

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 9, Issue 2, February 2020

Experimental Investigation of Solar Driven Diffuser Absorption Chiller

S.Sheik Mydeen¹, M.Raj¹, S.Rajamani¹, S.Stany Agneslu¹, M.Muthukumar², K.Robinston Jeyasingh²

Research Scholar, Department of Mechanical Engineering, Francis Xavier Engineering College, Tamil Nadu, India¹

Assistant Professor, Department of Mechanical Engineering, Francis Xavier Engineering College, NTamil Nadu, India²

Professor and Research & Head, Department of Mechanical Engineering, Francis Xavier Engineering College,
Tamil Nadu, India³

ABSTRACT: Nowadays, the diffusion absorption process is well known and mainly used as refrigerators in hotels and caravans. The huge advantage of this process is the noiseless and wear-free operation due to the absence of moving parts. There are few studies where the diffusion absorption process is combined with solar cooling. The main disadvantages are the low efficiency and the high weight in relation to the cooling capacity. This paper presents a diffusion absorption chiller directly heated by a solar collector with enhanced efficiency. The generator, acting as the bubble pump of the diffusion absorption process, is integrated into a double-glazed flat plate collector.

I. INTRODUCTION

There is a deep interest in solar cooling due to its great growth potential. The increase in the cooling demand conflicts with the shortage of fossil sources and the climate change resulting from the combustion of these resources. The solar cooling is a practical solution to solve this issue. The time overlap between the cooling demand and the availability of solar energy makes this technology even more attractive. The peaks of the electrical demand in the summer months are often caused by electrically-driven air conditioning units. These peaks can be reduced by using solar cooling systems. Therefore, the solar cooling systems help to stabilize the power grids in affected countries during the summer periods.

The schematic of the different technologies, even for the diffusion absorption process, were shown and the resulting advantages and disadvantages were discussed. There are only few studies where the diffusion absorption process is combined with solar cooling. Therefore, the knowledge gained from studies on solar cooling based on NH₃/H₂O absorption technologies must be used, in particular the knowledge on the refrigerant ammonia and the resulting required heating temperatures.

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II. PRINCIPLE OF THE ABSORPTION CHILLER

A solar-driven diffusion absorption chiller is currently investigated at the Institute of Thermodynamics and Thermal Engineering (ITW). The diffusion absorption chiller operates with ammonia as refrigerant, water as solvent and helium as inert gas. The diffusion absorption process runs without using any electrical energy.

COMPONENTS USED IN ABSORPTION SYSTEM

1. Evaporator
2. Condenser
3. Heatexchanger
4. Receiver Drier
5. Coppertube
6. Aluminiumtube
7. Pressuregauge
8. Solarcollector

III. COMPONENTS

1. Evaporator:-



Fig1:Automobile AC Evaporator

This component can be used in many field, such as a refrigerator, aquarium, car cooling system, airconditioner and many other cooling systems. Evaporator is a place where the refrigerant evaporates and absorbs heat from the air passed over it.

2. Condenser

The purpose of condenser is to receive the hot high pressure refrigerant and condense into liquid. In most automotive air conditioning systems, the condenser is located in front of the radiator.

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The high temperature refrigerant gas forced from the compressor into the condenser turns into liquid as it is cooled by the air flowing across the condenser fins.

3. Receiver Drier



Fig3: Receiver Drier

Automobile air conditioning units are more prone to leak than other units because of vibrations. Over a period of time, small leaks will occur requiring the addition of refrigerant. Also the evaporator requirements vary because of changing heat load.

A small receiver is used in the system to compensate for these variables. Refrigerant is stored in the receiver until it is needed by the evaporator.

4. Heat Exchanger



Fig4: Concentric Tube Heat Exchanger

Concentric tube heat exchangers are used in a variety of industries for purpose such as material processing, air conditioning. They create a temperature driving force by passing fluid streams of different temperature parallel to each other, separated by a physical

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Boundary in the form of a pipe. This induces forced convection, transferring heat to/from the product.

The primary advantage of a concentric configuration, as opposed to a plate or shell and tube heat exchanger, is the simplicity of their design. As such, the insides of both surfaces are easy to clean and maintain, making it ideal for fluids that cause fouling. Additionally, their built-in design means that they can withstand high pressure operations. They also produce turbulent conditions at low flow rates, increasing the heat transfer coefficient, and hence the rate of heat transfer.

