SOLAR COOLING SYSTEM FOR IRAQ

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ABSTRACT

The main purpose of this paper is to present the cooling conditions in Iraq. This paper is trying to show solar cooling technology, which can be used in residential buildings in Iraq. Appropriate solar collectors for solar cooling in Iraq and storage tank will be perfect according to Iraqi conditions. This paper also aims to address the increasing demand of the air-conditioning system in Iraq, due to the growth in economy and business, which has increased the demand for purchasing power in the last few years. The paper also focuses on reducing consumption of fossil fuels and proposes solar cooling system in Iraq, which would be economical and suitable for the environment.

INTRODUCTION

Solar Cooling is a technology which converts solar energy into useful cooling energy, which later on is delivered to the building or offices for space conditioning. The process involves a thermally driven cooling process, which uses the collected heat and generates chilled water or conditioned air for the use of buildings. Chilled water is not used for cooling in residential places, but is widely used for commercial buildings. In solar thermal cooling technologies, solar heat is required to drive the cooling process. The basic solar cooling process is shown in Fig.1. Solar cooling is a technology with a number of variants, which exists due to the availability of a number of components, which can be used in the solar energy collection, thermally-driven cooling process, and delivery stages. The configuration of these components can also be altered. Broadly, however, solar cooling can be categorized into Open Cycle and Closed Cycle systems (as the report solar energy industries association, 2012). Solar cooling offers Iraq an important opportunity to combat climate change by reducing the significant greenhouse gas (GHG) emissions generated by the electricity sector in servicing the residential and commercial buildings. Solar cooling is uniquely suited to Iraq, because most of the months of a year experience hot summers and relatively mild winters.

