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Analysis of solar desiccant cooling system for an institutional building in subtropical Queensland, Australia

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ABSTRACT

Institutional buildings contain different types of functional spaces which require different types of heating, ventilating and air conditioning (HVAC) systems. In addition, institutional buildings should be designed to maintain an optimal indoor comfort condition with minimal energy consumption and minimal negative environmental impact. Recently there has been a significant interest in implementing desiccant cooling technologies within institutional buildings. Solar desiccant cooling systems are reliable in performance, environmentally friendly and capable of improving indoor air quality at a lower cost. In this study, a solar desiccant cooling system for an institutional building in subtropical Queensland (Australia) is assessed using TRNSYS 16 software. This system has been designed and installed at the Rockhampton campus of Central Queensland University. The system's technical performance, economic analysis, energy savings, and avoided gas emission are quantified in reference to a conventional HVAC system under the influence of Rockhampton's typical meteorological year. The technical and economic parameters that are used to assess the system's viability are: coefficient of performance (*COP*), solar fraction, life cycle analysis, payback period, present worth factor and the avoided gas emission. Results showed that, the installed cooling system at Central Queensland University which consists of 10 m^2 of solar collectors and a 0.400 m^3 of hot water storage tank, achieved a 0.7 *COP* and 22% of solar fraction during the cooling season. These values can be boosted to 1.2 *COP* and 69% respectively if 20 m^2 of evacuated tube collector's area and 1.5 m^3 of solar hot water storage volume are installed.

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1. Introduction

Institutional buildings contain different types of functional spaces. Lecture theatres, libraries and laboratories are the most important spaces within institutional buildings and they are

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usually the largest air conditioned area which host the daily occupants' activity, machinery and instruments. In institutional buildings, HVAC is a very important means to maintain a comfortable living space and to provide clean air to the occupants. However, the supplied cooled air is often contaminated with dust, microbes, viruses and fungi [1]. In addition, high indoor humidity is a major contributor to the accumulation of moisture in a buildings envelope. These often cause dampness within the building and subsequent health-related problems for the occupants. Moreover indoor humidity affects humans, library contents (books and furniture) and laboratories (machines and equipment). Institutional buildings have a very high occupational density compared to most other commercial buildings. This high occupancy density generates a high heat gain as well as a high emission of body odours and water vapour. It is known that the human body has a constant temperature of 36–37 °C, independent of surrounding conditions and muscle activities. As a consequence, the human body has to transmit the excess heat to the environment by means of different heat transfer mechanism. This excess heat consists of latent and sensible heat. The sensible heat is transferred by means of convection and radiation from the human body to its surroundings, while latent heat is transferred to the surrounding by diffusion of vapour through skin and exhaled air [2]. The most common practice to overcome contaminations and to ensure an acceptable air quality is using hypo filters in conjunction with dampers. Conversely, the hypo filters which are made of organic material act as a nidus for the growth of fungi in the presence of HVAC condensing moisture [3]. While the most common procedure to conquer the HVAC's condensing water issue is by overcooling the treated air below the dew point this is also considered an expensive practice. Designers, developers and architects are therefore urged to use non conventional HVAC system's as solar cooling technologies. Furthermore, using non conventional HVAC technologies which use clean materials and renewable energy resources can significantly reduce building energy consumption and enhance indoor air quality. In solar cooling systems, solar heat is required to drive the cooling process, and this can be done by collecting solar radiation using solar collectors to convert it into thermal energy, and then this energy is used to drive thermally driven cooling cycles such as desiccant, absorption and adsorption cycles [4].

