A Review on Solar Powered Refrigerators

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Abstract- *Utilization of alternative energy source is always viable and better for the environment. From many applications, refrigeration is a leading field for transforming into solar energy powered utilities. Also many people in world still don't have an access to the electricity and many other can't afford the electricity charges. Solar powered refrigeration is best suited for remote areas with no electricity connection and for portability.*

Keywords- Solar refrigeration, solar energy, absorption refrigeration, adsorption refrigeration, sorption refrigeration.

I. INTRODUCTION

Refrigeration is generally done by electric supply. But only 85.3% of world has electricity supply (Source World Bank Data). The rest of population is off the grid. Hence for supply of fresh food, vegetables and also medical supplies, refrigeration is important. For such cases solar refrigeration is an important option.

There are two type of solar refrigerators –

1. Autonomous
2. Secondary power supply

The autonomous solar refrigerators are totally powered by solar irradiance while for other operations such as pumps, valve actuation and other purposes if the refrigerator utilizes electricity or other fuel for heating they fall under second categories.

Refrigerators are also operated by different types of cycle such as absorption, adsorption or sorption depending upon effectiveness, cost and simplicity.

II. REVIEW OF WORK CARRIED OUT

F. Gutirttrz

Solar powered refrigerators can fall in to two categories as the refrigerator is totally operated by solar power or a part of the total energy requirements (corresponding to heat). Generally partial electric power is required for operating pumps, fans, power controls etc.However, for the remote areas with no electricity supply it was important for the refrigerator to be fully autonomous. But in that case the cost of solar refrigerator would rise than average refrigerator due to the utilization of PV panels. Hence he performed this experiment to check the feasibility of the solar refrigerator that too with least supervision using flat plate solar collector.

He used an adsorption – diffusion cycle to avoid the use of pump for pumping in a typical ammonia-water absorption cycle from absorber to the generator. For this the pressure required is about 2 to 15 bar.

For prototype he used a 250-liter capacity used refrigerator. A Platen-Munters system was utilized. In this refrigeration system the refrigerator was activated by a gas or kerosene burner. A high temperature, flat plate solar collector was installed instead of the burner and some minor modifications were done in the system. The collector was supplied with adequate quantities of ammonia to the condenser and a weak solution to the absorber.

The schematic diagram of the refrigerator is shown below.

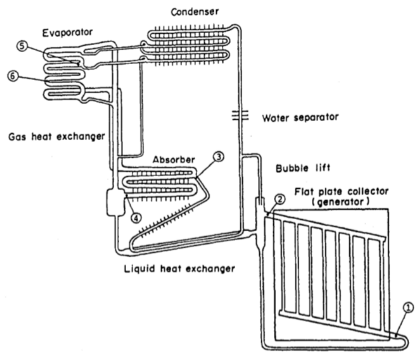


Fig. 1. Schematic view of the solar refrigerator. The temperature measuring points are indicated with numbers. 1 = collector inlet, 2 = collector outlet, 3 = absorber liquid entrance, 4 = absorber liquid exit, 5 = evaporator inlet, 6 = evaporator middle section.

The total collector area was 2.5m^2. The observed conditions were as follows

1. Generator temperature- 105 °C.
2. Concentration of strong and weak solution- 42% and 39.5%.

3. Circulation rate – 23.2 (quantity of weak solution produced perliberated ammonia unit).

The performance can be seen in following graph-

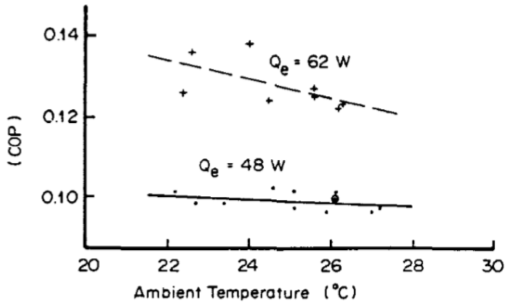


Fig. 3. COP variation with ambient temperature when operating in the solar simulator (I = 850 W m^{-2}).

So at general a COP value of 0.11 was obtained under the constant irradiance of 850 W/m^2[1].

F. Buchter-

He tested an adsorption pair of carbon and methanol operated solar refrigerator. The refrigerator had an adsorber area (area) of 2m^2. The condenser is cooled by air through natural convection. Evaporator is filled with 40L if water that can freeze into ice and that can be used for cold storage off cold cabinet of volume 440L.

