International Journal of Research and Review
[Indexed, Peer-Reviewed Journal]
Volume 12; Issue: 11; November 2025
Website: www.ijrrjournal.com
Research Paper
E-ISSN: 2349-9788; P-ISSN: 2454-2237

Design and Construction of Absorption Solar Refrigerator

J. C. Echewodo, B.C. Anusionwu, E.C. Mbamala, J. A. Ezihe, E. Onuoha

Department of Physics, Federal University of Technology, P.M.B. 1526, Owerri, Nigeria

Corresponding Author: J. C. Echewodo

DOI: https://doi.org/10.52403/ijrr.20251121

ABSTRACT

This study contributes an important knowledge and method in the development, fabrication and application of absorption solar refrigerator as a better alternative to the commonly used compressor refrigerators in the rural areas where there is epileptic power supply or power supply is not available. This work focuses on the design and construction of absorption solar refrigerator. The refrigerant used was 400 g activated charcoal and 250 ml methanol. Consequently, the design was fabricated using locally sourced materials. It was designed to use direct solar radiation as its power source (parabolic solar concentrator). It also used heat energy from a kerosene stove as alternative power source. The absorption solar refrigerator was designed to be simple, handy and readily handled by anyone in case of malfunctioning. Though, the main limitations of the absorption solar refrigerator were the long time it used to achieve cooling and less ease of relocation. Generally, it is very efficient as its calculated coefficient of performance (COP) is 0.185 which compared favourably well with the literature value of 0.100 - 2.00. The minimum evaporator temperature achieved by the refrigerator was 5°C after 10 hours.

Key words: Parabolic solar concentrator, absorption refrigerator, coefficient of performance

INTRODUCTION

According to the International Institute of Refrigeration (IIR), a 15% global estimate of all power produced is expected to be utilized for various types of refrigeration and air conditioning activities.[1] There is a basic trend toward a constant growth in the global demand for freezers and air conditioners.[2] Absorption Solar refrigerators are alternatives to compressor refrigerators in the rural areas where there are no electricity or the supply of electricity is epileptic. This is because it utilizes direct solar radiation as its power source. Solar energy may be utilized to power refrigeration systems by combining current technology to turn it into heat or electricity. [3] A number of nations; Australia, Spain, and the USA, implemented solar-powered refrigeration systems later on a global scale. For air conditioning systems, the majority are thermally driven absorption systems. Globally, individuals are more inclined to select a refrigerator and vapour compression air conditioner when there is reliable electrical grid available to them.

Research and development on solar thermal powered refrigeration systems was significantly lower prior to the energy crisis of the 1970s. Consequently, devices for compressing vapor that are powered by electricity have become rather important in the market. Photovoltaic (PV) technology was not as common then as it is now, and it was also more expensive. [4] Solar energy has once again gained popularity as a renewable energy source because of the lack of electricity in some areas, particularly following the energy crisis of the 1970s. Along with an increase in solar cooling research, there has been a tremendous growth in solar energy research and development.

Adel and Ahmed in 2010 analyzed experimental work on the use of Direct Solar Energy in Absorption Refrigeration, employing aqueous ammonia of mass fraction 0.45 (NH_3-H_2O system). The objective of their work was to study the coefficient of performance for solar absorption refrigeration by using direct solar energy. They made use of intermittent absorption cycle. The results showed that the maximum generator temperature was (92°C - 97°C) during June 2009, and the minimum evaporator temperature was (5°C - 10°C) for aqua ammonia system. It was, also, found that the coefficient of performance, cooling ratio and amount of cooling obtainable increased with increasing maximum generator temperature and pressure. While the minimum evaporator temperature and concentration decreased with increasing maximum generator temperature and pressure. The coefficient of performance was (0.1096 - 0.2396). [5] Ugwu (2012) designed, fabricated and analyzed the performance of a Micro-Absorption Refrigerator. The refrigerant used was ammonia gas. Its calculated coefficient of performance (C.O.P) is 1.21. The power source used by the refrigerator is electricity. Ugwu recommended that other sources of powering the machine (solar, waste, heat, etc) should be encouraged for further studies to improve its operation and performance. [6] Rahman *et al*, (2006) studied, designed and constructed a solar powered absorption refrigeration system. The system used solid absorption pair of activated charcoal and methanol, 2 kg activated charcoal and 500 ml of methanol. A simple flat plate collector with an exposed area of 0.4 m^2 was employed to produce cooling. The generator was heated by steam from the water stored in the flat plate collector. The generator was heated to a maximum temperature of 82°C and minimum temperature obtained at the evaporator was 16°C for the pair of activated charcoal and methanol. Rahman encountered problem of leakage which affected the operation of the system. [7] Anyanwu E.E. and Ezekwe C.I. (2003) Designed, constructed and tested a solid absorption solar refrigerator using activated carbon/methanol, as adsorbent/adsorbate pair and flat plate solar collector as the power source. In their work, a simple absorption device received heat from a solar boiler, which led to chilling. The refrigerator yielded evaporator temperatures ranging over 1.0–8.5 °C from water initially in the temperature range 24–28 °C. The maximum possible net solar COP was found to be 0.093. [8]

