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New way of cooling by desiccant cooling system

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Abstract : Desiccant cooling system is one of the options in our daily life to provide the best indoor air quality and thermal comfort with the minimum consumption of energy. In cooling systems a solid desiccant or a liquid desiccant solution can be used to assist in the cooling process. Desiccant has a property of regeneration so it can be recirculated and reused. In this cooling system we use liquid CO_2/dry ice to achieve the sensible heat reduction while using silica gel(desiccant) to absorb moisture and decrease latent heat.The desiccant systems are reasonably-priced, produce no CFCs, and capable of both drying and filtering the air. They provide an opportunity to control humidity and temperature independently, and have the capability of using low quality thermal energy. The performance of the system is evaluated using Cooling Capacity (CC) parameter. The system under a typical summer day of hot and humid climate was tested. A remarkable decrease about 40-65% in the specific humidity and with a supply air temperature lower than 25°C of the proposed system was observed. The study is important and helpful to improve the effectiveness of this kind of liquid desiccant system in hot and humid places.

Key words : Desiccant cooling, Solid desiccant, Liquid desiccant, Humidity, Temperature

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Desiccant cooling systems are heat-driven cooling units and they can be used as an alternativeto the conventional vapor compression and absorption cooling systems. Its operation is basedon the use of a rotary dehumidifier Desiccant Wheel (DW) in which air is dehumidified. The system may be operated in a closed cycle or more commonly in an open cycle in ventilationor recirculation modes. A heat supply is needed in the system to regenerate the desiccant(natural Zeolite) and a low-grade heat at a temperature of about 60.95. C may be used (Pundir and Mishra, 2012).The desiccant cooling can be used with energy source such as solar energy and waste heat resulting in the reduction of the operating cost and increase the accessibility to the air conditioning for the population of urban areas (Srivastava, 2016). Desiccant evaporative cooling basically absorb the latent heat in the air *i.e.* reduces the humidity of the air**.** This property of desiccants is due to its low vapor pressure**.** Desiccant cooling systems process water vapor in the earth's atmosphere to produce cooling. Since mass transfer occur between the system and its environment they are referred to as open-cycle system. These systems all use a liquid solution or solid material called a desiccant to remove water vapor from the air (Bora *et al.*, 2017).

The desiccants are natural or synthetic substances which are capable of absorbing or adsorbing water vapor due the difference of water vapor pressure between the surrounding air and the desiccant surface. The desiccants could be in both liquid and solid states.Some commonly used desiccant materials include lithium chloride, triethyleneglycol, silica gels, aluminum silicates (zeolites or molecular sieves), aluminium oxides, lithium bromide solution and lithium chloride solution with water, etc. (Srivastava, 2016). Desiccants has high affinity towards moisture they can draw water vapour directly from the surrounding air This affinity can be regenerated continually by applying heat to the desiccant material to drive off the collected moisture (Bora *et al.*, 2017).

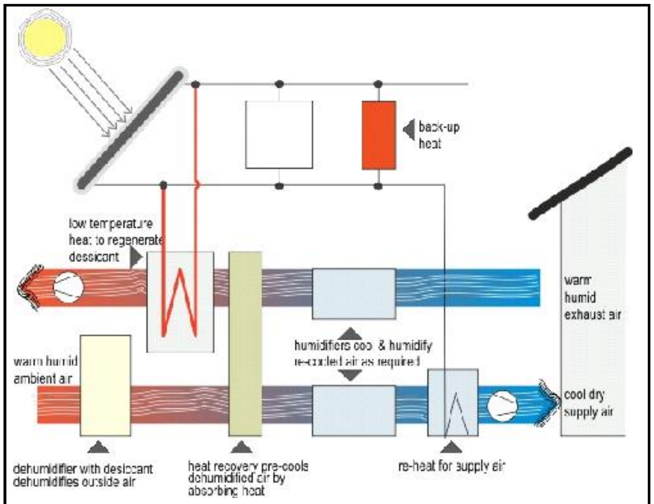

Fig. 1 : Dessicant cooling

Principle of dessicant cooling :