For the irradiance of 19-25 MJ/m^2 to 25MJ/m^2 the solar refrigerator was tested and the ambient temperature was averagely 27.4 °C at sunrise and 37.4 °C at mid-afternoon.
Buchter found that two type of sorption system can be solar powered for better refrigeration-

1. Chemical Reaction Solar Refrigerators.
2. Adsorption Solar Refrigeration.

For the performance of solid sorption systems, the largest coefficient of performance was between 0.10-0.12 for the adsorption system of zeolite + water and carbon + methanol. Alsomethanol can easily evaporate at temperatures below 0 °C, so that ice can be produced to act as the cold storage for night.

For the machine tested in Ouagadougou the technique of single-glazed flat-plate selective solar collector was utilized. Cold chamber could be chilled up to 5 C by cold thermal storage during the next day or up to 3 days for cloudy weathers. The fig 2 shows the schematic diagram of the apparatus [2].

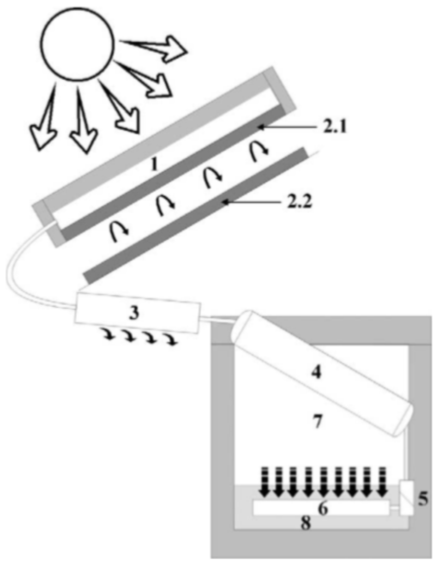


Fig. 2. Schematic of an adsorptive solar refrigerator: solar collector-adsorber (1), ventilation dampers in closed position (2.1), ventilation dampers in open position (2.2), condenser (3), graduated bottle (4), check valve (5), evaporator (6), cold cabinet (7), ice storage (8).

Anyanwu2003-

Solid absorbent like zeolites, activated carbon, silica gel with different refrigerant such as water, fluorocarbon, alcohol, ammonia are used to create a solid absorbent refrigeration cycle powered by solar energy and has no moving parts. The adsorbents adsorb the fluids naturally and desorbs their vapors when heated. Hence solar energy is utilized for heating.

When zeolite is used with water as refrigerant Tchernev fabricated and tested a 100dm^3 refrigerator. The collector/generator/absorber had 5cm thick 50 kg of zeolite per square - meter. For the net solar energy input of 6kWh, the refrigerator produced 900 Wh ofcooling per square meter of collector area. For this the coefficient of performance (COP) was 0.15. The ice production rate is between 3.71-8.14 kg/m^2 [3].

C. Hildbrand –

An adsorption pair of silica gel + water was used to create an adsorptive solar refrigerator with no moving parts. A flat plate collector with cylindrical pipes, of area 2 m^2 was used. The condenser was air cooled by natural convection and the evaporator contained 40-liter of water that can be freezed and can be used as cold storage.

The first test showed a gross solar cooling coefficient of performance of 0.19. On other tests the COP_{sr} varies between 0.10 and 0.25 with a mean value of 0.16. That COP had the highest value till date that Hildbrand performed the experiment. The adsorption refrigerator is developed to be used in hot regions generally with no electricity supply.

The refrigerator being perfectly autonomous is solar powered by 24-hour cycle . Here is the photograph and schematic diagram of the refrigerator [4].