In this work therefore, a solar absorption refrigerator was designed and constructed integrating solid absorbent for optimum performance as developed by Adel *et al (2010)* for absorption refrigerator. [5] The work also sought to improve the work of Ugwu [6] and Rahman *et al* [7] on the absorption refrigerator by using solar energy harvested with a parabolic reflector as the source of power, condenser cooled in a water bath, 400g activated charcoal and 250ml methanol as refrigerant.

MATERIALS AND METHOD

Figure 2.1 shows the schematic diagram of absorption solar refrigerator showing the main components of the refrigerator. The solar refrigerator has six main parts: Heat source, Cabinet, Generator, Condenser and Evaporator. To fabricate these parts the following materials were used during this work and they were sourced from the local market.

i) Activated Charcoal ii) Methanol iii) copper pipe iv) Aluminum sheet v) Brass valve vi) Plane Mirror, vii) thermometer viii) calorimeter ix) beakers x) stop watch xi) spring balance xii) kerosene stove

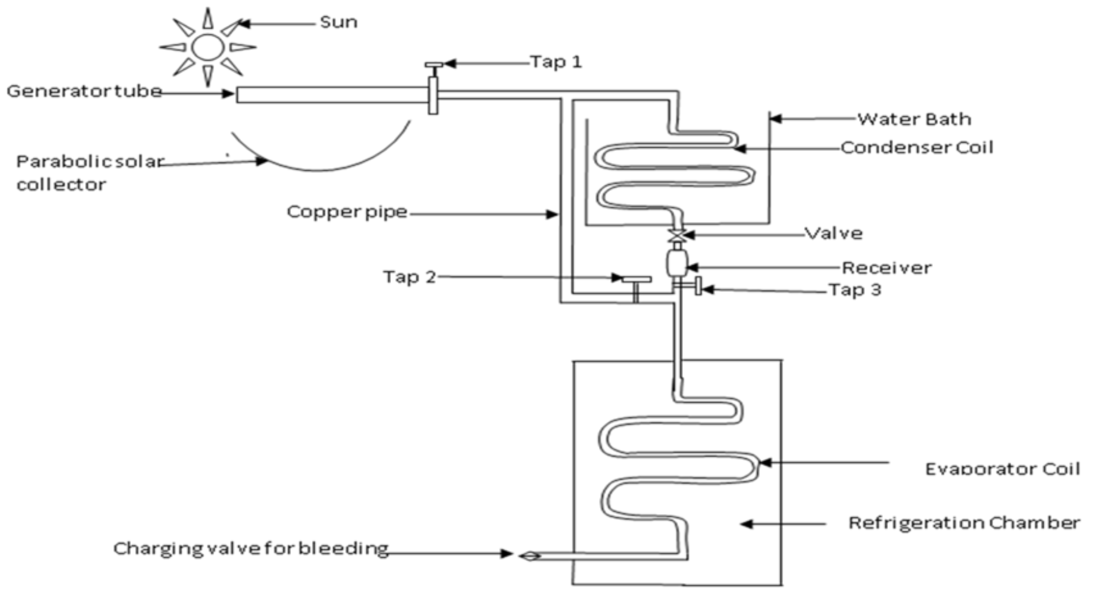

Fig. 2.1: Schematic diagram of solar absorption refrigerator.