There are significant disadvantages however, the two most noticeable being their high cost in proportion to heat transfer area; and the impractical lengths required for high heat duties. They also suffer from comparatively high heat losses via their large, outershells.

5. Copper Tube



Fig5: Copper Tube

This AC copper tube is highly malleable and has a high chemical resistance. Copper tubes are commonly used in the construction industry for water supply lines and for refrigerant lines in HVAC (heating, cooling, and air conditioning) systems. Copper tubes can be manufactured as soft or rigid copper and offers excellent corrosion-resistance and reliable connection.

6. Aluminum tube

Aluminum tubing is an extruded product with a large number of uses in all types of fabrication and building projects due to its light weight, relative strength and superior resistance to corrosion, among other favorable qualities. Aluminum tube is much easier to bend than any other tube, due to the greater wall thickness, since it is less likely to collapse or deform when you bend it.⁷⁷

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7. Pressure Gauges



Fig6:AC Pressure Gauge

Air conditioning gauges is used to measure air conditioner units pressure within closed system to evaluate or troubleshoot the central air units. Gauges manifold set is the most frequently used item when it comes to refrigerant or pressure. There are two types of pressure gauges used in AC system, they are low pressure gauge and high pressure gauge.

8. Solar Collector

The development of a directly solar-heated generator integrated into a collector is a focus in this paper. The harp-shaped lift tubes are parallel-connected. They are directly connected to the absorber plate of the solar collector and lead from the distribution channel to the separator. The heat is transferred from the solar energy to the working fluid inside the lift tubes through thermal conduction via the absorber plate of the solar collector and the lift tubes. An interconnected heating circuit is not required so that the temperature of the working fluid in the generator corresponds to the temperature of the collector.

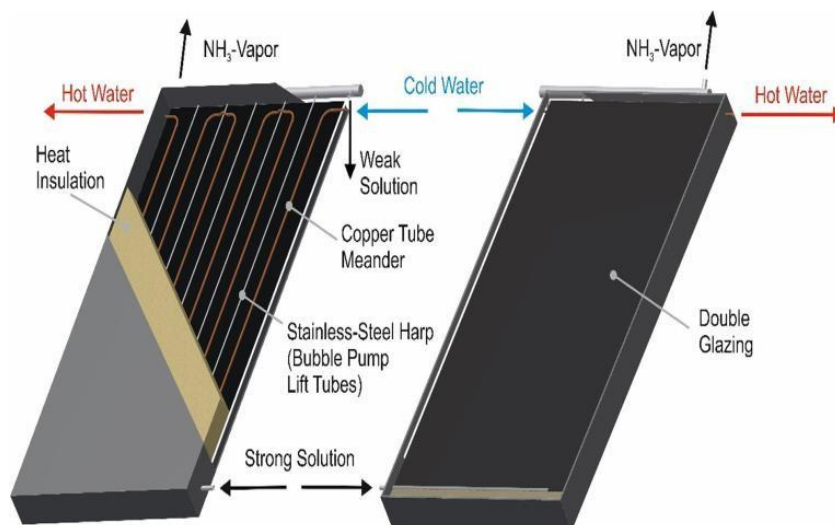


Fig7: Sectional schematic drawing of the solar collector with the integrated generator

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APPLICATIONS

1. To increase the cooling demand conflicts with the shortage of fossil resources.
2. Peaks of the electrical demand in the summer months are often caused by Electrically driven air conditioning units.
3. The solar cooling systems help to stabilize the power grids in affected countries during the summer periods.

