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Experimental Modelling of Liquid Desiccant Air - Conditioning System

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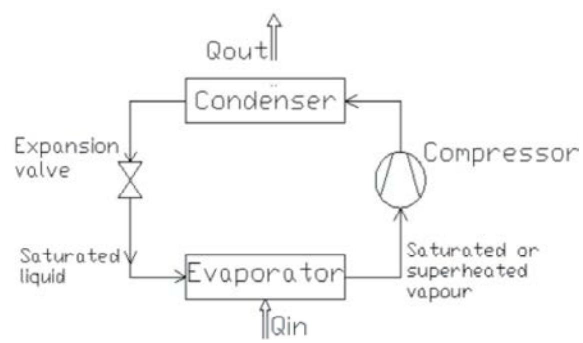
Abstract: In the present study, experiments have been conducted on an Indirect Contact Liquid Desiccant Vapour Compression Hybrid Air- Conditioner system, desiccants are coupled with vcrs cycle and the load of evaporator is shared by it, while the condenser heat is _tilized for regeneration of the same. The energy efficiencies of conventional air conditioning and desiccant coupled air conditioning are evaluated. Various parameters like air specific humidity, air flow rate, desiccant flow rate and air temperature affect the system are done.

Key words: The system are done · In the present study

INTRODUCTION

In recent years, desiccant cooling systems have received considerable attention because of increased energy costs which has motivated a search for methods which conserve energy. Since air conditioning became one of the most essential parts of modern life, efforts are made to build a system which is energy efficient, environment friendly and affordable. It is known that, air quality increases with decrease in humidity [1]. Hence, humidity is considered as a pollutant and efforts are made to reduce it to comfort condition in a space provided in the present experimental set-up. Desiccants have the property of extracting and retaining moisture from the air brought into contact with them [2]. For dehumidification to occur, the liquid desiccant is used to absorb water vapour from air. Dehumidification of air by desiccant takes place due to the fact that; the partial pressure of water vapour in the air is greater than that of the water vapour in the desiccant. Desiccant can hold up water until the partial pressure of water in the desiccant and that of air are equalized. This water vapour removing capability of d esiccants leads to the shifting of latent load from refrigerant cycle to desiccant cycle and to energy saving which is associated with the latent load. Desiccant cooling system is demonstrated to be effective when Sensible Heat Ratio (SHR) is very low [3].



Basic Vapour Compression Refrigeration Cycle: Low-pressure liquid refrigerant in the evaporator absorbs heat from its surroundings, usually air, water or some other process liquid. During this process it changes its state from a liquid to a gas and at the evaporator exit is slightly superheated.The superheated vapour enters the compressor where its pressure is raised [4]. The temperature will also increase, because a proportion of the energy put into the compression process is transferred to the refrigerant. The high pressure superheated gas passes from the compressor into the condenser. The initial part of the cooling process de-superheats the gas before it is then turned back into liquid. The cooling for this process is usually achieved by using air or water. A further reduction in temperature happens in the pipe work and liquid receiver, so that the refrigerant liquid is sub-cooled as it enters the expansion devices. The high-pressure sub-cooled liquid passes through the expansion device,

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which both reduces its pressure and controls the flow into the evaporator [5]. The condenser has to be capable of rejecting the combined heat inputs of the evaporator and the compressor.

Desiccant: Desiccants attract moisture from the air by creating an area of low vapour pressure at the surface of the desiccant. The pressure exerted by the water in the air is higher, so the water molecules move from the air to the desiccant and the air is dehumidified. The essential characteristic of desiccants is their low surface vapour pressure. If the desiccant is cool and dry, its surface vapour pressure is low and it can attract moisture from the air, which has a high vapour pressure when it is moist. After the desiccant becomes wet and hot, its surface vapour pressure is high and it will give off water vapour to the surrounding air. Vapour moves from the air to the desiccant and back again depending on vapour pressure differences [6].

