SOLAR THERMAL AIR CONDITIONER USING LIQUID DESICCANT DEHUMIDIFICATION AND IEC.

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Abstract : Today, in the 21st century era, global warming has taken over our mother earth. The demand for conditioned air has only increased at a exponential rate for the past decade. The only way to deal with climatic problems is to rely on renewable energy sources and technology. One such technology is the liquid desiccant system. These technologies incorporate the utilization of solar energy and are proven to have greater Coefficient of Performance. The liquid desiccant system under inspection incorporates a packed bed design. Desiccant used in the below system is Tri Ethylene Glycol which dehumidifies the air to be conditioned and then is recirculated in the closed loop system for regeneration using the solar concentrator. The night-sky cooling system is coupled with concentrator for effective night and day time use of the concentrator. The setup consists of a dehumidifier with a regenerator, heat exchanger, a concentrator, desiccant cooling system, controlled temperature reservoir and a control system. Experiments will be conducted on this system using different parameters and operating conditions of the desiccant.

***IndexTerms* - Solar cooling, Liquid Desiccant Systems, Dehumidification, Regeneration.**

I. INTRODUCTION

The conventional and widespread vapour compression air conditioners demand very high power and consequently high cost. Solar power air conditioner on the contrary would consume no power. The use of solar cooling systems is quite common, but solar air conditioners have not been as popular. The thermal energy from the sun is used to dehydrate the desiccant which in turn has dehumidified the air in various buildings and complexes where cooling is desired. The use of solar energy for cooling can be used to provide refrigeration for preservation of food or to provide comfort cooling.

II. SCOPE

Renewable energy sources are coveted globally. The overall climate in India is dry with temperatures ranging close 20 degrees throughout the year. Also the whole country is located close to the equator which means that the sunlight is available for extended period of time. Though there is no denying the fact that solar energy is a vital and an abundant resource, it cannot be utilized as efficiently. A few applications of solar systems are listed below:

1) Educational complexes: Universities, schools, colleges and others.
2) Commercial edifices: Such as galleries, malls, shopping buildings, marts,etc..
3) Dwelling structures: Lounges, hotels, motels.
4) Industries, storage of commoditiess eg. Fruits, vegetables and dairy.
5) Remote areas.
6) In locations where electricity availibility is scarce.

Comfort is expected out of an air conditioning system for the residents. There are systems for this purpose. They are also called comfort air conditioning systems. This project proposes the development of a feasible cooling mod designed with a Solar AC to cool the room air. This cooling system needs to be powered up by a DC or AC power supply, which can be designed or by using a off-shelf DC power supply.

The scope of the projects involves the following:

1) Sizing and Designing of the Solar AC
    a) Design of IEC
    b) Design of Dehumidifier
    c) Design of Regenerator
    d) Design of concentrator
2) Selection of a Pump
3) Selection of Heat sinks and Fans
4) DC power supply determination.
5) Prototype Fabrication.
6) Temperature measurements for evaluation.
7) Power supply evaluation and troubleshooting.