PROJECT LAYOUT

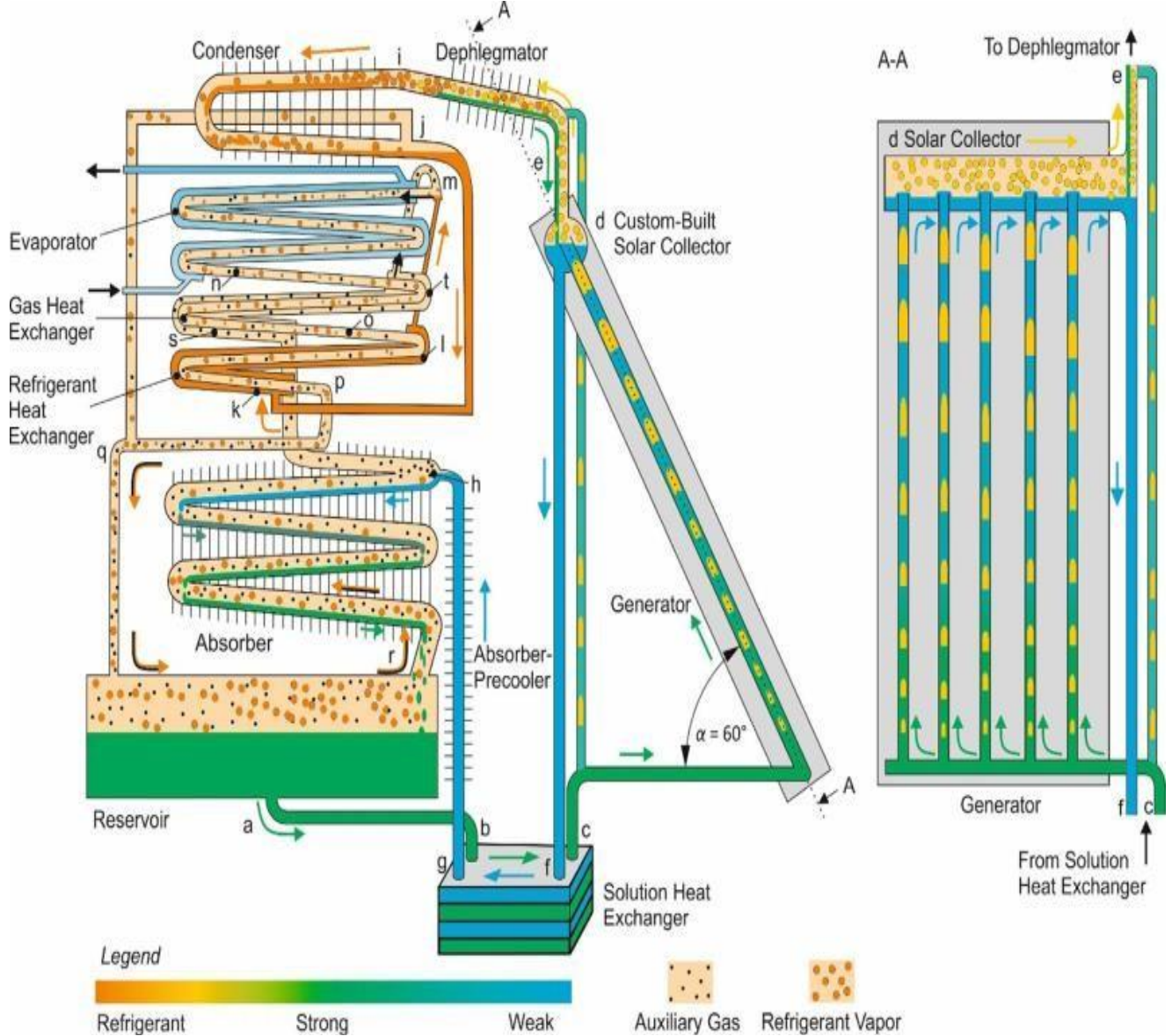


Fig8: Schematic design of the diffusion absorption chiller

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JOURNAL PAPERS

Dr. John White (2013)



Figure9: Active carbon/methanol adsorption cooling system.

The main purpose of this paper is to provide essential understandings of the solar energy or waste heat adsorption cooling systems and to give a useful procedure regarding designs parameters of adsorbent bed used in adsorption cooling. Adsorption cooling technology can meet the needs for cooling requirements such as air-conditioning, food preservation [1-5].

Handing Wang (2012)

