International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622
National Conference on Advances in Engineering and Technology
(AET- 29th March 2014)

RESEARCH ARTICLE OPEN ACCESS

Desiccant Cooling System- A Novel Technique for Air Conditioning

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ABSTRACT
Now a days, due to energy crisis/high energy costs, novel techniques for air conditioning are to be explored. In this paper various techniques that can be used for air conditioning or dehumidification purpose are investigated. These techniques improve the indoor air quality a lot with a considerable savings in energy consumption. The working of desiccant dehumidifier & conventional dehumidifier air conditioner is discussed along with the performance comparison is also done for better understanding.
Keywords— Air Conditioning, Dehumidification, Desiccant Cooling

I. INTRODUCTION

The average global air temperature of the Earth's surface is increasing day by day. It has been proved that the greenhouse gases are mainly responsible for it [1]. Residential energy accounts for 40% of the primary energy consumptions relative to the CO_2 emission in the EU, of this HVAC (heating, ventilation and air conditioning) systems consume approximately 50%, lighting accounts for 15% and appliances 10% [2].

With the increasing requirements for indoor cooling, sustainable cooling systems have recently gained prominence. These novel cooling systems utilize renewable energy gained from solar collector, cooling tower, ground thermal source etc, and avoid CFC and CO_2 emissions. Desiccant cooling system is one kind of innovative technologies which employs renewable energy to produce the desired air for comfortable working/living spaces [3]. These systems have little dependency on fossil-fuel energy and are environment friendly.

II. DESICCANT COOLING

Desiccant cooling consists in dehumidifying the incoming air stream by forcing it through a desiccant material and then drying the air to the desired indoor temperature.

To make the system working continually, water vapour absorbed must be driven out of the desiccant material (regeneration) so that it can be dried enough to absorb water vapours in the next cycle [4]. This is done by heating the material desiccant to its temperature of regeneration as shown in Figure1.

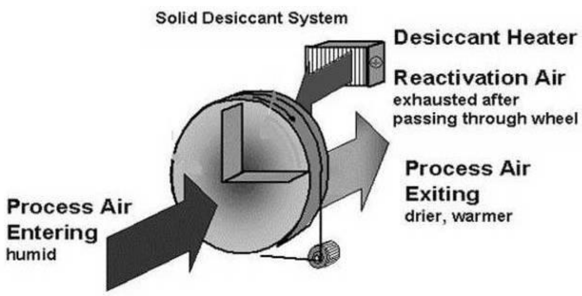

Figure1: Principle of Desiccant Cooling System

2.1 SOLID DESICCANT COOLING SYSTEM

A Solid desiccant cooling system comprises principally three components [4] as shown in figure 2

- Dehumidifier (desiccant material)
- Cooling Unit
- Regeneration Heat Source

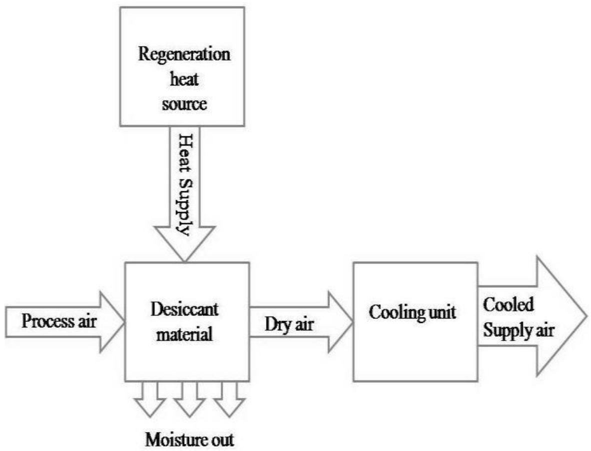

Figure 2: Solid Desiccant Cooling System

2.1.1 DEHUMIDIFIER(DESICCANT MATERIAL)

In the case where the desiccant is employed in its solid state, the desiccant dehumidifier is generally a slowly rotating desiccant wheel or a periodically regenerated adsorbent bed.
Solid desiccant dehumidification employs the porous and strong hydrophilic materials to absorb moisture from the air stream [4]. The generally used solid desiccants include silica gel, natural and synthetic zeolites, activated alumina, titanium silicate, synthetic polymers, lithium chloride etc.