Types of Desiccant:

- Solid desiccants
- Liquid desiccants

Solid Desiccant System: The common solid desiccants available are: silica gel, zeolite, activated alumina and carbon. Silica gel is a desiccant with high performance, but it can be destroyed after rapid absorbing of great deal of water and it is not a heat-resistant material [7]. Generally, solid desiccants can hold more water vapour and they poses high drying capacity relative to liquid desiccants

Liquid Desiccant Systems: The common liquid desiccants available are: lithium chloride, lithium bromide, calcium chloride and triethylene glycol. Other desiccants include KCOOH, glycols like MEG (mono-ethylene glycol), DEG (Di ethylene glycol), propylene glycol and mixtures of desiccant LiCl + LiBr or LiCl + CaCl2. This type of desiccant systems, show several advantages like higher air dehumidification, at the same driving temperature range of solid desiccant cooling systems and the possibility of high energy storage by storing the concentrated solution [8].

In this project liquid desiccant used is calcium chloride.

Factors for choosing calcium chloride is as follows:

- Low cost
- Less hazards effects when compare to other. desiccants when exposing continuously
- Less corrosive

Dehumidification: Dehumidification is the process of removing water vapour from moist air. Here, absorption method is used due to the easiness created by the liquid desiccants. In absorption method of dehumidification, desiccant solution absorbs the water vapor in air.

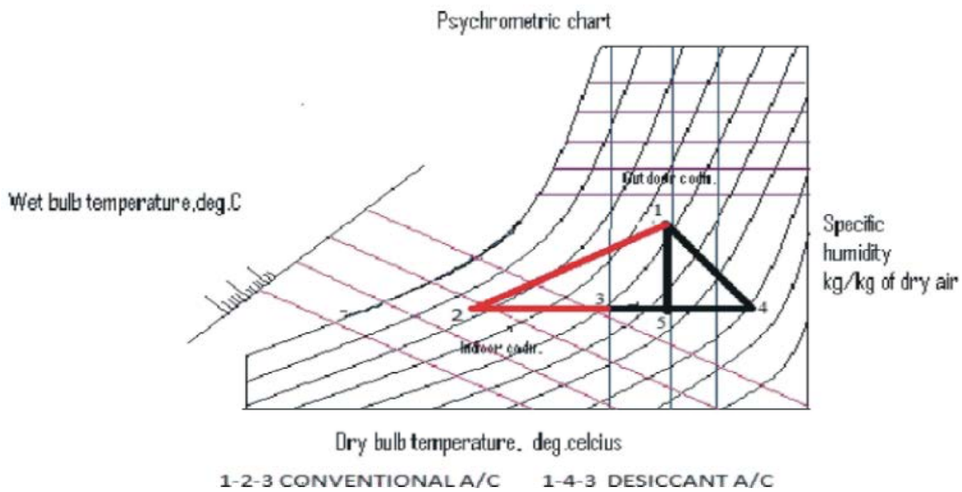
The liquid desiccant solution is allowed to flow over the desiccant arrangement, where cold and moist air enters which interacts with the desiccant and looses the moisture to the desiccant. As the desiccant absorbs water, it gets diluted. To maintain the dehumidifying capacity of the system, the absorbed water must be removed from the desiccant. This is achieved by regenerating the desiccant solution where the water in the desiccant is evaporated.

Regeneration: A liquid desiccant is generally regenerated by heating the desiccant solution which has absorbed water vapour in air. As the temperature of the desiccant increases, the water vapour pressure in the solution increases. The moisture vapour pressure of the desiccant decreases with increasing desiccant concentration and increases with increase in desiccant temperature. For air, the partial pressures of water vapour increases with increasing air dry bulb temperature and absolute humidity. When the vapour partial pressure of the desiccant becomes higher than that of the surrounding air, a desiccant system starts to work as a regenerator and releases out all the water vapour absorbed in air.