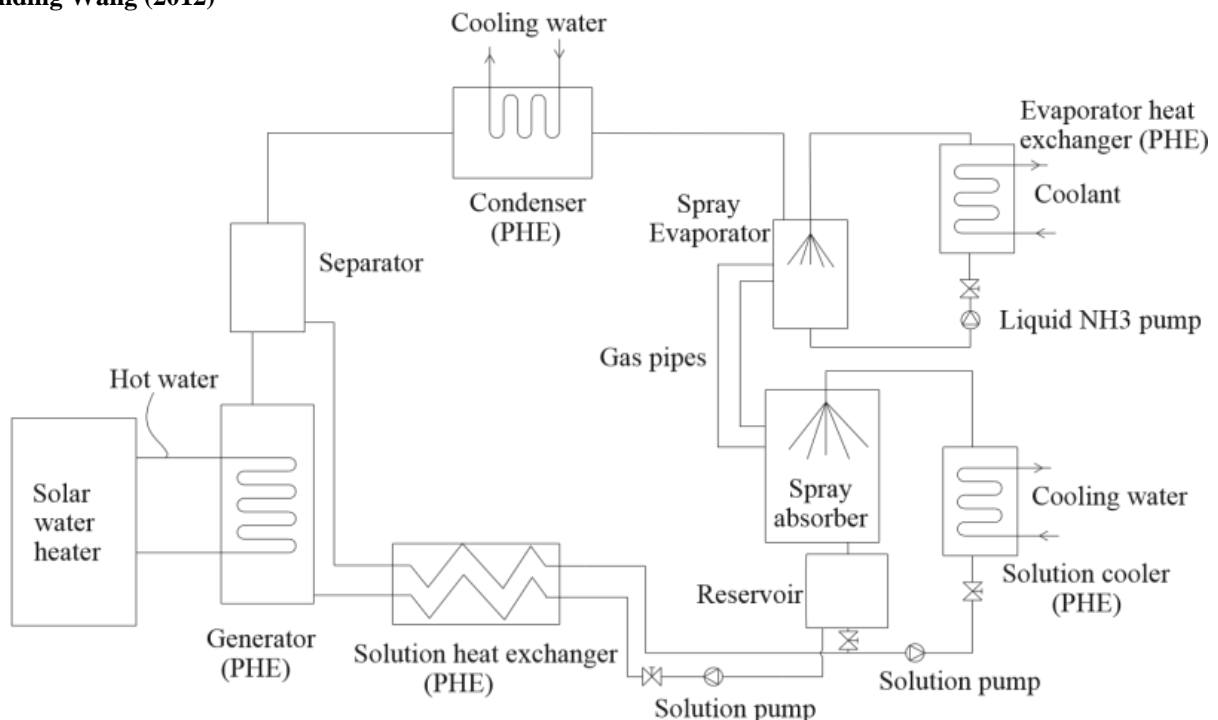


Fig9: Diagram of flow chart of the new type DAR (PHE means plate heat exchanger)

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In order to utilize clean energy such as solar energy to reduce electricity consumption in heating, ventilating, air conditioning and refrigerating (HVAC&R) engineering, the author developed a new style diffusion-absorption refrigerator (DAR) with solution pumps. It can be driven by low-temperature heat sources, in which $\text{LiNO}_3\text{-NH}_3\text{-He}$ is used as working fluids and an adiabatic spray absorber with a plate-type solution cooler is designed to enhance the mass and heat transfer, respectively. This paper is mainly concern on the principle and operating performance of the DAR, especially the relationships of evaporator temperature (T_e), absorber temperature (T_a) and parameters such as the volume flow rate and inlet temperature of $\text{LiNO}_3\text{-NH}_3$ solution sprayed from the top of the adiabatic spray absorber.

Ghilen Najeh en tl (2017)