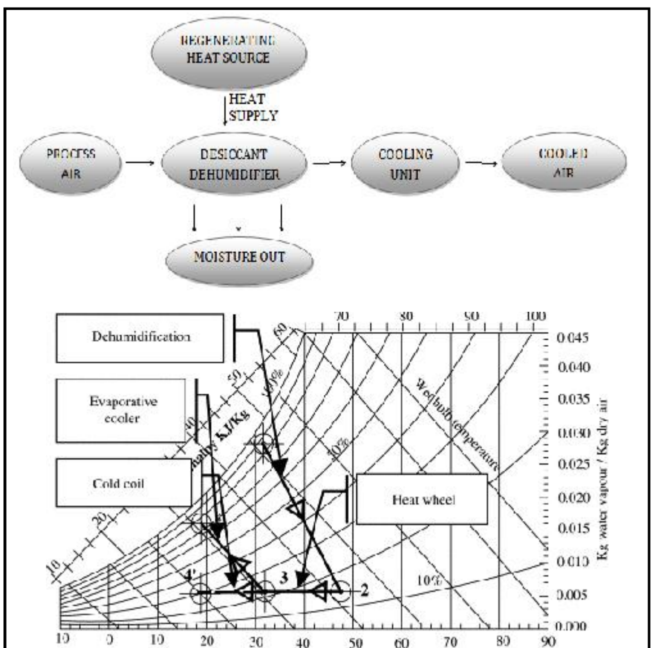

Fig. 2 : Psychometric chart illustrating the principle of dessicant cooling

Energy sources for dessicant cooling system:

Desiccant cooling systems require electricity to operate pumps and fans and heat energy to pre-heat the desiccant solution for regeneration. As the desiccant system can operate on low heat, heat energy can be provided through solar thermal systems or any waste heat source from chimneys, power plants, etc. Energy can also be obtained from several other sources, like waste heat from a combined heat and power plant. Riffat and Jradi investigated into the configuration and operation strategies of a tri-generation system. A tri-generation system is a combined heating, cooling and power system. This system can operate using gas turbine, internal combustion unit. While heating can be provided from the waste energy, it can also be used to operate a desiccant cooling system (Sahlot and Riffat, 2016).

Energy storage of dessicant cooling system:

Desiccant cooling systems operate on low-grade heat, which can be obtained from various sources. However, interim unavailability of such sources can impede the operation of desiccant systems or they would have to rely on electricity or other auxiliary heating devices for their operation. A solution to this problem is to store the thermal energy in the form of regenerated desiccant solution and use it for dehumidification when thermal energy is not available. Research has shown that the energy storage ability of liquid desiccants like lithium chloride and calcium chloride is 3.5 times that of solid desiccants like silica gel and zeolites. Kessling and his colleague developed new dehumidifiers and performed experiments to study the relationship between dehumidification enthalpy storage and various impacting factors in a cooled absorber . A heat exchanger has been added to cool the air during the dehumidification process by recovering cold from exhaust air. Weak desiccant solution is stored in a storage tank. It is regenerated using a hot water heat exchanger and strong solution is stored in another tank. Thus, thermal energy is stored in the form strong solution, which can be used for dehumidification when low-grade heat is not available for regeneration (Sahlot and Riffat, 2016).

Types of desiccants:

A desiccant is a substance that promotes drying by absorbing moisture or water vapor from the air. Consumers are probably most familiar with small paper packets of desiccants that are often packed with items so that they will not rust or mold during shipment, especially for imported items that will spend time in the hold of a ship between the time they leave the factory and arrive at the store.In industrial settings, desiccants are used for the same reason in compressed air dryers: to dry the air. The changes in pressure when air is compressed will cause water to condense, and this moisture must be removed. To do this, compressed air is passed over desiccant material to dry it out.