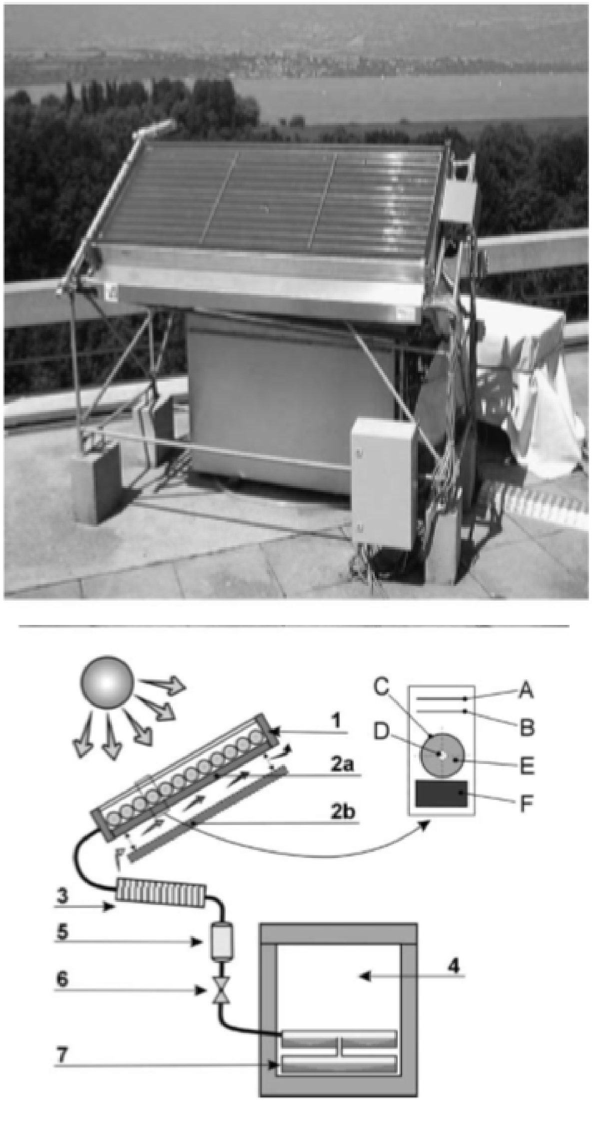


Fig. 2. Photograph and plan of an adsorptive solar refrigerator: solar collector–adsorber (1) with detail: glass cover (A), Teflon® film (B), tube covered with selective surface (C) and internally layered with Papyex®, central tube for vapour transport (D), silicagel bed (E), thermal insulation around the collector (F); ventilation dampers (2) closed (2a) and open (2b), condenser(3), cold cabinet (4), graduated tank (5), valve (6), evaporator and ice storage (7).

M. Li –

A flat-plate solid-adsorption refrigeration ice maker was built for demonstration purposes and tested. The refrigerator works on methanol used as the refrigerant and activated carbon as the adsorption medium. The adsorbent bed was constructed of two flat plate collectors with net surface area of 1.5m^2. The solar irradiance was simulated by quartz lamp for testing and important paramers such as temperature, pressure etc of each subsystem were handled by a computer.

Wang pruposed a new method of using solar energy to provide both heating and cooling by a hybrid system. An electic heater was fabricated to simulate solar irradiance was succesfully fabricated. Here is the schematic diagram of the solar ice maker-

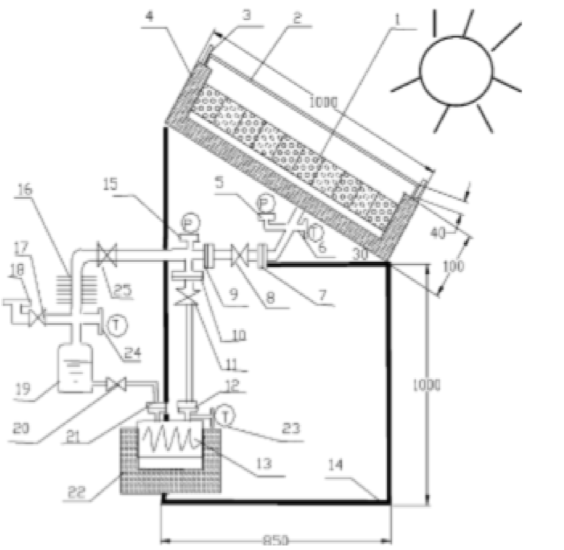


Fig. 1. Schematic of the solar solid-adsorption ice maker: (1) adsorbent bed; (2) glass cover; (3) damper; (4) insulated material; (5,15) pressure gauges; (6,23,24) temperature gauges; (7,9,10,12) connecting flanges; (8,11,17,20,25) valves; (13) evaporator; (14) bracket; (16) condenser; (18) refrigerant input pipe; (19) reservoir; (22) ice box.

This machine can produce upto 4–5 kg of ice after receiving 14–16 MJ of radiation energy with a surface area of 0.75 m^2, while producing 7– 10 kg of ice after receiving 28–30 MJ of radiation energy with 1.5 m^2 of area. Those were most prominent results for an solar powered icemaker so far [5].

C.O. Rivera-

Rivera performed experiment to represent the performance of an intermittent absorption refrigeration system. The refrigerator was operated by ammonia-lithium nitrate mixture. Condenser, generater-absorber, valve and an evaporater are the primary components of refrigeration cycle. For generator – absorber a compound parabolic concentrator with glass cover was used. A rectifier was used for the seperation of lithium nitrate mixutere as lithium nitrate dosent evaporate. The CPC efficiency varied betweeen 0.78 to 0.33 depending upon the time of the day.