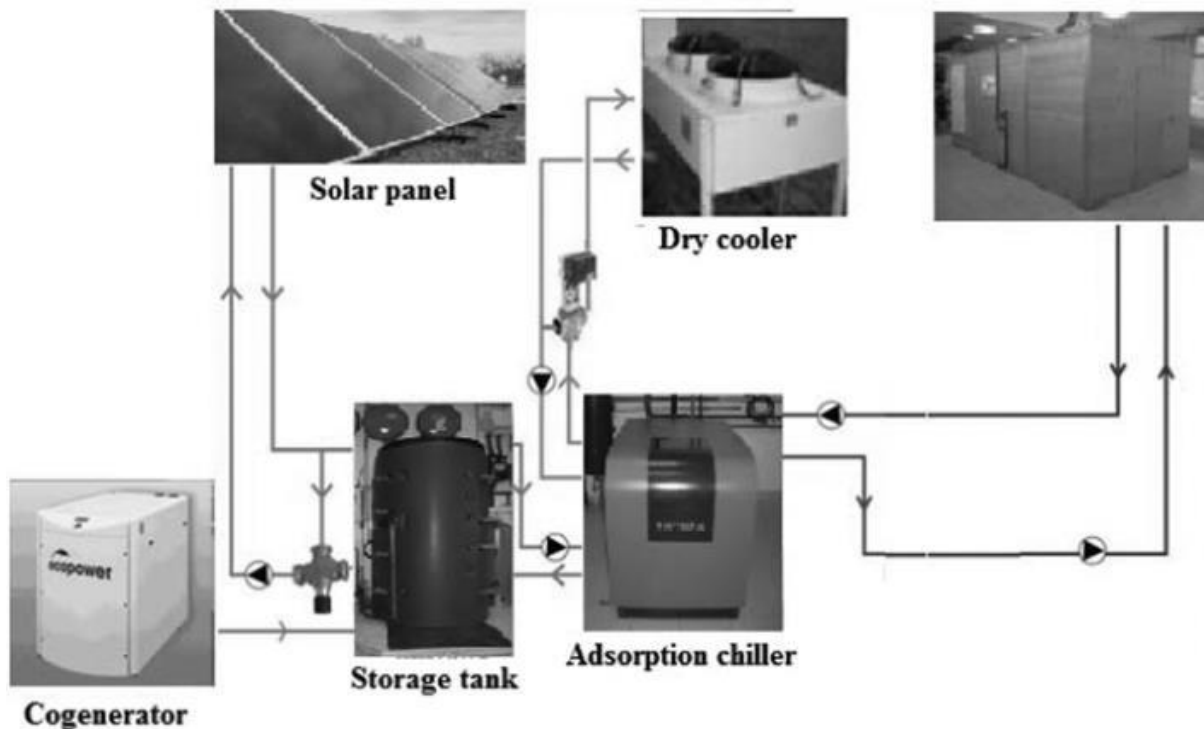


Fig10: Experimental device (Enerbat platform)

Adsorption refrigeration method as the green refrigeration technology has received much attention due to the increase of energy consumption and environment protection. They are powered by heat, such as solar energy, biomass or recovered heat. It contributes to the reduction of CO_2 emissions by using a non-fossil energy sources. Thus, adsorption refrigeration machines have the advantage of being environmentally friendly, with zero Ozone Depletion Potential (ODP) and zero Global Warming Potential (GWP). The adsorbents are often chosen according to their adsorption capacity and their high thermal conductivity. The adsorption capacity must be higher at low temperature and the equilibrium pressure of the evaporator. On the other hand, it must be low at high temperature of the cycle associated with the equilibrium pressure in the condenser. Since adsorption is a surface phenomenon, the choice is made for the micro porous adsorbent with a greater specific surface area.

Dr.Randip en tl (2010)

For countries with a high potential of solar energy, producing cooling effect using solar energy is a promising way to achieve sustainable development, since the energy used is free and not harmful for the environment. This analysis deals

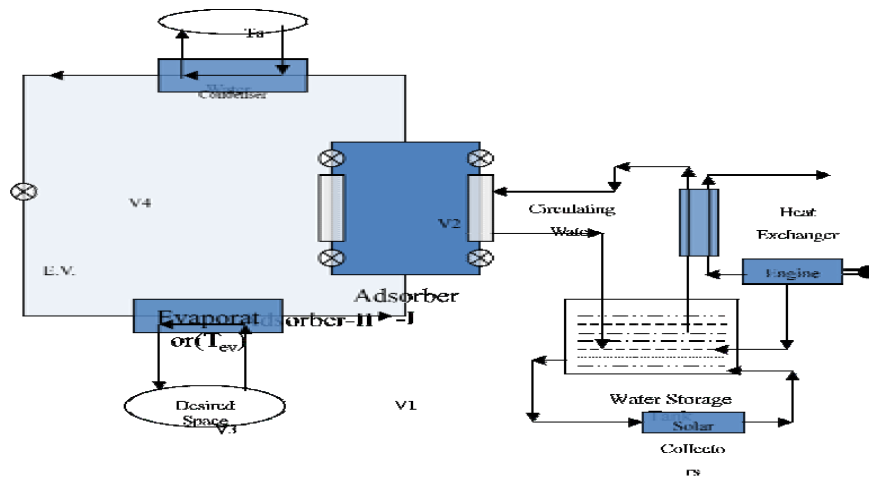
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with adsorption cycle. The proposed cycle consists of one basic adsorption refrigeration cycle. The adsorption cycle is silica-jell bed with water as refrigerant. The heat source is waste heat from diesel engine and solar energy. The performance of the proposed cycle evaluated with the help of the mathematical model at equilibrium condition is compared with the performance of the basic two-bed adsorption refrigeration cycle. This makes s the system a continuous process. It is seen that the cooling effect as well as COP of the proposed cycle is superior to the basic cycle. The system is used for providing air conditioning for a conference room of seating capacity 15. The refrigeration power output for the whole running cycle is about 3 TR.