2.1.2 COOLING UNIT

The cooling unit can be the evaporator of a traditional air conditioner, an evaporative cooler or a cold coil [4]. The role of the cooling unit is the handling of the sensible load while the desiccant removes the latent load.

2.1.3 REGENERATION HEAT SOURCE

The regeneration heat source supplies the thermal energy necessary for driving out the moisture that the desiccant had taken up during the adsorption phase. Because the thermal energy source is required, a variety of possible energy sources can be utilized [4].Those includes solar energy, waste heat, and natural gas heating, and the possibility of energy recovery within the system.

2.1.4 WORKING

Desiccant cooling systems can be operated in a recirculation mode, in ventilation mode, Dunkle cycle and wet-surface heat exchanger cycle.
In recirculation mode, also called recirculation cycle, the process inlet air is the return air from the space being conditioned and the regeneration air is the outdoor air.

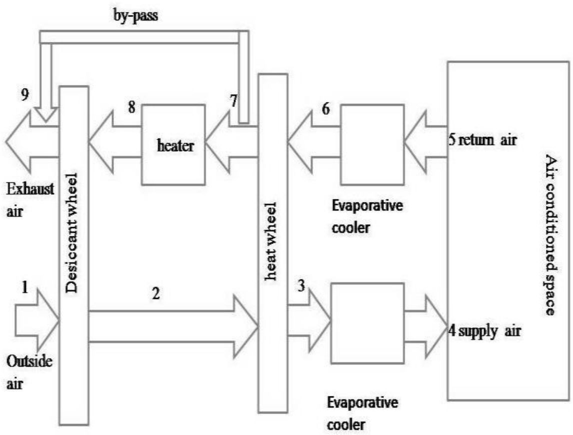

Figure 3: Solid Desiccant Cooling System with Evaporative Cooler

In the ventilation mode, the process inlet air is the outdoor air and the regeneration inlet air can be either the outdoor air (standard vent cycle) or the conditioned space exhausted air.
The system described here is in ventilation mode with regeneration air being returned from the conditioned space.

In the system presented in figure 3 the outdoor air stream is passed through rotary desiccant wheel. Its moisture is partly but significantly adsorbed by the desiccant material and the heat of adsorption elevates its temperature so that a warm and rather dry air stream exits at the state 2.The air stream is then cooled successively in the heat exchanger (heat wheel) from the state 2 to the state 3, and then in an evaporative cooler from the state 3 to the state 4.

This cool and dry air supplied to air conditioned space. There it takes heat and moisture so its humidity and temperature will be increased.
Another evaporative cooler is used to cool down the return air from the state 5 to the state 6 and the cold air stream serves as heat sink to cool the supply air in the heat exchanger. Consequently, its temperature is risen when exiting the heat wheel at the state 7 [5]. At this point, it is ready to undergo a complementary heating to reach a temperature high enough at the state 8 in order to be able to regenerate the desiccant material. A certain portion (about 20%) of the return air stream, at the state 7, bypasses the heating source in order to reduce the regeneration heat consumption.

2.2 Liquid Desiccant Cooling System

A liquid desiccant cooling system, therefore, comprises principally three components [9] as shown in figure 4

- Conditioner
- Regenerator
- Interchange Heat Exchanger (IHX)