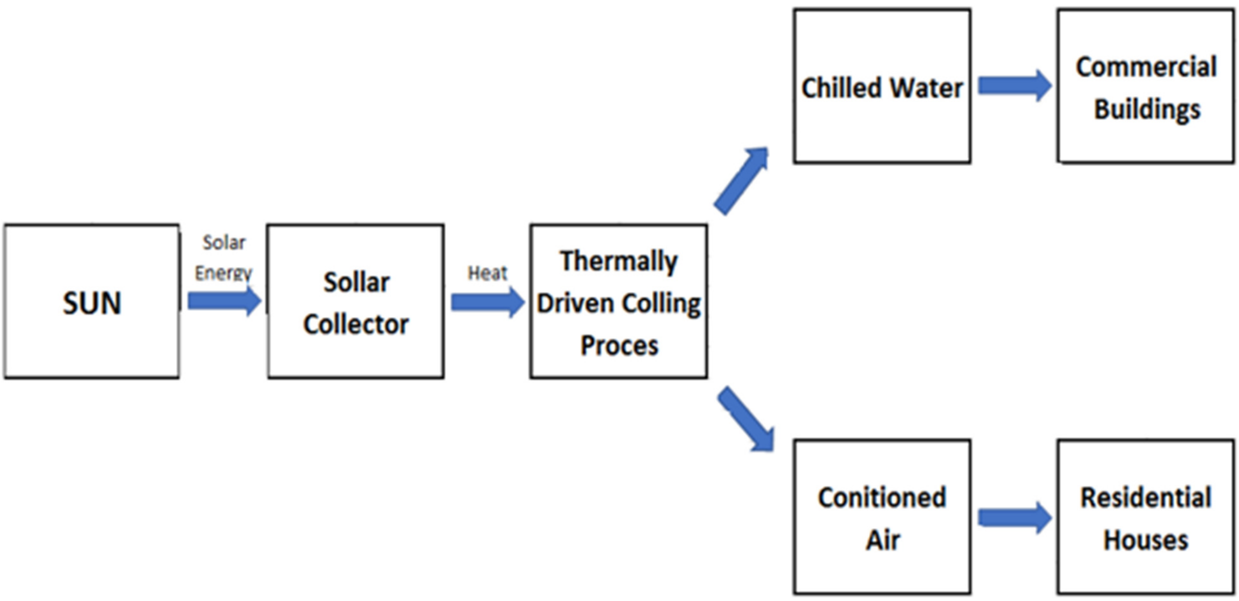

Fig. 1. Basic idea of Solar cooling process

THERMAL VS ELECTRIC (PHOTOVOLTAIC) SOLAR COOLING

Solar thermal and electric cooling are both different from each other. Firstly, the means or tools used for conversion of solar energy to thermal or electric energy (solar collectors and PV panels); secondly, the generation of a cooling effect. In solar thermal cooling systems, thermal driven chillers are used, while in solar electric cooling systems, traditional (electric driven) vapor compression chillers are used. The efficiency of the commercial PV panels is usually up to 17%. And this efficiency goes down as the surrounding air temperature rises. While on the other hand, the efficiency of the thermal collectors reaches higher than 50%. In thermal collectors the increase of surrounding air temperature leads to increase of the energy collected. Hence, the solar thermal cooling systems are better than the solar electric cooling system. Apart from that thermal system are eco-friendly, they do not produce any harm to the environment (as the report in Sohen Mohammed Frakhraldin,2016).

Solar thermal cooling

The phenomenon of sorption physical or chemical attraction among substances, is the principle mechanism for the production of cooling effect in solar thermal cooling systems.

Solar thermal systems can be classified into two different types which are as follows:

- open system
- close system

Open System: In open systems, the sorption process serves as a dehumidifier of the air (these systems are called the desiccant system), thereafter this dry air is cooled and supplied to the building through an evaporative cooling process.

Closed System: In closed systems, the refrigerant is circulated in a closed loop and the cooling effect takes place through heat exchange between the refrigerant and the air supplied to the building (using fan coil units and air handling units). Generally, there are two technologies used in closed systems: absorption and adsorption. The principle difference between both is the nature of the sorbent used. In the absorption system, the sorption process takes place between liquid (sorbent) and gaseous (refrigerant) substances, and the refrigerant undergoes a change in its phase, while in the adsorption system, the sorption process takes place between solid (sorbent) and gaseous (refrigerant) substances, without any changes in the nature of the substances.

Solar absorption system

Absorption systems were the first systems, which were used for air conditioning. They are still most prevalent worldwide. The absorption system processes with the help of a heat source and pump, which works as a compressor in a vapor compression system. Figure 2 shows Absorption Chiller.