III. LIQUID DESICCANT CYCLE

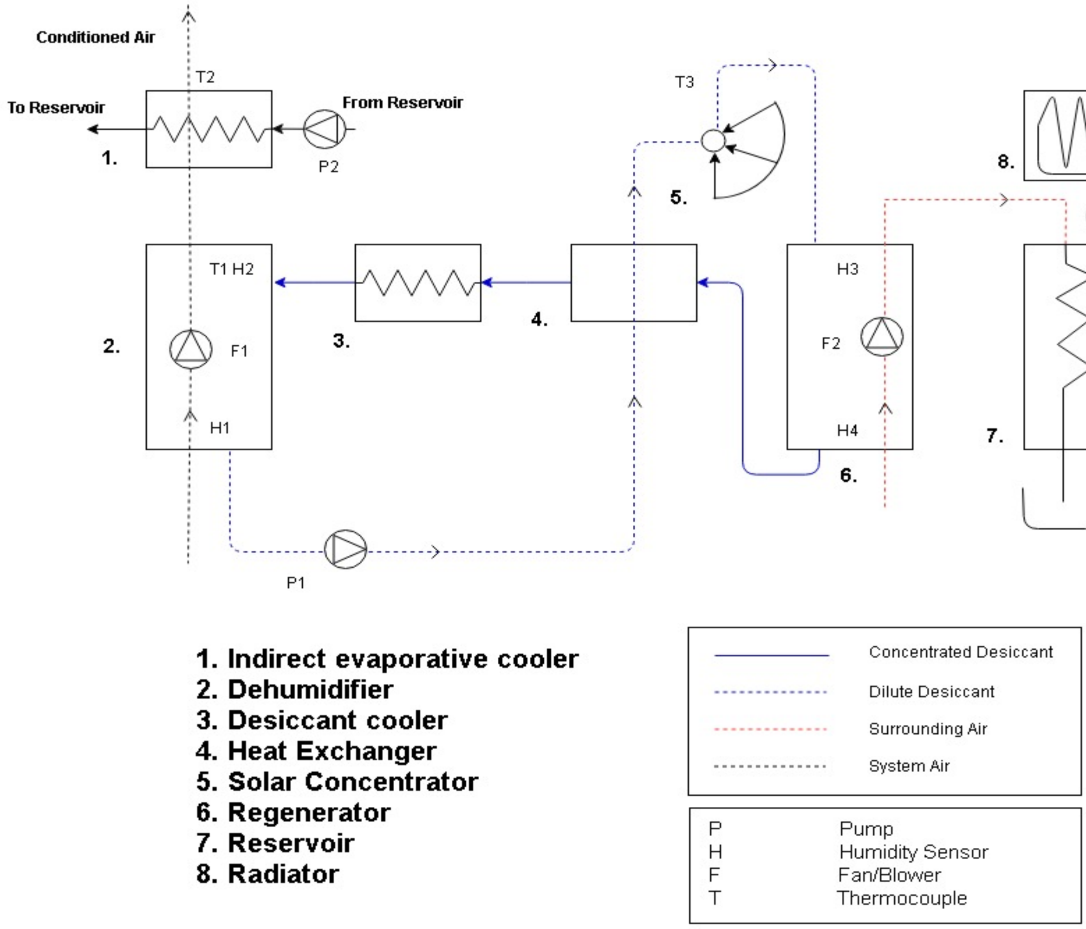

Fig. 1. Schematic Of Liquid Desiccant Cycle With Night Sky Cooling

The project inculcates a highly precise analysis and design methodology path to achieve the goals. Fig. 1. shows the desiccant cycle proposed for the project. Room air is blown in by a blower through the dehumidifier. The dehumidifier is gauze packed to allow maximum air-gauze surface area direct contact with the cross-flowing desiccant. Liquid desiccant flows downwards and the air stream flow is horizontal. After the air is dehumidified, it is passed on to the Indirect evaporative cooler (IEC).The IEC is supplied with a slow drip of water and is under constant draft air flow. Evaporation is caused by either sunlight or/and the draft fan creating a pressure differential allowing to lower the boiling point of the water and causing low temperature evaporation.

Air is cooled as it passes through the tubes in contact with the evaporating fluid and is passed to the room. The desiccant passing through the dehumidifier becomes dilute as it absorbs the moisture from the air and now requires regeneration for reuse. Before entering the regenerator, the dilute desiccant is supplied with rejected heat through a solid-state passive heat exchanger or a thermo-electric Peltier based forced heat exchanger. This increases the temperature of the dilute desiccant and allows it to gain more heat in the Solar concentrator. After the desiccant passes through the solar concentrator it enters the regenerator at a temperature of greater than 100 degree Celsius to allow the rapid evaporation of water in the low-pressure regenerator (please note that the boiling point of Tri ethylene Glycol is 280 deg).

A similar type gauze packing suitable with the temperature environment is also used for the regenerator with a cross-flow of ambient air through it and out allows the regeneration of the desiccant. Now a concentrated form of Liquid desiccant, still hot from the regeneration is passive or actively cooled by the dilute desiccant leaving the dehumidifier, indirectly. Then further cooled down in a dedicated desiccant cooler before entering the dehumidifier to lower the vapor pressure of the concentrated desiccant so as to increase the effectiveness of absorption. An experimental setup of Night Sky Cooling by radiation is to be tested for a cold water reservoir which will be insulated to minimize the heat exchanged during day time. We shall call it a Controlled Temperature Reservoir (CTR). The CTR is derived from the phenomenon of night sky radiation where the Electromagnetic radiation in the range of 8 microns to 15 microns are actively able to escape the earth’s atmosphere.

This technique has been previously deployed in Iraq where they were able to create Ice during night time. If said Cooling method works , the possibility of atmospheric water generation is to be considered for the reduction of tap water consumption in the IEC. The solar Control and Capture system uses Trackers, Micro controllers and Sensors for continuous, automatic and smooth functioning of the Air conditioning system.

A. Night Time Cooling And Day Time Concentration

The concentrator works during the day to input a significant amount of heat to the desiccant cycle and is unused during the night time. The effect of night sky cooling can be coupled with the concentrator in order to use the concentrator as a night sky radiator during night time. The benefit of such a coupling is that the area required for cooling is decreased and the liquid being cooled by the night sky system also can be effective in reducing any scaling that may occur. Another benefit of using the concentrator for night time is that the radiation that is emitted from the pipes is directed to the sky via the concentrator thereby allow increasing the surface area of contact for the desired cooling. A proposed system developed to achieve the same is in the making. A test setup is been built and testing has commenced.