At generation temperature of about 120°C the system could produce upto 11.8kg of ice, showed the result. The overall efficiencies of the system were between 0.15 and 0.4 depending upon the geration and condensation temperature.
Following figure shows the schematics of the refrigeration system.

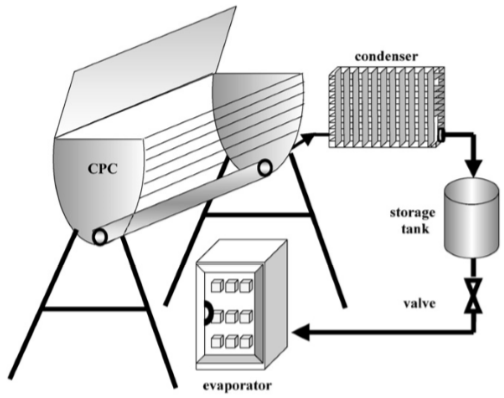


Fig. 1. Schematic diagram of an intermittent solar absorption refrigeration system.

During day the ammonia-lithium nitrate mixture is heated in CPC until it reaches its saturation temperature. Then the ammonia vapours are condensed in condensor by air or water and then stored in a tank. In night the ammonia passes through the spread wall and hence gets its temperature and pressure reduced. Hence the refrigeration occures in avaporation in the evaporator. In low ambient temperature the generator-absorber temperature and pressure is reduced while the ammonia absorbs heat in evaporator has increase in temperature and pressure, in this way the pressure is inverted. Hence the ammonia vapours returns to the generator-absorber where it is absorbed by the strong solution starting the cycle again.

Following graphs shows some results of the experiment [6]

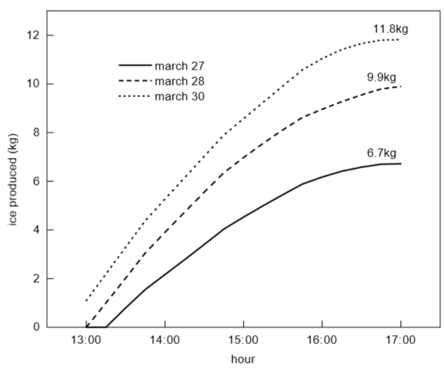


Fig. 8. Ice produced by the solar refrigeration system on three different days of March 2001.

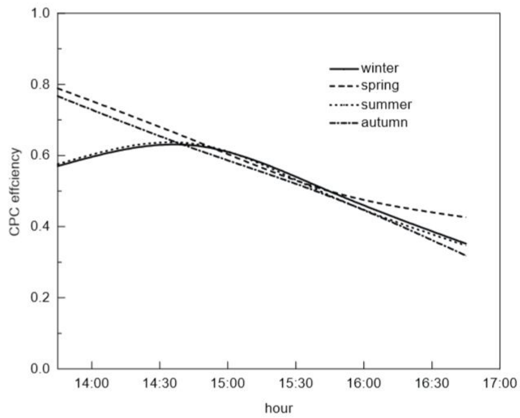


Fig. 9. Efficiency of the CPC during the day for different seasons of 2001.

L.L. Vasiliev-

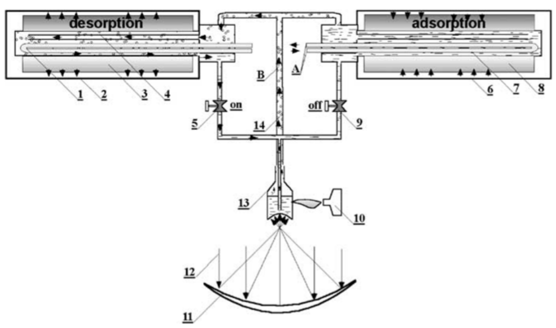
Vasiliev performed this experiment to design a sorption refrigerator in which physical adsorption and chemical reactions are used simultaneously for a heat and cold generation.

The main components were – Solar collector, adsorbed natural gas vessel (ANG) and compact and portable refrigeration system. The refrigeration system had f two small adsorbers with heat pipe heat recovery system. For sorbent bed an active carbon fiber "Busofit" saturated with different salts (CaCl2, BaCl2, NiCl2) was used, while ammonia was the refrigerant. For backup methane gas burner was used so as to provide thermal energy in improper solar conditions.