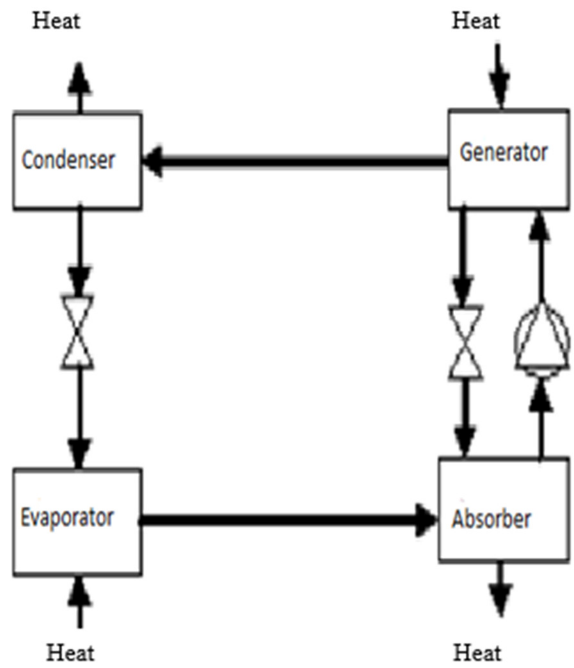

Fig. 2. Absorption Chiller

Absorption systems require a small number of moving parts for the operation. Hence, their maintenance is quite low in comparison to other solar cooling systems. Figure 3 shows Schematic diagram of an absorption system. In an absorption chiller, lithium bromide water (LiBr-H_2O) solution is used, because it's more suitable for air-conditioning applications. In the evaporator, the water gains its latent heat from the warmer water which comes from the space to be cooled, because of it the cooling effect is supplied, and refrigerant undergoes a phase change to vapor. Then, the water vapor goes to the absorber and mixes with a LiBr-H_2O solution. Here the water vapor is again turned to the liquid phase and then the solution goes back to be diluted. After this, mixing, an amount of heat is emitted, where it is ejected to the cooling water from the cooling tower circuit. Through a heat exchanger, the LiBr-H_2O solution is pumped to the generator, which is preheated by the thermal energy which is gained from solar energy. The water is condensed in the condenser to a liquid state. Then the water is passed to the evaporator through an expansion valve. In addition, there is a storage tank to store excess chilled water for future use, if there is any shortage (as the report in Sohen Mohammed Fakhraldin, 2016).