Water
Fig11: Basic adsorption working model diagram

Kush Ashokkumar Soni (2018)

Adsorption refrigeration systems are developed due to the need of replacing the conventional systems which utilize environmentally harmful refrigerants and consume high grade electrical power. Solar adsorption refrigeration devices are of significance to meet the needs for cooling requirements such as water chiller, air-conditioning, ice-making and medical or food preservation in remote areas. They are also noiseless, non-corrosive and environmentally friendly.

Keeping this as my motivation, I decided to work on water chiller problem.

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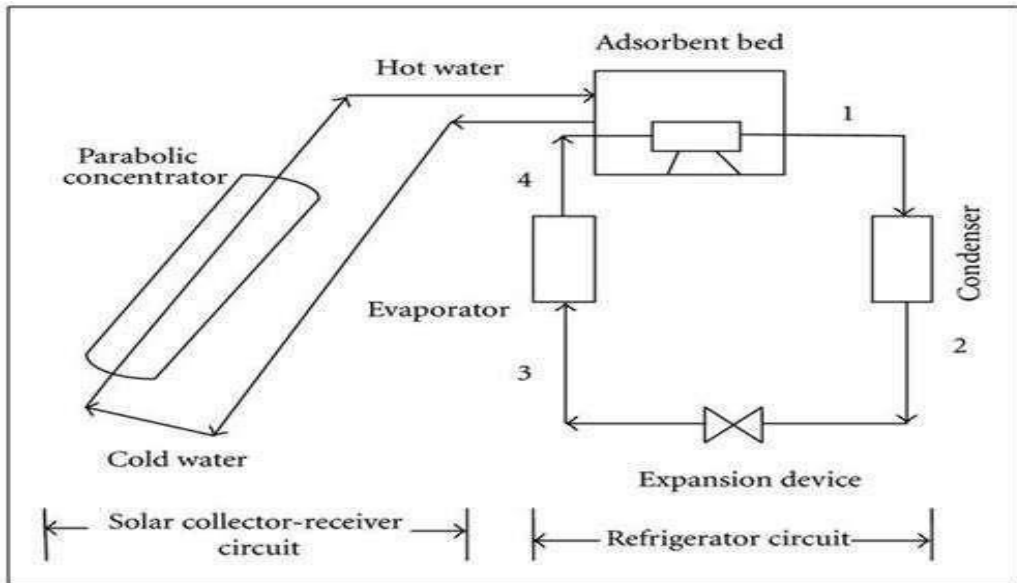


Fig12: Solar powered vapor adsorption system

Walter Mittelbach et al (2008)

This paper presents the development and investigation of the thermally driven ACS 08, a novel single effect, silica gel/water adsorption chiller with nominal cooling capacity of 7.5 kW, developed by Stitch AG for solar cooling. The chiller has a compact design, which is based on the development of a new coating technology Stitch AG and is currently integrated in the chili® Solar Cooling Kit of the Solar Next AG under the brand of chili® STC8.

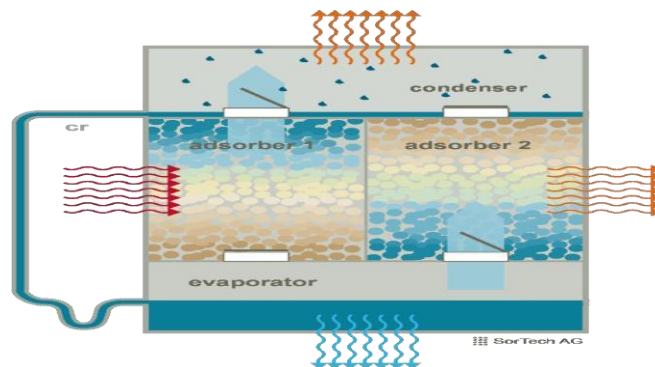


Fig13: Working process of the adsorption chiller (source: Stitch)

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Jatin R Patel et al (2016)

The continuous increase in the cost and demand for energy has led to more research and development to utilize available and renewable energy resources efficiently. The absorption refrigeration system (ARS) is becoming more important because it can produce higher cooling capacity than vapor compression systems, and it can be powered by other sources of energy (like waste heat from gas and steam turbines, sun, geothermal, biomass) other than electricity. But as far as COP of these refrigeration systems is concerned, it is always a challenge to the researchers to significantly increase the COP for these systems. The most popular refrigeration and air conditioning systems at present are those based on the vapour absorption systems. These systems are popular because they are reliable, relatively inexpensive and their technology is well established. However, these systems require high grade energy for their operation. There are still problems to be solved in research field, especially small cooling capacity machine (about 1 to 10 kW) which are suitable for small farmers and residential uses. Apart from this, the recent discovery that the conventional working fluids of vapour absorption systems are causing the ozone layer depletion and greenhouse effects has forced the scientific researchers to look for alternative systems for cooling applications. The natural alternative is of course the absorption system, which mainly uses heat energy for its operation. Moreover, the working fluids of these systems are environment friendly.