The sorbent beds are used as a single storage systems with physical sorption (active carbon fiber"Busofit"),complex compound single stage systems with physical sorption and chemical reactions (active carbon fiber "Busofit" + CaCl2), or a complex compound two stage systems ("Busofit" + BaCl2 and "Busofit" + NiCl2) with the internal and external heat recovery. The application of a constant source of energy (∼1 kW) with special valves to heat and cool the sorbent beds alternatively increaseaCOPR of the system, to compare with the application of periodically switched on and off sources of energy.

The solar concentrator was made from a aluminium plate tray, an parabolic antenna with 1.8 m diammeter. The degree of reflection of the concentrator was 0.68 (mirror).

The following diagram shows schematics of the system



Solar/gas refrigerator has a solar receiver 1 gas flame system to heat the water boiler 10, two sorbent bed canisters 2 and 6, connected by the heatrecovery loop A, two phase heat transfer system B (vapor-dynamic thermosyphon), one condenser 5 (Fig. 2) with low temperature two evaporators 10, 16 and two cold panels 11, 14 (loop heat pipes) heated by the air.

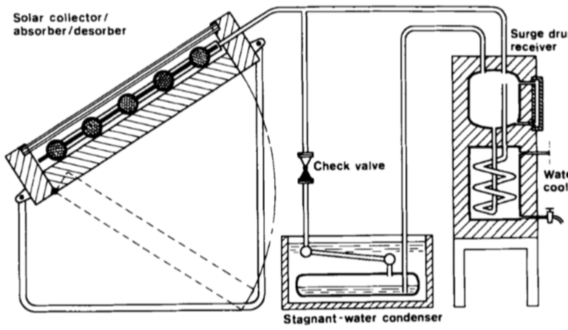
Here is actual photograph of the refrigerator-

The refrigeration occures by the adsorped ammonia vapours. The COP^R of the tested refrigerator was near about 0.43, but the calculations for recombined refrigeration and power-generation system operating on gas/solar energy with heat recovery shows that a COPR of 0.75 is achievable [7].

P. Worseschmidt –

He developed an solar powered refrigeration cycle driven by solid-absorption of $CaCl_2$ and NH_3. From a survey at paris it was found that calcium chloride as absorbent and ammonia as refrigerant was best suited for the adsorption refrigeration. With this combination he could easily attain the evaporation temperatures os 10 to 15°C.

Following diagram shows the schematics of the refrigerator.



There was 2 m^2 of collector area of each of 2 units. The liquid ammonia is stored in the receiver at the bottom of the basin. The check valve then closes and the liquid ammonia is driven bythe saturation pressure in the receiver to the combined receiver and surge drum. The evaporation temperature of 10°C approximately is achieved. Ice is frozen at evaporator coil aftre the water has been cooled to 0°C, this acts as cold storage during day [8].

III. CONCLUSION

From this review we will get to find various attempts to improve solar refrigerration system. We easily get to see and compare the performance of this refrigerators. Still there is plenty of work that can be done to improvise effectiveness of the solar refrigerators created so far

REFERENCES

[1] F. GUTIERREZ "BEHAVIOR OF A HOUSEHOLD ABSORPTION-DIFFUSION REFRIGERATOR ADAPTED TO AUTONOMOUS SOLAR OPERATION" Solar Energy Vol. 40, No. I. pp. 17-23, 1988
[2] F. Buchter "An experimental solar-powered adsorptive refrigerator tested in Burkina-Faso" International Journal of Refrigeration 26 (2003) 79–86.
[3] E.E. Anyanwu "Review of solid adsorption solar refrigerator I:
an overview of the refrigeration cycle" Energy Conversion and Management 44 (2003) 301–312
[4] Catherine Hildbrand, Philippe Dind, Michel Pons, Florian Buchter "A new solar powered adsorption refrigerator with high performance" solar energy 77 (2004) 311-318.
[5] M. Li, R.Z. Wang, Y.X. Xu, J.Y. Wu, A.O. Dieng "Experimental study on dynamic performance analysis of

a flat-plate solar solid-adsorption refrigeration for ice maker" Renewable Energy 27 (2002) 211–221

[6] C.O. Rivera, W. Rivera "Modeling of an intermittent solar absorption refrigeration system operating with ammonia–lithium nitrate mixture" Solar Energy Materials & Solar Cells 76 (2003) 417–427

[7] L.L. VASILIEV,D.A. MISHKINIS, A.A. ANTUKH AND L.L. VASILIEV JR. "Solar-Gas Solid Sorption Refrigerator" Adsorption 7: 149–161, 2001

[8] P. Worsøe-Schmidt "Solar refrigeration for developing countries using a solidabsorption cycle" International Journal of Ambient Energy, 4:3, 115-124 (2011)