. Alizadeh and W.Y. Saman [11] (2002) determined, “The rate of evaporation of water depends on air inlet, air regenerator length, solution mass flow rate and outlet air concentration, air Reynolds number and the glazing of the regenerators solution climatic conditions” (p. 154)

Fig. 2. Parabolic Profile Concentrator

B. Literature Survey Of Liquid Desiccant System(LDS), IEC,Regenerator and Dehumidifier

V. Oberg and D.Y. Goswami [14] (1998),established that “Design variables that have a great impact on the effectiveness of the dehumidifier are the flow rate of air and the humidity ratio, the desiccant temperature and concentration, and the packed bed height” (p. 290). “The liquid flow rate must ensure wetting of the packing. Riangvilaikul and S. Kumar [2] (2010) experimentally showed, to provide consistent result at various operating conditions, covering dry, moderate and humid climate” (p. 644). At inlet air temperature more than 30.8C, the velocity of air should be kept below 2.5 m/s to obtain wet bulb effectiveness more than 100%. G.P. Maheshwari, R. K. Suri and F L. Ragom [3] (2001) showed that, “The power requirements of a packaged unit air-conditioner to produce this cooling in tested areas are 3 times greater compared with only 1.11 kW needed by the IEC. Also, the energy savings of the IEC are 12,400 and 6300 kWh, for the inland and coastal regions, respectively” (p. 69). C.G. Moona, P.K. Bansala, and Sanjeev Jainb [1] (2009), “Studied the effect of main factors that affect the performance of the dehumidification system and quantified through experimentation. These included air flow rate, air humidity ratio, air temperature, solution flow rate, solution temperature and solution concentration” (p. 532). A.S.A. Mohamed , M.S. Ahmed , A.A.M. Hassan and M. Salah Hassan [12] (2016), “Have studied the mass transfer between the air and desiccant when they flow through gauze structured packing dehumidifier” (p. 260). P. Gandhidasan [13] (2003) established that “The effect of changing the desiccant flow rate on the water condensation rate is more pronounced at low cooling water inlet temperature than at high inlet temperature on condensation rate” (p. 415). P. J. Erens and A.A. Dreyer [4] (1993) found “The simplified model shows good results and is recommended for the determination of performance of systems and for initial design while the more sophisticated methods should be used for more accurate performance prediction” (p. 22). A.E. Kabeel [10]

(2005)suggested, “Rate of water evaporation depends on the concentration of solution and forced flow rate. The free convection solar regenerator is lesser of lesser efficiency than forced convection cross flow. The mass transfer coefficient for the forced unit used in this work is much higher than the free unit” (p. 338). Shahram Delfani , Jafar Esmaeeliana,, Hadi Pasdarshahri and Maryam Karami [6] (2010)“Demonstrated the performance and energy reduction capability of combined system has been evaluated through the cooling season. The results indicate IEC can reduce cooling load up to 75% during cooling seasons. Also, reduction in electrical energy consumption of PUA can be obtained” (p. 2169). Yonggao Yin-, Xiaosong Zhang and Zhenqian Chen [8] (2010) “Devised that the desiccant air conditioning system utilizes low-grade heat such as solar energy, and can provide comfortable air temperature and humidity with good indoor air quality. Water is used as the refrigerant so that it is environmentally friendly” (p. 1806).

C. Literature Survey Of Night Sky Reservoir and Solar Concentrator

Thomas Fend , Bernhard Hoffschmidt , Gary Jorgensen , Harald Kuster , Dirk Kruger , Robert Pitz-Paal , Peter Rietbrock and Klaus-Jurgen Riffelman [5] (2003) suggested, “Materials suitable for long-term outdoor applications are various silvered glass mirrors, a silvered polymer film, and an anodized sheet aluminium having an additional protective polymer coating” (p. 149).

Ghassem Heidarinejad , Moien Farmahini Farahani and Shahram Delfani [7] (2009)“Proposed the advantage of sky as a renewable source of the passive cooling, a hybrid cooling system can be considered as an environmentally clean and energy efficient system” (p. 2073). Ana Dyreson , Franklin Miller [9] (2016) “Analyzed a radiation-enhanced cooling system for thermal power plants with a detailed heat transfer model and shown to be feasible for Concentrated Solar Plant. The proposed system consumes no water and has the potential to out-perform air-cooling” (p. 276).

Fig. 3. Circular Profile Concentrator

IV. CONCLUSION

A. Determination of rate of regeneration

For the decided location (Kharghar, Navi Mumbai) the average insolation is about 960 W/m2. Therefore, the maximum possible available heat that can be utilized effectively needs to be considered. The flow of liquid desiccant through the copper pipes being heated by the concentration of sunlight shall be determined. The experimental setup uses a semicircular profile type concentrator built with 180 mm diameter PVC pipes and is coated with 90% reflective film. After consideration of losses due to wind effect, efficiency of the angle of acceptance of circular profile and the effectiveness of the reflective film, the current approximate available heat would be around 440 W/m2. Using this information currently a concentrator is being built to ensure good flow rate and outlet temperature of 110 degree Centigrade.

B. Determination of Size of Regenerator

After the average flowrate has been determined a housing and capacity of regenerator can be calculated. The air flow rate through the regenerator with respect to the desiccant flow rate needs to be twice as much to avoid saturation of air stream.

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