Desiccants can be solids or liquids, a liquid absorption dehumidifier contacts air with a liquid desiccant solution. The liquid has a vapor pressure lower than water at the same temperature, and when the air passing over this solution reduced vapor pressure, and then it is dehumidified. In application, the behavior of a liquid desiccant can be controlled by adjusting its concentration, its temperature, or both. simple heaters and coolers controlled the Desiccant temperature (Pundir and Mishra, 2012).

There are several types of desiccants:

Silica gel :

Silica occurs in nature as Silica dioxide, SiO. It is processed into gel-like beads for use as a desiccant dryer. Silica gel was first used in World War I to absorb vapor in gas mask canisters. Pure silica gel is one of the few desiccants that is safe for use around food.

Indicating silica gel :

Indicating silica gel is silica gel that is processed with cobalt chloride. The cobalt chloride will change color from blue to pink as the silica gel absorbs moisture. This 'indicates' when the silica gel is becoming saturated. Because cobalt chloride is a heavy metal salt, it cannot be safely used around food.

Clay :

Clay that is high in magnesium aluminum silicate, a naturally occurring mineral, is processed into Montmorillonite clay for use in drying. It works best at room temperature or below. Clay is one of the most inexpensive desiccants, which makes it popular for industrial use.

Quicklime and gypsum :

Quicklime is a common term for Calcium Oxide. It is alkaline and highly caustic, so special care in handling is necessary. Its chief benefit is that it can be used to gradually drop the humidity to a very low state. Gypsum is Calcium Sulfate. Its color-indicating form is Drierite™.

Molecular sieve :

Molecular Sieve is a synthetic desiccant manufactured from aluminosilicates. Like the name sounds, it has many tiny holes or pores the absorb liquid and gas. It is a highly effective desiccant that can absorb water upto 22% of its own weight.

Delsorb 10 :

Delsorb 10 is one of the major adsorbent/ desiccant used world wide for moisture removal, purification and other treatments. A highly porous form of aluminum oxide, it works both under static and dynamic conditions.

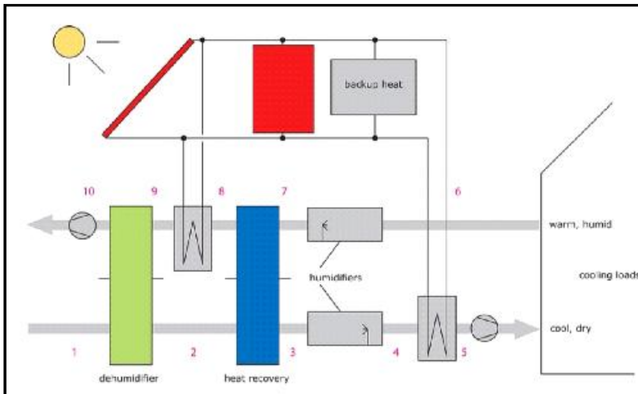

Fig. 3 : Solid dessicant cooling system

Solid dessicant cooling system:

The main components of a solar assisted desiccant cooling system are shown in the figure above. The basic process in providing conditioned air may be described as follows. Warm and humid air enters the slowly rotating desiccant wheel and is dehumidified by adsorption of water (1-2). Since the air is heated up by the adsorption heat, a heat recovery wheel is passed (2-3), resulting in a significant pre-cooling of the supply air stream. Subsequently, the air is humidified and thus further cooled by a controlled humidifier (3-4) according to the set-values of supply air temperature and humidity. The exhaust air stream of the rooms is humidified (6-7) close to the saturation point to exploit the full cooling potential in order to allow an effective heat recovery (7-8). Finally, the sorption wheel has to be regenerated (9-10) by applying heat in a comparatively low temperature range from 50°C – 75°C and to allow a continuous operation of the dehumidification process (*www.articsolar*)

The solid desiccant cooling system is primarily based on the application of solid-based desiccant materials in controlling air moisture content. The sorption mechanism in the solid material is either through absorption or adsorption.Cooling by means of heat recovery, evaporative cooling or other means are applied to the system . The desiccant material is typically impregnated to the honeycomb designed wheels or of the cross-flow heat exchangers (Khoukhi, 2013).