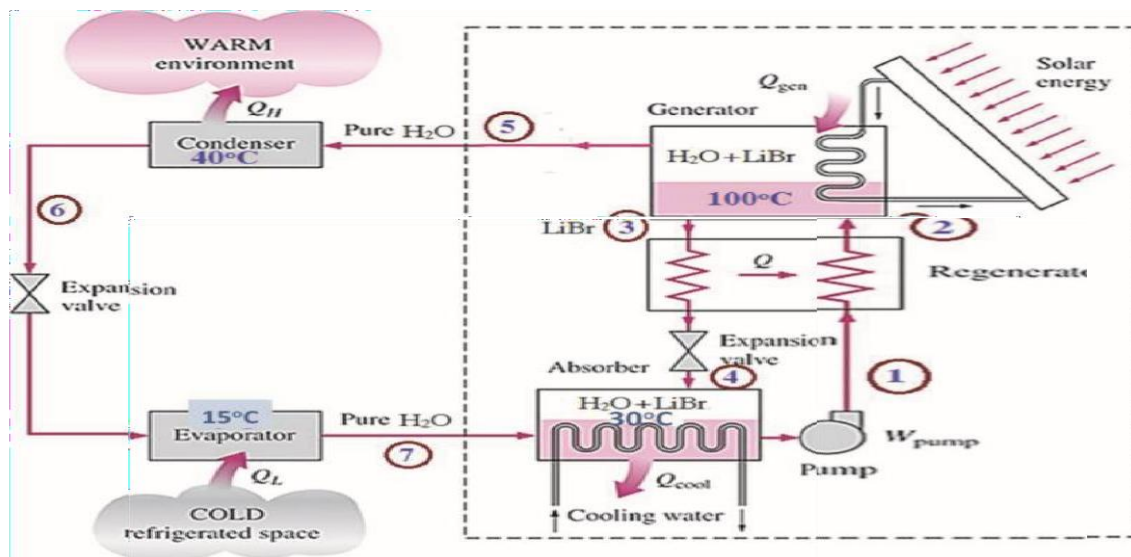


Fig14: Schematic view of ITR Vapour Absorption Refrigeration Syst

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Robert De Boer et al (2006)

The SOCOOL project focuses on the development of a small-scale combined cold, heat and power (tri-generation) system, which utilizes the engine waste heat for cold production. It is demonstrated at the CRF Eco-Canteen in Turin, Italy. The cooling machine is made of two separate sub-cooling systems, each of which is to produce 5 kW of cooling power. One of the cooling systems is driven by 'low-temperature' engine cooling water, the other by 'high temperature' engine exhaust gases. Tri-generation systems that use heat-driven cooling, offer the possibility of saving 15-20% primary energy.

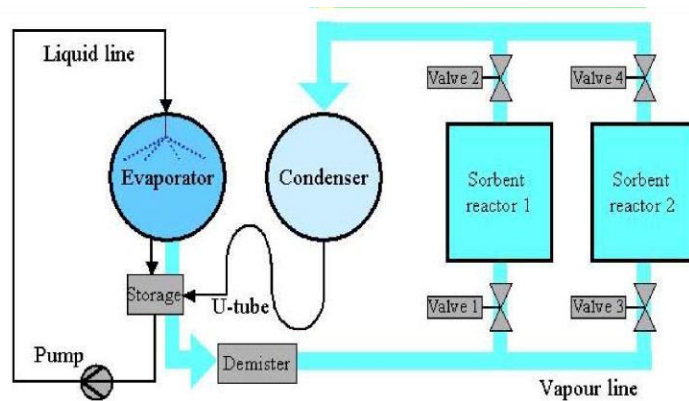


Fig15: Basic system layout of the absorption cooling system

Fabian Schmid et al (2019)

Nowadays, the diffusion absorption process is well known and mainly used as refrigerators in hotels and caravans. The huge advantage of this process is the noiseless and wear-free operation due to the absence of moving parts. There are few studies where the diffusion absorption process is combined with solar cooling. The main disadvantages are the low efficiency and the high weight in relation to the cooling capacity. This paper presents a diffusion absorption chiller directly heated by a solar collector with enhanced efficiency.