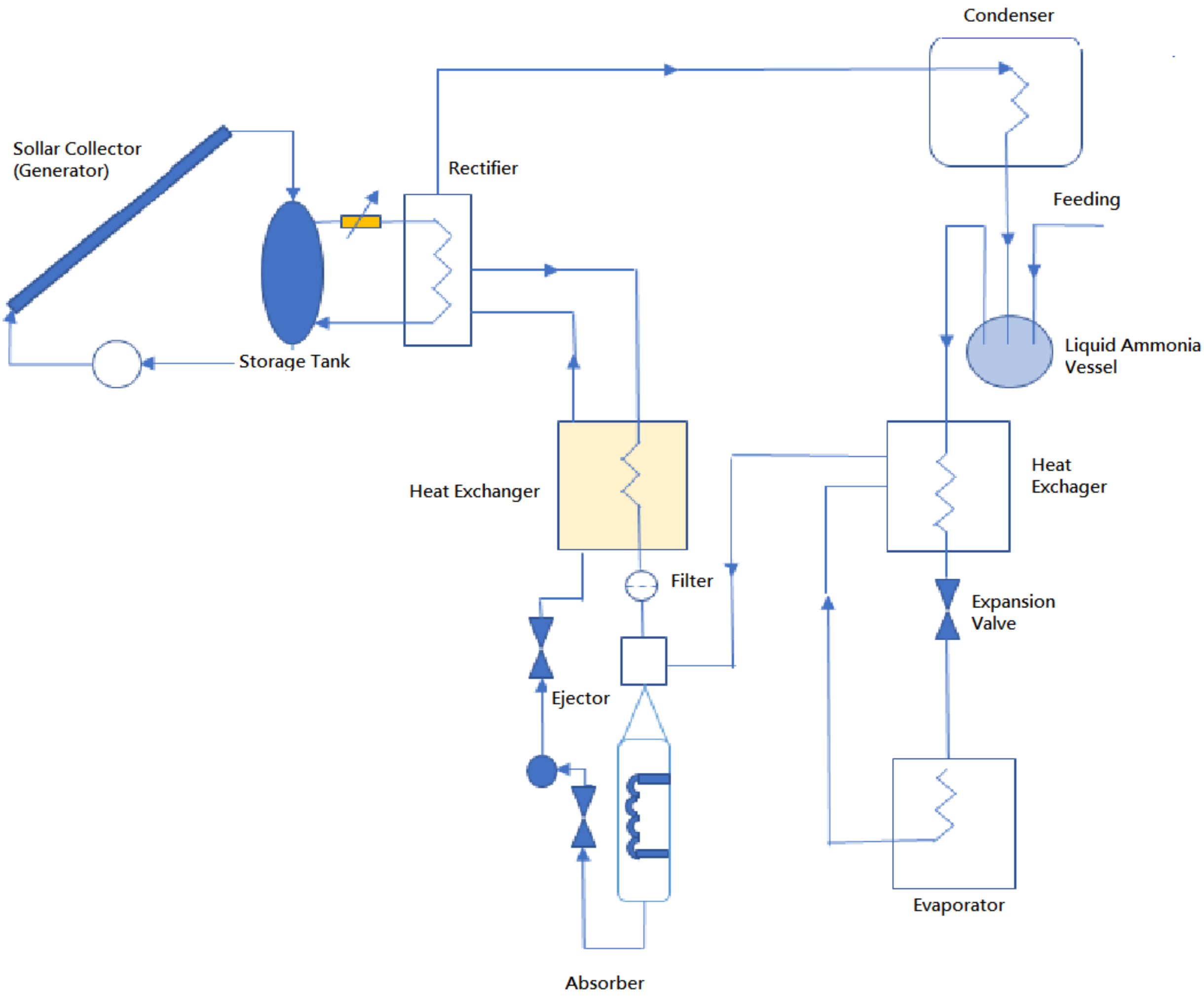

Fig. 3. Schematic diagram of an absorption system.

There are two factors which describe the performance of the solar absorption system:

- Coefficient of Performance.
- Solar Fraction.

$$COP = \frac{Q_{evaporative}}{Q_{generator}} \quad (1)$$

$$COP = \frac{Qevaporative}{Qsolar+Qauxiliary\ heater} \quad (2)$$

Here, $Q_{generator} = \boldsymbol{Q_{solar}} + \boldsymbol{Q_{auxiliary\ heater}}$
While a solar fraction is a ratio between solar energy and total heat of the generator.

$$SF = \frac{Q_{solar}}{Q_{generator}} \quad (3)$$

SOLAR THERMAL COLLECTORS

Solar collectors can be defined as a special type of heat exchanger which converts solar radiation to useful thermal energy.
Basically, solar collectors are of two types:

- non-concentrating collectors
- concentrating collectors

Non-concentrating collectors include flat plate collectors also known as FPC, evacuated collectors known as ETC.

Concentrating collectors include parabolic through collectors, linear Fresnel reflectors, parabolic dish reflectors, heliostat field collectors and pool collectors (as in the report in Sohen Mohammed Fakhraldin, 2016). Table 1. Shows different types of collectors.

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Kind of collector	Collector Type	Absorber shape	Concentration ratio	Temperature Range (℃)
Non-concentrating	Flat Plate Collector (FPC)	Flat	1	30-80
	Evacuated Tube Collector (ETC)	Flat	1	50-200
Concentrating	Compound Parabolic Collector (CPC)	Tubular	1-5	60-240
	Parabolic Trough Collector (PTC)	Tubular	10-85	60-400
	Linear Fresnel Reflector (LFR)	Tubular	10-40	60-250
	Parabolic Dish Reflector (PDR)	Point	600-2000	100-1500
	Heliostat Field Collector (HFC)	Point	300-1500	150-2000

EXPERIMENTAL INVESTIGATIONS

(As the report in Hidalgo,2008 and Syed,2005) examined the impact of choosing an inappropriate size of absorption chiller on the basis of primary energy consumption and CO_2 emission. They considered 35KW single stage LiBr-H_2O absorption chiller and energized it by hot water from a hot storage tank. They used 50m^2 flat solar collector to heat the storage tank. And the result showed a COP of 0.33. In the early eighties in Iraq, a solar absorption system was consisting of two absorption chillers of 60 TR (Ton of Refrigeration) refrigeration. Each with 1587 evacuated tube collectors. Evacuated tube collectors had an area of 1.33 m^2. This fulfills the requirement of air conditioning in the Solar Energy Research Center, Baghdad. This building has five floors with an air-conditioned area of 3700 m^2. 64% of solar collectors are erected on the front surface of the building, which is at a slope of 45°, while the other collectors are placed in the front space of the building at an angle of 17°. Hence, from the above investigation, it's clear that selecting an appropriate size of chiller is essential for solar cooling to increase the capability of the absorption chiller to achieve efficient solar cooling for buildings. Enlarging a hot storage tank to store more solar energy not increase the performance of the solar collector, but it might increase the chances of heat losses. Using a dry cooling tower will decrease the performance of the system as the ambient temperature will rise. Use of a cold storage tank could be a good solution to improve the efficiency of the solar absorption system (as shown in the report Sohen Mohammed Fakhraldin, 2016).

