RESIDENTIAL APPLICATION OF SOLAR LIQUID DESICCANT COOLING SYSTEM IN TROPICAL COUNTRIES OF SOUTH EAST ASIA

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Abstract

The South East Asian region is characterised by its high humidity and low variation of outdoor air temperatures all year round. Conventional vapour compression systems have served to provide thermal comfort for the well off residents in this region. These systems, however, have often been associated with less satisfactory attainment of thermal comfort and increasing electricity demand. Liquid desiccant cooling systems are known to have good dehumidifying capability independent of cooling. This paper discusses the potential application of liquid desiccant systems in three cities: Bangkok (Thailand), Jakarta (Indonesia), and Singapore. The cooling load characteristics of a relatively large floor area house are analysed and, based on this analysis, possible configurations of such systems to bring about the optimum performance are proposed.

INTRODUCTION

South East Asian is one of the fastest growing economies in the world. The last three decades have witnessed continuous economic growth of this region; in 2005, the minimum growth rate was 3% (Brunei), the maximum was 9.8% (Cambodia) with an average growth rate of 5.5% (ASEAN Statistical Pocketbook, 2006). The economic “boom” of these nations has resulted in escalating energy consumption per capita during the last 3 decades. The increased numbers of middle class population in this region have resulted in increased number of households able to procure energy-intensive appliances such as air conditioners. This in turn puts pressure on energy resources, in particular electricity.

Little variation of outdoor air temperature and humidity all year round are characteristics of this region. The thermal performance of conventional vapour compression air conditioners installed in this region has been often the subject of buildings occupants' complaints: it is either too cold or too stuffy. This is due to the inability of these systems to satisfy simultaneously the sensible and latent loads independently when the off-design conditions occur. These systems therefore are only able to perform reasonably well during the periods in which design conditions prevail which only occur at the very short period annually.

Liquid desiccant air conditioning is a type of thermally driven open cooling cycles based on a combination of evaporative cooling and dehumidification by a desiccant (Henning, 2007). A number of advantages of desiccant systems over the closed-cycle systems are (Saman et al., 2004): they operate at ambient pressures, heat and mass transfer occurs in direct contact, and both air cooling and dehumidification can be provided independently according to the prevailing load. However they have lower COPs, potentially high parasitic losses and possible contamination of the desiccant by dust from air which may entail the periodic replacement of the desiccant.

One of the characteristics of desiccant systems is their efficient handling of latent load but less efficient handling of the sensible load (Gommed & Grossman, 2004). An alternative solution, according to Gommed and Grossman, is to handle the latent load with a solar powered desiccant cooling system and to provide cooling with electric-powered heat pump. In this way, the heat pump system is expected to operate more efficiently due to the absence of the requirement for cooling the air below its dew point.

This paper reports on the preliminary study on the potential application of liquid desiccant air conditioning system in three cities in South East Asia: Bangkok (Thailand), Jakarta (Indonesia), and Singapore. The main emphasis of this study is to check the characteristics of cooling load and to propose how the liquid desiccant system can serve the cooling load demand in the climatic region.

HOUSE DESCRIPTION

A typical large house having 235 m^2 floor area was modelled. It has 3 large bedrooms, 2 small (servant) bedrooms, a living room, a dining room, an inner court, a kitchen and 2 bathrooms. The total conditioned area is 198 m^2. The choice of a relatively large floor area house as a basis for the study was based on the assumption that the introduction of a new system of air conditioning in this region will firstly target the middle class house owners who are keen to use new technologies and who can afford to acquire them.

For the purpose of an “objective” thermal performance comparison, it was decided to have this house as a representation of the houses in the three cities. The house is subjected to local climatic data of each city. The floor plan of the house, taken from a website source (Country Woods, 2007), is shown in Figure 1.

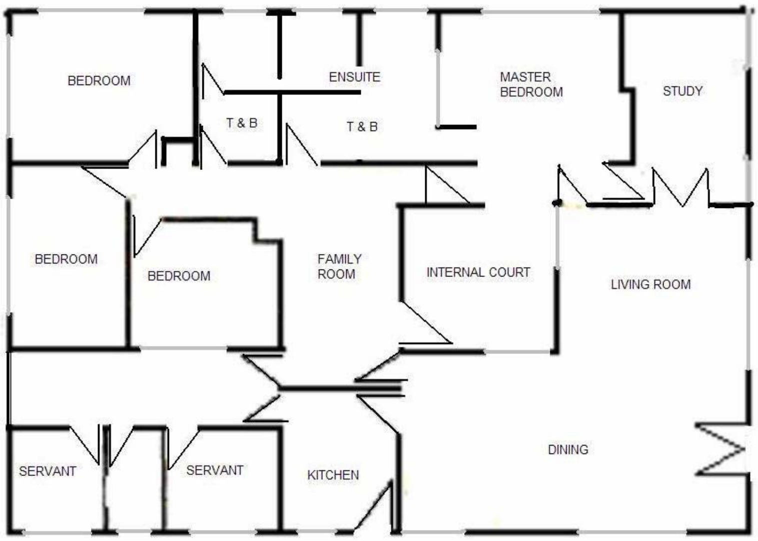

Figure 1 – Floor Plan of the House

The assumed indoor conditions are: 25°C and 50% relative humidity. The hourly outdoor conditions are according to the weather data available in TRNSYS weather data files generated using Meteonorm (TRNSYS, 2005)

Results and Discussion

The simulated results of the annual cooling energy requirements of the house subject to local weather conditions of the cities are shown in Table 1. Annual total cooling energy requirements for Bangkok, Jakarta and Singapore are: 52 GJ, 50 GJ and 52 GJ, respectively. The monthly cooling energy requirement profiles for Jakarta (6˚20’S) and Singapore (1˚44’N) are very similar with small variation all year round.