Layout of Liquid Desicccant Air Conditioning System: In this system, liquid desiccant loop is superimposed over the normal refrigerant loop. Liquid desiccant loop consists of two parts, namely dehumidification and regeneration part. In coconut fibre dehumidification unit atmospheric air stream is passed over the fibres where the liquid desiccant comes in direct contact with the air, the moisture in the air is absorbed by the liquid desiccant and then air is passed over the evaporator. Again the liquid desiccant is passed over the condenser for regeneration where the moisture in the desiccant is removed by the condenser heat. Now solution has lower vapour pressure than air and the solution can be used for dehumidifying air in the cycle [8-17].

Desiccant Dehumidification: This process is mainly used to remove the latent and can also be used for some comfort air - conditioning installation requiring either a low relative humidity or low dew point temperature in the conditioned space. In this process the air is passed over the desiccant which has an affinity for moisture. As the air comes in contact with the desiccant the moisture gets diffused into it leaving its latent heat. Due to this the specific humidity decreases and dry bulb temperature increases. The path followed during this process is along the constant wet bulb temperature line or constant enthalpy line.

Desiccant Cycle:



(a) psychometric of desiccant cycle

For Desiccant Cycle:
Energy Efficiency Ratio (EER) = h4-h3compressor work done

h4 = enthalpy of air at desiccant outlet at temperature T_4 [(kJ/kg)of dry air]
h3 = enthalpy of air at evaporator outlet at temperature T_3 [(kJ/kg)of dry air]

For Conventional Systems
Energy Efficiency Ratio (EER) = h1-h3compressor work done+heater work done.

where,
h1 = enthalpy of air at evaporator inlet at temperature T_1 [(kJ/kg)of dry air]
h2 = enthalpy of air at evaporator outlet at temperature T_2 [(kJ/kg)of dry air]
h3 = enthalpy of air at heater outlet at temperature T_3 [(kJ/kg)of dry air]

Energy Efficiency Ratio Tabular Column

TIME	DBT(EI)	RH INLET%	DBT(EO)	RH%(EO)	DBT(DO)	RH%(DO)	DBT(HO)	RH%(HO)	$EER_{(CAC)}$	$EER_{(DAC)}$
5:55*	29	64	22	82	35	38	25	68	5.25	8.33
6:30*	28	66	22	86	31.5	48	25	68	4.2	6.66
7:05*	27	67	22	86	29	50	25	68	2.1	3.33
7:50*	25	64	21.5	83	31.5	48	25	68	3.41	5.4
9:15*	25	74	21	88	29	50	25	68	2.63	4.16
11:20	29.5	58	22.5	78	32.5	42	25	68	4.72	7.5
11:50	30	58	22	80	35	38	25	68	5.77	9.1

DBT(EI) = Dry Bulb Temperature of Environment Inlet (°C)
DBT(EO) = Dry Bulb Temperature of Evaporator Outlet (°C)
DBT(DO) = Dry Bulb Temperature of Desiccant Outlet (°C)
DBT(HO) = Dry Bulb Temperature of Heater Outlet (°C)
RH (HO) = Relative Humidity of Heater Outlet (%)
$EER_{(CAC)}$ = Energy Efficiency Ratio of Conventional Air Conditioning System
$EER_{(DAC)}$ = Energy Efficiency Ratio of Desiccant Air - Conditioning System

CONCLUSION

From the observed readings, it is clear that desiccant air-conditioning system perform well in the hot climate when the relative humidity of air is kept constant with increase in its dry bulb temperature. Further, the desiccant air conditioning systems also seems to be good for same dry bulb temperature and increased relative humidity conditions in the humid climates. So, it is well and good to conclude that the DAC systems are the most suitable to be introduced at hot and humid climates. To achieve the indoor conditions by the desiccant processed air, the cooling capacity required by the evaporator is less than the capacity required by the reheater and the evaporator in the normal vapour compression refrigeration systems.

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