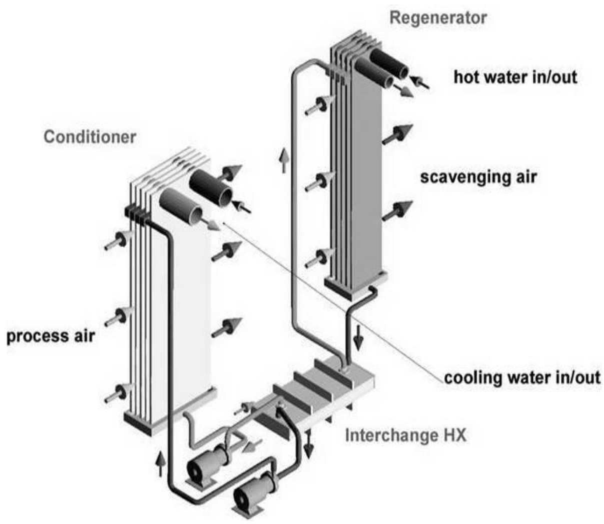

Figure 4: Liquid Desiccant Cooling System

2.2.1 CONDITIONER

The conditioner is a parallel-plate liquid-to-air heat exchanger. A coolant, typically cooling tower water flows within the plates and a very low flow of liquid desiccant flows down the outer surfaces of the plates [5]. Thin wicks on the plate surfaces create uniform desiccant films.

The air to be processed flows horizontally through the gaps between the plates. As this humid air comes in contact with the desiccant, water vapor is absorbed.The heat released by this absorption is transferred to the coolant. The air leaves the conditioner much drier, although its temperature may not significantly change**.**

2.2.2 REGENERATOR

The dilute desiccant that leaves the conditioner is pumped to the regenerator. The regenerator has the same configuration as the conditioner: a parallel-plate liquid-to-air heat exchanger.Again, very thin films of desiccant flow in wicks on the outer surfaces of the plates, and air flows in the gaps between the plates.

For the regenerator, however, a hot heat transfer fluid flows within the plates. This hot fluid can be supplied by a gas-fired boiler, solar thermal collectors, recovered heat from an engine or fuel cell, or other energy source.

2.2.3 INTEREXCHANGE HEAT EXCHANGER

The hot, concentrated desiccant that leaves the regenerator and the cool, dilute desiccant that flows to the regenerator exchange thermal energy in the interchange heat exchanger. This exchange increases the efficiency of the regenerator and decreases the cooling load on the conditioner.

Figure 5 shows another liquid desiccant cooling system in which strong and weak desiccant flows in the whole system.

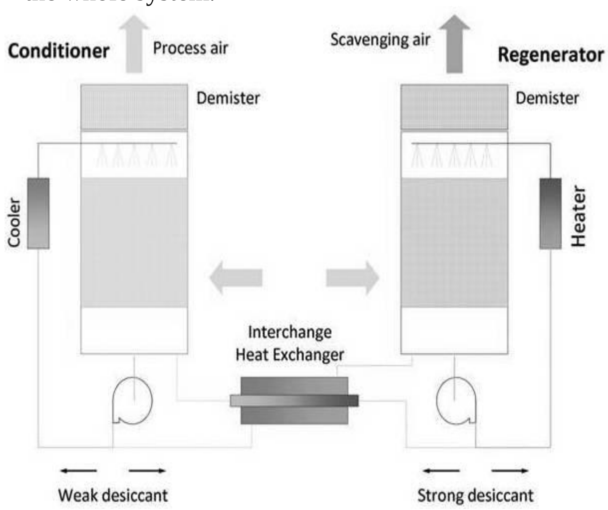

Figure 5: Liquid Desiccant Dehumidifier and Cooler

III. ADVANTAGES OF DESICCANT ENHANCED COOLING

- It extends the climatic applicability scope of the evaporative cooling to the hot and humid zones.
- The preheating being eliminated, energy(can reduce the power consumption by 24%-48% as compared to VCR) and costs can be saved.
- The regeneration heat can be supplied by free energy sources.
- The system is environmental friendly since doesn't use any Chlorofluorocarbon based refrigerant.
- The sensible and latent cooling loads can be handled independently.
- The evaporative cooler can be replaced by the evaporator of a significant downsized traditional air conditioner, depending on the sensible heat ratio (SHR) of the room being conditioned. This will be conducive to significant energy and cost savings.

Some of the solid desiccant material are Silica Gel, Indicating Silica Gel, Molecular Sieve, Calcium Oxide, Calcium Sulphate and Other Adsorbents whereas the Liquid desiccant material are Methyl Glycol (MEG), Lithium Bromide and Brine solution.