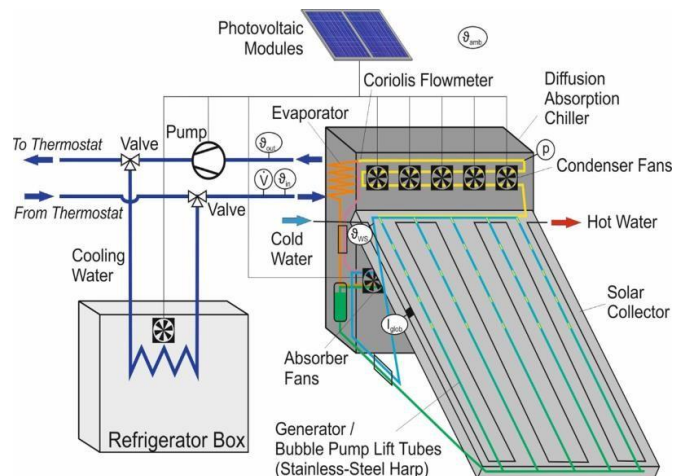


Fig16: Measurement setup of the diffusion absorption demonstration plant.

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Lin Wang et al (2011)

In order to enhance the coefficient of performance of solar absorption refrigerator and analyses the system performance, it was necessary to collect the operation parameters in the system. This paper put forward to combine the technique of visual instrument and the characteristic of solar absorption refrigerator, using National Instrument's product Lab view, to develop an effective data acquisition (DAQ) system. This DAQ system can realize the realtime data acquisition of temperature, water flow rate and pressure as well as data transmission, processing, and display, in addition to provide users with historic data inquire. It saved a lot of labor power and material resources so that it made measurement more convenient and fast.

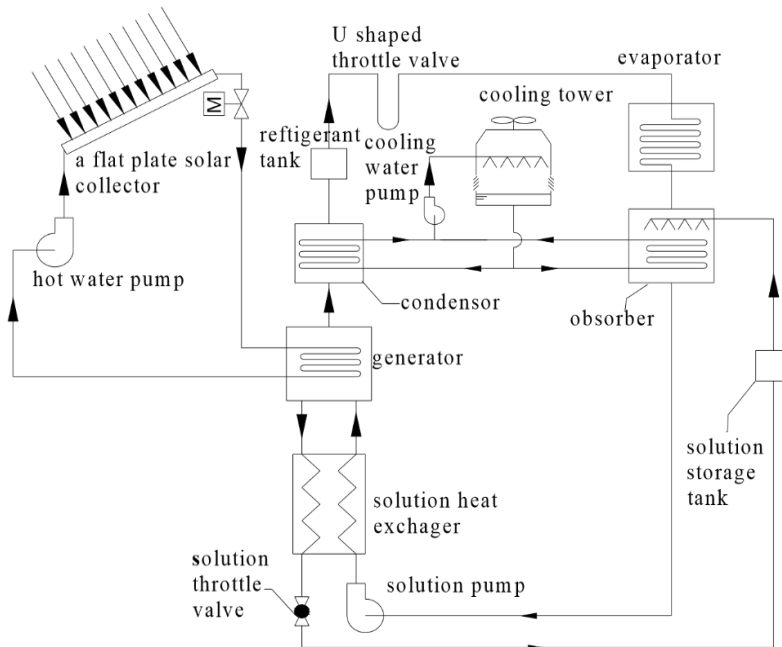


Fig17: Schematic diagram of the solar absorption refrigerator

IV. RESULTS AND DISCUSSION

During the outdoor tests, there are alternating and non-influenceable environmental conditions as fluctuating wind, ambient temperature and radiation. Therefore, a characteristic diagram is not recorded but only the start and operational behavior is investigated during the outdoor test. A characteristic diagram of the diffusion absorption chiller is recorded using the solar simulator of the ITW.

V. CONCLUSION

A solar-driven diffusion absorption chiller was designed and built up. The setup was based on previous laboratory tests focusing on the stability of the process and the auxiliary gas circuit. Another focus was the development of a custom-built collector with an integrated generator. After the previous studies, a demonstration plant was built using the collector with the integrated generator as the central element of the solar-driven diffusion absorption chiller.

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