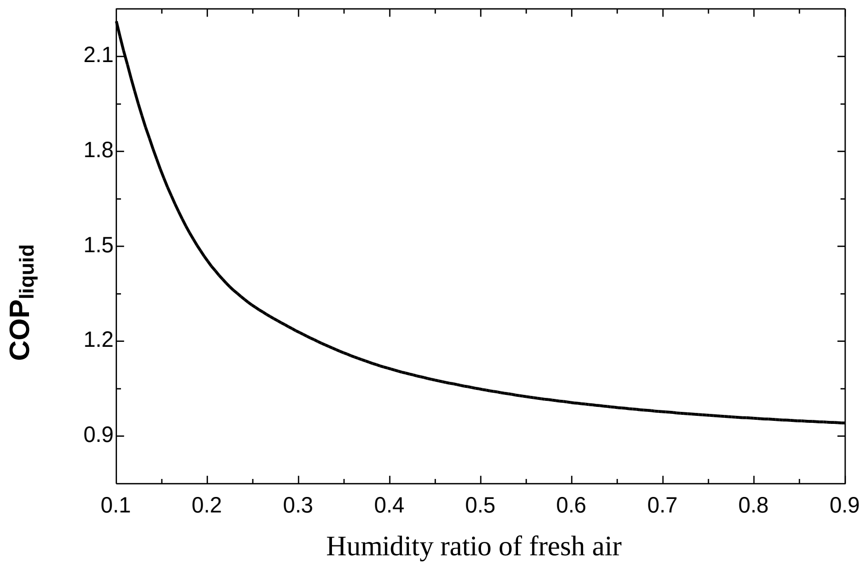
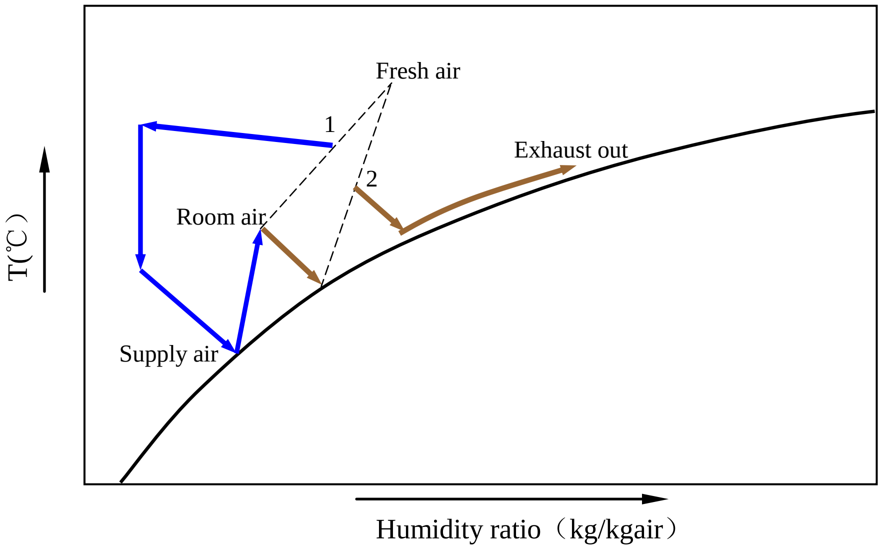


Figure 4 COP_{liquid} by varying out door humidity ratio(ventilation mode)

The LDAC can work at ventilating mode, which means the supply air is completely fresh air. Figure 4 gives the COP_{liquid} changes of ventilation mode by varying out door humidity ratio. If the humidity ratio increases, the COP_{liquid} of the LDAC will decrease.

The LDAC can also work at recycling mode, in which the supply air is the mixture of the fresh air and the return air. The process of this mode can be described as figure 5. The fresh air and the room return air are mixed together, dehumidified and cooled, and then are supplied to the room. While the others return air is mixed together with some fresh air to cool down the process.



Point 1 supply in   Point 2 exhaust in

Figure 5 the process of recycling mode

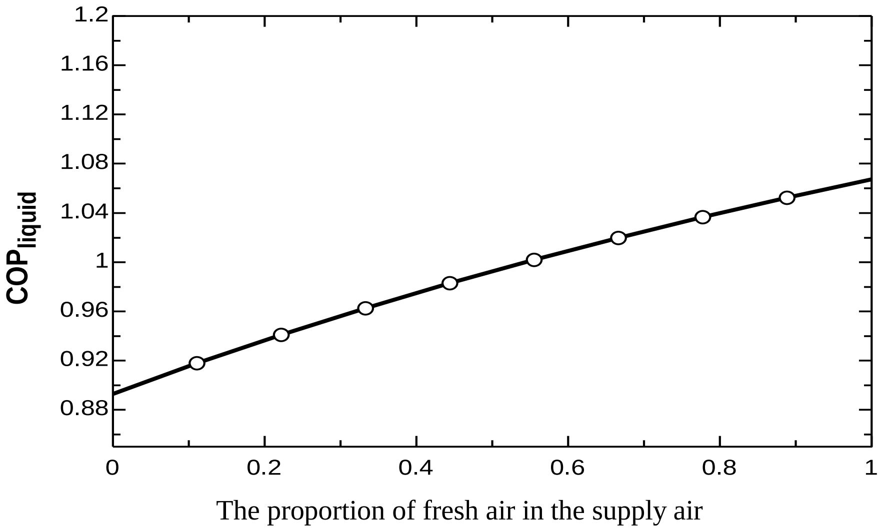


Figure 6   The COP_{liquid} by varying fresh air proportion (recycling mode)

For the certain out door air condition, the COP_{liquid} become bigger by the increase of fresh air proportion (Figure 6). Because at this outdoor state, the cooling effect of the exhaust air is decreased after mixed with fresh air. The results will changes with the outdoor air state.

From the above analysis, the COP_{liquid} of the LDAC is higher than 0.8 at the given out door state. While the sorption chiller driven by the heat source of the same temperature level can only acquire the COP of less than 0.5. But the LDAC system is much cheaper.

Conclusions

This paper introduces the liquid desiccant air conditioning system with centralized regenerator. The LDAC system can be divided in to two parts: the regenerator and the air handling module. The centralized regenerator can have high regeneration efficiency. The air handling module can be designed in stage type in order to acquire counter flow and lower the irreversible loss of the heat and mass transfer.

Under the regeneration temperature of 80^{o}C, the LDAC system has a higher COP than the sorption chiller. The state of the outdoor air and the working mode can greatly influence the COP of LDAC.

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