DESICCANT COOLING (DEC)

The desiccant cooling system basically uses water as a refrigerant in direct contact with air and dehumidifies it. Desiccant systems also known as thermally driven air conditioning systems. A desiccant is basically a substance, either solid or liquid. The desiccant initially is used to absorb moisture from the air, which later is regenerated by heating the desiccant, that releases the absorbed moisture. It improves the air quality and energy efficiency. The desiccant material absorbs moisture due to the difference in vapor pressure (as shown in the report Net Zero Energy Buildings,2013). Figure.5 shows Working of a desiccant cooling system.

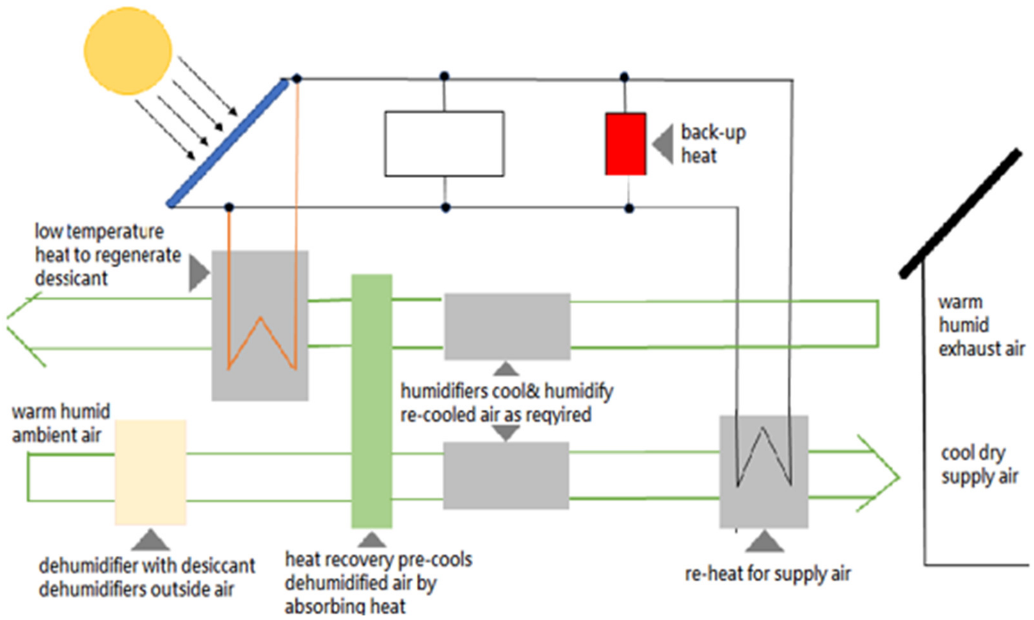

Fig. 5. Working of a desiccant cooling system.

There are two basic categories for desiccant systems which are as follows:

- open Desiccant Systems
- closed Desiccant Systems

In open desiccant systems, desiccant comes into direct contact with the air for the process of dehumidification. Closed desiccant system, in this system the desiccant is confined to a closed chamber and then dehumidifies the air indirectly.

Based on the type of desiccant used, it can be categorized into

- solid Desiccant
- liquid Desiccant

Solid Desiccant: In solid desiccant, a dry desiccant is used like silica gel or zeolite, titanium silicates, alumina, molecular sieves, etc. These desiccants have a high regenerative temperature. For silica gel and alumina, it is about 200-300°C, the temperature for molecular sieve is about 100°C. The drying capability of solid desiccants is higher than that of liquid desiccants.