The system used a generator containing 250 ml methanol and 400 g activated charcoal. The heat source is a parabolic solar collector. A parabolic solar collector was chosen for this design because it has axial focus while parabolic dish collectors have point foci. Because of its axial focus, it is easier to track the sun. The solar collector was made of a parabola of large diameter of 160 cm and small diameter of 24 cm. A reflecting surface was used to cover the surface of the parabola. The reflecting surfaces used were plane mirrors of dimension 2.5 cm x 2.5 cm. The plane mirrors were held to the surface of the parabola with glue. The surface area of the collector is 1.0 m^2. The focus of the collector was determined using the formula

$$F = \frac{D^2}{16d} \qquad 2.1$$

where D and d, are the large and small diameter respectively. [9]

The fabrication process of the cabinet (casing) involved the sourcing of the steel materials, the welding process and furnishing of the steel materials. The dimensions of the casing were as follows: length 31.0cm, height 30cm and breadth 26cm.

The evaporator was made of aluminum plate, a small rubber cooler and copper pipe of length 500cm and internal diameter of 1.0cm. The condenser was made with copper pipe of length 400cm, and an internal diameter of 1.0cm. The copper pipe is coiled and inserted into a water bath.

The parabolic solar collector was used to heat the mixture (activated charcoal and methanol) in the generator. The methanol vaporized and was driven off on heating. A condenser at the top of the system condensed the methanol vapor into a liquid. The liquid flowed by gravity into the liquid receiver and then into the evaporator. As the system cooled, the pressure dropped causing the methanol in the evaporator to boil (Flash off) and absorb heat. The cycle was completed when vaporized methanol was re-absorbed into the generator. Figure 2.2 is the photo plate of the absorption solar refrigerator.

The refrigerator was operated in continuous mode and in intermittent mode. Continuous mode means that heating and refrigeration was taking place. This mode was achieved by opening taps 1, 2 and 3. (Fig. 2.1). Intermittent mode means that refrigeration starts when the heat source is removed (Post cooling). [10]

Fig 2.2: Photo plate of the absorption solar refrigerator.

To determine the quantity of heat energy generated by the kerosene stove per second (power in watts), a copper calorimeter was weighed when empty and the mass (M_c) recorded. Then, the weight of the calorimeter when filled with water was weighed and the mass of water (M_w) determined and recorded. The initial temperature of the water in the calorimeter (T_i) was measured and recorded. The calorimeter with the water was heated on the stove till the water just began to boil. The final temperature of the boiling water (T_f) and the time (t) taken for the water inside the calorimeter to boil were read and recorded.

The quantity of heat generated by the stove was estimated using equation 2.2.

$$Q = M_w C_w (T_f - T_i) + M_c C_c (T_f - T_i) \qquad 2.2$$

where C_c is the specific heat capacity of copper and C_w is the specific heat capacity of water. Hence, the estimated power (P) of the stove was obtained using equation 2.3.

$$P = \frac{Q}{t} \qquad 2.3$$

The above procedure was repeated to determine the power of the solar collector.

RESULTS AND DISCUSSION

Figure 3.1 shows the results obtained when the absorption solar refrigerator was operated using a kerosene stove as the heat source and 400g activated charcoal and 250ml methanol used as the refrigerant in continuous mode. The minimum evaporator temperature recorded was 16°C. It was observed that when the kerosene stove was operated at a higher power (56.95 watts) the minimum temperature of the evaporator T_e was observed to be 16°C. But when the kerosene stove was operated with lower power (40.68 watts) it was observed that the minimum temperature of the evaporator was 19°C, this occurred after four hours. From the results it can be seen clearly that when the quantity of heat energy supplied by the stove was high, a lower evaporator temperature of 16°C was obtained after four hours. The evaporator temperature remained constant even when the supply of heat was maintained.

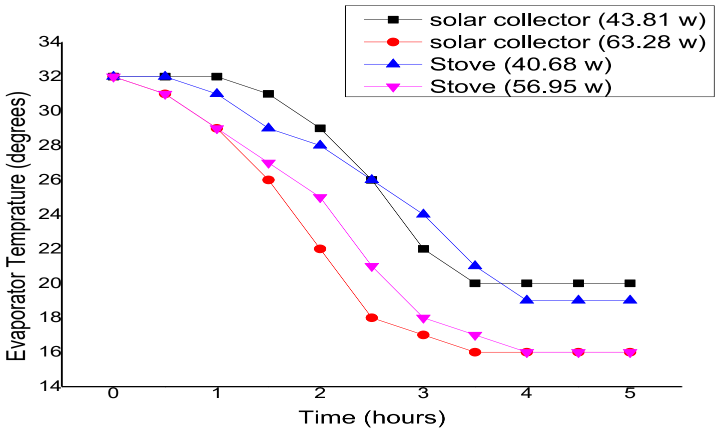

Fig. 3.1: Variation of evaporator temperature with refrigeration time using stove or solar collector as heat source in continuous mode.