Solar desiccant cooling systems are an energy efficient and environmentally friendly way to improve indoor air quality due to its superior latent load control. This technology is considered as a great alternative for conventional air conditioning in commercial buildings particularly institutional buildings and health care buildings to reduce contaminated air transmissions [5]. The solar desiccant cooling systems works as an open cycle which is based on the combination of desiccant processes and evaporative cooling. The main principle of the desiccant cooling cycle is the systems capability of removing or reducing vapours and moisture out of the treated air using a physical sorption process [6]. The sorption process can be undertaken using adsorption or absorption. The adsorption process is a physical process where the property of the desiccant material remains unchanged, while in the absorption process, the physical characteristic of the material changes when attracting moisture [6]. Desiccant materials are available as solid or liquid. Example of desiccant materials are silica gel, titanium silicates, calcium chloride, activated aluminas, zeolite (natural and synthetic), molecular sieves, lithium chloride, organic-based desiccants, polymers, compound and composite desiccants [7]. Market available desiccant systems include liquid spray towers, solid packed tower, rotating horizontal bed, multiple vertical bed and rotating desiccant wheel [8]. The main component of a solar desiccant cooling cycle are the solar energy system which consists of solar collectors and hot water storage, the dehumidifier which consists of a rotating wheel containing desiccant material and the evaporative cooler. The cooling process starts in the dehumidifier as shown in Fig. 1, where the desiccant material dries the supplied air to produce a dry and warm air. Then the warm and dry air is passed to the evaporative cooler to reduce its sensible temperature to near ambient conditions and then to the cooled space. This continuous air drying eventually makes the desiccant materials saturated, and cannot function again unless regenerated. In order to use the desiccant material again, thermal energy is required for the regeneration process. Generally this thermal energy can be supplied by gas or solar [6,9].

Solar desiccant cooling systems can deliver a dryness enough to treat 7.5 l of wet air per second per person and the personal moisture load of 70 W latent (0.1 l per hour) [10,11]. Due to using a low grade thermal energy and environmentally friendly materials, solar desiccant cooling systems have become attractive to researcher's to resolve issues associated with using conventional air conditioning and indoor air quality.

A number of studies have been carried out to investigate and evaluate solar desiccant cooling technology. Experimental investigations started when Baum et al. [12] followed by Kakabaev et al. [13] investigated a liquid desiccant cooling system based on a theory presented by Kakabaev and Khandurdyev [14,15]. Dai et al. examined the numerical performance of a hybrid solar solid desiccant cooling system for grain storage [16]. Halliday et al. demonstrated the potential of using solar energy to drive a desiccant cooling system [17]. Goldsworthy and White have recently investigated a desiccant cooling system with an indirect evaporative cooler [18]. Alizadeh performed an experimental study of a forced flow solar collector regenerator using liquid desiccant for Brisbane climate [19]. Ismail et al. evaluated a solar regenerated open cycle desiccant bed system used in a grain storage in Melbourne [20]. Leutz et al. have investigated sorption

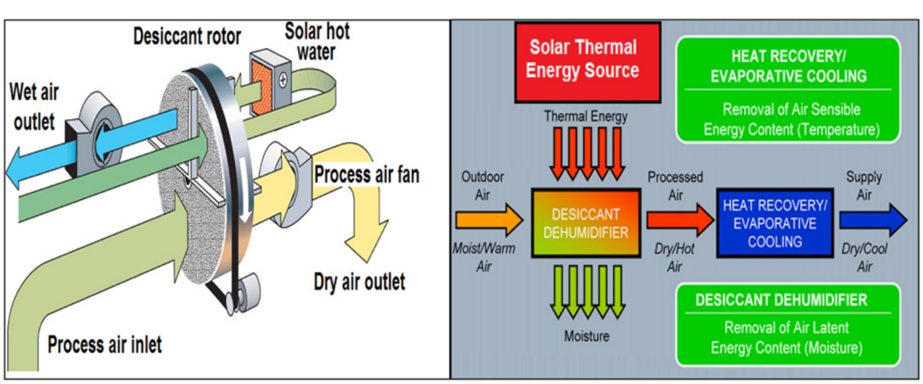

Fig. 1. Desiccant cycle and the operational concept of desiccant cooling system.