The figure for Bangkok (6˚16'S), on the other hand, is somewhat curved – peaking at the months of March, April and May.

Table 1- Monthly Sensible, Latent and Total Cooling Loads (in MJ) of the House Exposed to Bangkok, Jakarta and Singapore Weather

	J	F	M	A	M	J	J	A	S	O	N	D
BANGKOK												
SNS	1162	2327	3076	3164	3204	2818	2842	2768	2453	2549	2230	2092
LAT	1226	1469	1895	2062	2174	1968	1976	1979	1947	1952	1461	1098
TOT	2388	3796	4971	5226	5377	4786	4818	4747	4400	4501	3691	3190
%LAT	51.3	38.7	38.1	39.5	40.4	41.1	41.0	41.7	44.3	43.4	39.6	34.4
JAKARTA												
SNS	1352	2141	2557	2354	2589	2393	2416	2461	2548	2996	2546	2563
LAT	2047	1728	1998	2056	2100	1935	1752	1719	1746	1969	1909	1962
TOT	3400	3869	4554	4410	4689	4327	4168	4180	4294	4965	4455	4525
%LAT	60.2	44.7	43.9	46.6	44.8	44.7	42.0	41.1	40.7	39.7	42.8	43.4
SINGAPORE												
SNS	1106	2013	2409	2324	2536	2366	2432	2415	2194	2340	1981	1978
LAT	1771	1668	1947	2029	2189	2028	2021	2023	1956	2010	1955	1869
TOT	2877	3681	4356	4353	4725	4394	4453	4438	4149	4350	3936	3847
%LAT	61.6	45.3	44.7	46.6	46.3	46.1	45.4	45.6	47.1	46.2	49.7	48.6

The main characteristics of the cooling loads in these cities are: (1) the magnitude of the cooling loads are almost constant all year round, (2) the percentage of monthly latent load are significantly high, ranging from as low 34.4% to as high as 61.6% with an average of 44.5%.

The first characteristic is a real advantage; the system will operate in nearly full capacity all year round and does not need a control strategy to switch the system operation to alternative season. The second characteristic is also an advantage, in that the system main function as the dehumidifier matches the load characteristics. This also means that a combined system of liquid desiccant and conventional vapour compression unit to handle both latent and sensible loads is an option worth considering.

One disadvantage of such a system operating in a humid climate is the high humidity of ambient air which may limit the regenerating capability of the desiccant system.

This will mean that the optimal use of return air from the room (which is drier than the outdoor air) for desiccant regeneration must be sought.

Possible System Configurations

Considering the local outdoor and indoor air conditions in the three cities, there are a number of possible configurations where desiccant systems can be expected to provide some comfort.

Configuration 1

In this configuration (Fig. 2), fresh air is dehumidified in the liquid desiccant (LD) sub-system and is cooled in a heat exchanger (HX). Further cooling will be accomplished in the vapour compression (VC) sub-system as and when required. Before entering VC, fresh air can be mixed with some of the return air to ease the VC sub-system duty. This scheme can reduce the size of latter due to its increased coefficient of performance – COP – (Daou et al., 2006). This configuration can also be used as a 100% fresh air system.

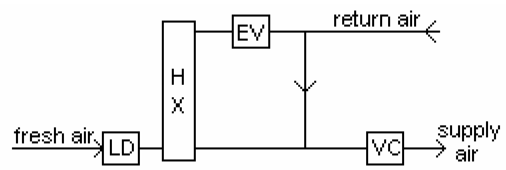

Figure 2 –Fresh air is dehumidified in the LD sub-system, cooled in the HX, and mixed with return air before entering VC sub-system for further cooling (if necessary)

Configuration 2

In this scheme, (Fig. 3), the mixture of the fresh and return air is dehumidified by the LD sub-system. This dry mix is then cooled consecutively in the heat HX and VC sub-systems.

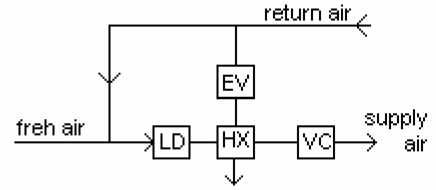

Figure 3 – Fresh and return air is dehumidified in the LD sub-system, and consecutively in the HX and VC sub-system before entering the room

The technical and economic feasibilities of the above possible configurations are currently under investigation. Recent work (Krause et al., 2006) on the possible application of the LD system for Brisbane, Australia, has shown encouraging results.

Conclusions

Cooling load analysis for a residential house exposed to South East Asian climatic conditions reveals that the monthly latent loads represent about 35 – 60% of the total load. The preliminary analysis also reveals that variation of monthly total and latent cooling loads is small. These are favourable conditions for a liquid desiccant system which, in combination with conventional vapour compression system, can potentially lead to substantial reductions in the cooling energy and peak electricity demands for this region.

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