Liquid Desiccant: Liquid desiccant system is a new and emerging technology which consists of a contact surface, which is either a cooling coil or cooling tower. Liquid desiccant comprises of lithium chloride, lithium bromide, tri-ethylene glycol, calcium chloride and potassium format. The liquid desiccants usually have a lower generation temperature than solid desiccant which is below 80°C. In a cooling system, to achieve the dehumidification and cooling of air usually, a pre-cooled desiccant is used. A liquid desiccant removes extra moisture and leads to the increase of temperature. The advantage of using liquid desiccant is that liquid desiccants can be stored and used when the heat source is not available. It is quite small and compact (as shown in the report Minnal Sahlot and Saffa B. Riffat, 2014).

OVERALL SYSTEM PERFORMANCE OF DESICCANT COOLING SYSTEM

For open cycle desiccant system, the performance can be expressed by two terms:

- Coefficient of Performance.
- Cooling Capacity.

Coefficient of Performance (COP): It can be defined as the heat removed from the air stream by the energy input to the cycle.

$$COP = \frac{m_p(h_a - h_{sp})}{Energy\ Input} \qquad (4)$$

Where:
m_p= mass flow rate of process air (kg/s)
h_a= enthalpy of ambient air (J)
h_{sp}= enthalpy of supply air (J)
Energy Input=Electric energy used to circulate air, water, and rotating desiccant wheel, and auxiliary regeneration heat.

$$Auxiliary\ energy = m_{reg} c_p (T_{reg} - T_o) \qquad (5)$$

Where
m_{reg}= mass flow rate of regeneration air (kg/s)
c_p= specific heat of air (J/Kg K)
T_{reg}= temperature of regeneration air (°C)
T_o= temperature of outlet (°C)

Cooling Capacity: It is the air supplied by the system. It can usually be defined as the difference in enthalpy between the supply air and any given interior condition. It can be calculated as

$$CC = m_p c_p (T_{reg} - T_o) \qquad (6)$$

Where
T_{reg}= temperature of regeneration air (°C)
T_o= temperature of outlet (°C)

The influence of ambient temperature, regeneration temperatures, temperature outlet, auxiliary energy, and the effectiveness on the performance of the desiccant cooling system can be evaluated in the terms of supply air, sensible cooling capacity and system coefficient of performance (as shown in the report Mustafa Moayad Hasan, 2013).

For dehumidifier performance with constant inlet ambient air, increasing the regeneration temperature reduces the moisture content from the air. The important parameter for desiccant cooling is the coefficient of performance and cooling capacity of the system.

STORAGE TANK

A storage tank basically is a water tank used to store hot water for space heating and domestic use. Water has high specific heat capacity in comparison to other substance hence; it's the best medium available to store the heat. A storage tank is insulated and can retain the heat stored for several days (as shown in the report Wikipedia,2017). Basically, the thermal process of a heat storage tank is divided into two phase:

- heat storage phase.
- exothermic phase.

Heat storage phase: In this phase, the heat is collected more than it's actually lost.

Exothermic phase: In this phase, the heat storage tank will release the heat.

CONCLUSIONS

It can be concluded that each location has its own characteristics and requirements, as in a case of Iraq. This paper also presented the absorption systems. The desiccant cooling system (DEC) can be a good solution to be used for the Iraqi location, because it's cheap and it has a very good efficiency too. Solar heating technology is getting matured. It's really important to select a heat storage tank with proper design and volume, because it improves the efficiency of the system. Hence, to establish a good solar cooling system in Iraq all the aspects should be considered including heating load, design, kind of solar collector and solar cooling system with the temperature variations (as shown in the report Tao Li and Jiaping Liu, 2015).

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