IV. PERFORMANCE COMPARISON

Both Desiccant Dehumidification & Conventional Dehumidification systems perform the same function, now question arises which one is the best. Choosing between the best, there are no simple answers, however there are some guidelines that help us in choosing the best system for our requirement.

- Both systems are much economical when used together.
- If electricity is cheaper & thermal energy is expensive in the region then conventional dehumidifier should be preferred to remove bulk of the moisture otherwise desiccant based system will be a right choice .
- Conventional dehumidifiers are best when used for higher temperatures & moisture levels. These are not suitable to dry air below 8°C dew point because condensation freezes on the coil, thus slowing the moisture removal process.
- Desiccant dehumidification is best suitable when air is cold (8°C or below) & humid or when low dew point is required.
- If dehumidified air with 100% RH (relative humidity) is required then solution is conventional dehumidification, on the other hand if desired result is conditioned air whose RH less than 100% then desiccant humidifier is the only solution.

- Generally desiccant dehumidification system is used for applications below 45% RH down to less than 1% RH.

V. CASE STUDY

5.1 CASE 1: PAINTBALL MANUFACTURING PLANT

Paintball manufacturing plant is Located in India on the north-west coast of Kandla about 600 km from Mumbai, this plant is one of a few in the world for the manufacture & export of color filled gelatin balls. The Gelatin balls called Paint Balls are in heavy demand for popular sport & recreation activities worldwide, particularly in Europe & US.

The plant is fully automatic and designed for producing large quantities of paint balls according to the highest quality standards in a climate control environment.

Problem:

The paintball paint, which is both water-soluble and biodegradable, is made at a specialty paint facility and then shipped to the encapsulating plant. Softened gelatin is loaded into the encapsulating machine, which automatically injects a precisely measured amount of paint into the cavity, encapsulating the paint. Since the gelatin is soft and warm, the balls must be cooled and hardened in a tumbling machine, then placed on shelves to dry. To ensure a safe flowing production in the above manufacturing process, climate control is crucial.

Solution:

Liquid desiccant units is used to transform the harsh ambient conditions of 29 ºC (84.2 ºF), 83% RH to stable, requested conditions of 22 ºC (71.6 ºF), 12 R.H.

5.2 CASE 2: FERTILIZER PLANT

The Fertilizer plant situated in Goa, India is a modern, fully automated facility. The plant has an annual installed capacity of 946,200 metric tons of fertilizers. It comprises a single stream ammonia plant, a urea plant, an NPK plant and a DAP plant along with related on-site and off-site facilities for handling raw materials end products as well as the generation of steam.

Problem:

The humidity level in Goa is high throughout the year. Due to the high humidity levels in the Packing Area, the bags have to be over packed since once they are shipped and humidity level changes and the gross weight of the bags declines. As a result, the plant is suffering significant losses due to the bag's over packing.

Solution:

To solve the problem, a liquid desiccant cooling unit was installed. The unit supplies dry air to the packaging area which enables correct weighing, improved product quality & improved productivity due to a better flow ability.

5.3 CASE 3: HOSPITALS

A hospital in the province of Milan, Italy recently built a new prestigious Dialysis Center.

In 2005, the Center installed a Radiant Partition Walls System for cooling and heating the Dialysis area as well as the adjacent premises including the waiting area, restrooms, medical premises and service rooms, a total of almost 4,000 square feet.

Problem:

The rise in humidity caused condensation buildup on the walls and ceilings of the Center, causing potentially hazardous conditions and patient discomfort.

Solution:

Liquid desiccant cooling Systems installed which supplies dry filtrated air to the Air Handling Unit (AHU) which treats the Dialysis Center, allowing both patients and staff to enjoy clean air and comfort without any condensation buildup in the Center.

VI. CONCLUSION

Desiccant cooling is one of the innovative technologies in the field of air conditioning and different case studies shows that it improves the indoor quality air weather it may be case of any industry, hospitals or any other refrigeration and air conditioning system. So desiccant cooling is an appropriate environmental friendly technology.

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