When the absorption solar refrigerator was operated in continuous mode with solar collector (solar heater) as the heat source, higher amount of heat energy was generated, and the average power was 63.28watts. The refrigerator was exposed to heat source from solar radiation for 5 hours (11.00 am – 4.00 pm). It was observed that the minimum temperature of the evaporator was 16°C. The time taken to achieve this temperature reduction was three and half hours. The refrigerator was also operated when the solar collector produced an average lower power of 43.81watts. This was achieved by putting the generator a little away from the focus. The minimum temperature of the evaporator obtained under this condition of lower power of heat source was 20°C and it occurred after 4hours. This result shows that this refrigerator can be operated effectively with kerosene stove, especially at night when there is no solar radiation available.

Figures 3.2 shows the results obtained when the absorption solar refrigerator was exposed for (1-5) hours to solar radiation under post cooling mode. Post cooling is the cooling effect obtained when the heat source has been removed. It was observed that the evaporator temperature dropped from 29°C to 5°C. This result shows that the solar absorption refrigerator is more efficient when it is operated in post cooling mode. This result is in line with the work of Anyanwu and Ezekwe [8] which showed that post cooling absorption is better than continuous absorption. This result is obtained because when the heat source is removed, the pressure at the generator drops, then the methanol at the evaporator can easily vaporize and be absorbed by the activated charcoal at the generator.

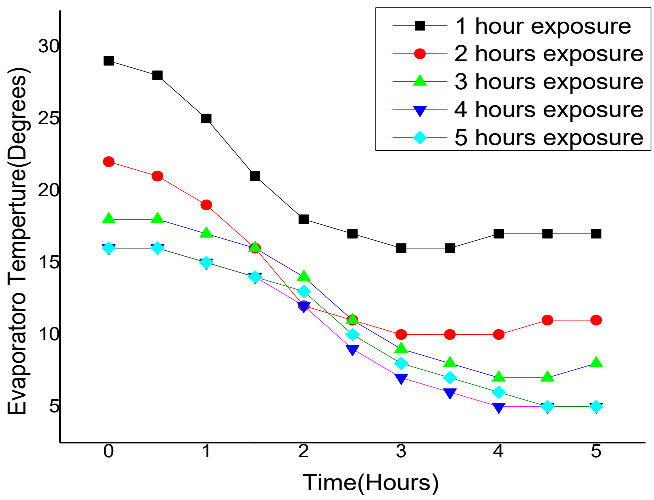

Fig 3.2 Variation of evaporator temperature with refrigeration time using stove or solar collector as heat source in post cooling mode.

Coefficient of performance of a solar-absorbing refrigerator is calculated using equation 3.2. [17]

$$COP = \frac{T_e}{T_c - T_e} \qquad 3.2$$

where T_e is the temperature of the evaporator and T_c is the temperature of the condenser. Measured value of T_e = 5°C and measured value of T_c = 32°C.

Hence,

$$\text{COP} = \frac{5}{32-5} = \frac{5}{27} = 0.185 \approx 0.19 \qquad 3.3$$

The solar absorption refrigerator's highest coefficient of performance, or C.O.P., was determined to be 0.19. This is consistent with the works. [12] - [16]
The Coefficient of performance (C.O.P) is used to represent the output to input ratio of the absorption refrigeration system and gauge its performance. [11] It has been shown that the standard normal Coefficient of Performance (COP) of an absorption refrigerator ranges from 0.100 to 2.00. [12] - [16]

CONCLUSION

A solar absorption refrigerator designed and constructed, integrating solid absorbent, solar energy harvested with a parabolic reflector as the source of power, condenser cooled in a water bath with 400g activated charcoal and 250ml methanol as refrigerant has shown relative efficiency in operation having a calculated coefficient of performance of value 0.185 which is higher than that of Anyanwu and Ezekwe [8] and within the literature value range of 0.10 – 2.00.

AUTHORS' CREDIT STATEMENT

J.C. Echewodo: Experimental Design, Material Synthesis, Result analysis, Writing Original draft. B.C. Anusionwu: Supervision
E.C. Mbamala: Experimental Design, Result Analysis, Manuscript Writing
J.A. Ezihe: Experimental Design, Result Analysis, Manuscript Writing.
E. Onuoha: Experimental Design, Result Analysis, Manuscript Writing.