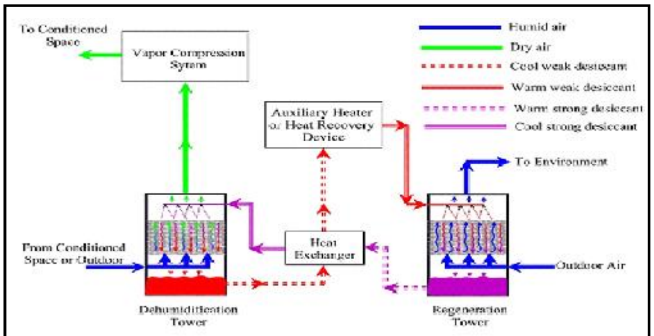

Fig. 4 : Liquid dessicant cooling system

Liquid dessicant cooling system:

Liquid desiccant systems will normally use the hygroscopic properties of a salt solution to dehumidify the air. The solution is exposed to the high relative humidity airstream – typically, outdoor air – and attracts water vapour from the high vapour pressure air to the lower vapour pressure liquid desiccant.Liquid desiccants for air conditioning applications include solutions of lithium chloride (LiCl), lithium bromide (LiBr), and calcium chloride ($CaCl_2$). As pure salts, these have a vapour pressure of practically zero. An example solution of Calcium chloride is 10% of the cost of lithium chloride, and using 50/50 blends of the two desiccants can provide equilibrium vapour pressures – and resulting air moisture content/dew point – very similar to that of using a single solution of lithium chloride. These salts are all very corrosive to metals typically used in air conditioning system (www.cibsejournal.com).

Liquid desiccant have several advantages over solid desiccant. The pressure drop through the liquid desiccant is lower than that through a solid desiccant system and can be stored for regeneration by some inexpensive energy such as solar energy and waste heat. Liquid desiccant system combined with vapor compression system can reduce area of evaporation and condensation by 34% and power consumption by 25%, compared with vapor compression system alone (Srivastava, 2016).

Advantages and disadvantages of dessicant cooling system:

Advantages:

– Improved air qualities in interior

– Less electricity consumption as alternate sources can be used.

– CFC, HFC, HCFC refrigerants are not used. Hence, this system is eco friendly

– Integration with convectional to remove latent load can be reduced energy consumption

– Low operating costs

– Dessicants are commercially available and inexpensive (Bora *et al.*, 2017).

Disadvantages:

– High initial setup of the system

– Experienced professionals are required to construct, install and service such systems.

– Liquid dessicant can be corrosive and damage the system components.

– Cost effective only when there is a source of waste heat available to regenerate dessicant.

– Limited application in high humidity climate areas.

– System effectiveness depends on a large extent on the dessicant properties (Bora *et al.*, 2017).

Conclusion:

Dessicant cooling can supplement them advantageously by extending their climatic applicability's scope. Experiments performed in Saudi Arabia and Persian Gulf Region have given remarkable results energy saving and effectiveness in controlling the temperature and humidity. Although the desiccant cooling has its penalty which is the energy required in regenerating the desiccant, it has been seen throughout this literature review that, its energy saving potential is significant. And the regeneration could be done with the help of free energy such as waste energy and solar energy.

Desiccant cooling is not only appropriate in comfort cooling but can also be used effectively in preservation of cereals and warehouses. Desiccant cooling systems do not use any ozone-depleting refrigerants. Moreover, they can operate successfully on low-grade heat from solar energy, combined heat and power plant or waste heat from factories or chimneys. An adiabatic desiccant system is mostly suitable for drying the air. If cooling is required, then a hybrid system has to be used.

There are concerns that require several design optimizations like carry-over of liquid desiccant at high flow rates, reverse dehumidification at low air humidity ratios and corrosion of the dehumidification unit and storage tank in case of any leakages. Many researches have suggested that the problem of carry-over can be by using micro-porous membrane, which would only allow the air to pass and not the liquid desiccant. However, such membrane also increases the mass transfer resistance.

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