Declaration by Authors

Acknowledgement: We appreciate support and assistance that we received from our colleagues.
Source of Funding: None
Conflict of Interest: I declare no known competing interest or personal relationship that could influence the work reported in this paper

REFERENCES

1. Assunta N, Wolfram S, Alexander T, etal Task 38, Solar Air- Conditioning and refrigeration. Monitoring Procedure for Solar Cooling Systems. A Joint technical report of Subtask A and B (D - A3a/D-B3b). Solar Heating and Cooling programme. International Energy Agency. 2011;
2. Christopher J.K. Managing Frozen Foods. CRC Press WoodHead Publishing Limited, Cambridge England. 2000.
3. Kalogirou, S.A. Solar Thermal Collectors and Applications. Progress in Energy and Combustion Science. 2004; 30(3): 231 – 295. Available online at www.sciencedirect.com.
4. Wimolsiri, P. Solar – Driven Refrigeration Systems with Focus on the Ejector Cycle, PhD Thesis, Division of Applied Thermodynamics and Refrigeration Department of Energy Technology, School of Industrial Engineering and Management Royal Institute of Technology, KTH. 2006.
5. Adel A, Ahmed D. N. The Use of Direct Solar Energy in Absorption Refrigeration Employing NH_3 – H_2O system. Iraqi Journal of Chemical and Petroleum Engineering. 2010; 11 (4): 13-21.
6. Ugwu, H. U. Design, Fabrication and Performance Evaluation of a Micro-Absorption Refrigerator. International journal of Engineering and Technology. 2012; 2(11): 30-40
7. Rahman M.H., Akhanda A.R. Sadrul A.K. Study, Design and fabrication of a solar powered absorption refrigeration system. ISESCO Science and technology. 2006; vision 2, 10-13
8. Anyanwu E.E, Ezekwe C.I. (2003). Design, Construction and Test Run of a Solid absorption Solar Refrigerator using using activated carbon/methanol, as adsorbent/adsorbate pair and flat plate solar collector as the power source. Energy conversion and management. 2003; 44 (18): 2879-2892.
9. Kharagpur, I.T. Lesson 14 Vapour Absorption Refrigeration Systems. Version 1 ME, 1 – 20.
10. Tangka J.K, Kamnang N.E. Development of a simpleintermitten absorption solar refrigeration system. International journal of low carbon technology. 2006; 128-138.
11. Ursual E, Dirk P. Design and Performance of a Solar Power Absorption Cooling

Systems in Office Buildings, Energy and Buildings. 2009; 41(1): 81-91.
12. Žanis, J. Liene, K., Imants, Z. Comparison of Solar Collectors and Conventional Technologies Used for Water Heating in Latvia. Engineering for Rural Development. 2007; 35-40.
13. Divine N. E, Claude V.A, Armand P. N. Design and implementation of solar powered mini refrigerator using thermoelectric cooler module. Energy2021-Conference. E3S Web of Conferences 354, 01007 (2022)
14. Khurmi R.S, Gupta J.K. A Textbook of Refrigeration and Air- conditioning, Reprint Edition, printed by Rajendra Ravindra Printers and Published by Eurasia Publishing House (P) Ltd, New Delhi, India. 2005; 1-37.
15. Sharma SD, Iwata T, Kitano H, et al. Thermal Performance of solar cooker based on an evacuated tube solar collector with a PCM storage unit, Solar Energy. 2005 78(3); 416-426. DOI:10.1016/j.solener.2004.08.001
16. Dorgan C.B, Dorgan C.E, Leight, S.P. Application Guide for Absorption Cooling/Refrigeration using Recovered Heat, Published by American Society of Heating, Refrigerating, and Air-conditioning Engineers (ASHRAE), Atlanta, Georgia, USA. 1995; 1- 2
17. Anadi M, Didarul A, Mohammade A. I. Design and construction of a solar driven Ammonia Absorption Refrigeration System. International journal of scientific and research publications. 2015; 5(10).

How to cite this article: J. C. Echewodo, B.C. Anusionwu, E.C. Mbamala, J. A. Ezihe, E. Onuoha. Design and construction of absorption solar refrigerator. *International Journal of Research and Review*. 2025; 12(11): 188-194. DOI: *https://doi.org/10.52403/ijrr.20251121*

******