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# COP ANALYSIS OF A VAPOUR ABSORPTION REFRIGERATION CYCLE POWERED BY A SOLAR SYSTEM

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## ABSTRACT

The effectiveness of a vapour absorption refrigeration system which utilizes a binary mixture of ammonia and water, and sourced its power supply from solar energy was analyzed in this paper. Four different cases were considered, namely different evaporating temperatures ($267\mathrm{K} \leq T_e \leq 283\mathrm{K}$) but fixed generator and absorber temperatures; different absorber temperatures ($303\mathrm{K} \leq T_a \leq 313\mathrm{K}$) but fixed generator and evaporator temperatures; different generator temperatures ($343\mathrm{K} \leq T_g \leq 388\mathrm{K}$) but fixed evaporator and absorber temperatures; and different generator temperatures ($343\mathrm{K} \leq T_g \leq 388\mathrm{K}$), fixed evaporator temperature but different absorber temperatures.

## KeyWords
Absorber, Generator, Evaporator, Refrigeration, Binary

## Introduction

Solar energy is utilized for many purposes such as irrigation, lighting, refrigeration, air conditioning, etc. In view of awareness of limited reserves of fossil fuel, there is need to put in place systems that are powered by solar energy [1]. In places where there is epileptic or unreliable supply of electricity, there is limitation to application of refrigeration for storage of perishable items. In such situations, solar-powered refrigerating systems will be useful because it does not depend on electricity or other sources of energy.

Refrigeration has been achieved by vapor compression refrigeration system (VCRS). Aside the noise made by the compressor of vapor compression cycle when it is in operation, the liquid traces of its refrigerant may damage its compressor [2]. An alternative refrigeration system which carries out its operation by utilizing a binary solution can be used for refrigeration. This alternative cycle is known as vapour absorption refrigeration system (VARS). Unlike the VCRS, the liquid traces of refrigerant in VARS constitute no danger. Also, wear and tear that occurs in VARS is less than that in VCRS. VARS can make use of solar energy or waste heat for refrigeration, air-conditioning, etc. [3].

In bid to achieve refrigeration without encountering disturbance arising from electricity supply, researches have been carried out on solar-powered vapour absorption refrigeration system. Different ammonia-salts binary mixtures for use in vapour absorption refrigeration systems using low grade thermal energy such as solar energy was studied by Tyagi [4]. The mixtures were compared on the basis of coefficient of performance and tonne of refrigeration for evaporator temperature of 5$^{o}$C and absorber temperature of 40°C by evaluating the thermodynamic properties of the mixtures. It was discovered that the mixtures had a good potential as binary mixtures for vapour absorption.

A vapour absorption refrigeration system was designed and fabricated by Muthu et al. [5], using R134a-DMAC as working fluid and hot water as heat input. Experimental studies on the developed system were performed to evaluate the effects of various operating parameters on the systems performance. It was observed that sink and source temperatures play an important role in performance of the system. A coefficient of performance of up to 0.45 was attained.

Karamangil al. [6] presented thermodynamic analysis of single-stage absorption refrigeration system using different refrigerant–absorbent pairs and also compared the theoretical performances of the cycles. The results showed that the values of the coefficient of performance of the cycles increased with increasing generator and evaporator temperatures, but decreased with increasing condenser and absorber temperatures.

The feasibility of the solar powered vapour refrigeration system was proved by Bajpai [7] in his design work on solar powered vapour absorption system. The COP of the system was 0.58 and it was established that a solar powered vapour refrigeration system can be usefully employed for cooling purposes.

Modeling and experimental analysis of generator in vapour absorption refrigeration system was performed by Vazhappilly et al. [8] in which the heating coil generator system of the absorption refrigeration system was replaced by plate frame type heat exchanger, there by utilizing the exhaust gases of an internal combustion engine.

An absorption refrigeration refrigerating unit was fabricated with a solar concentrating collector by Johnson and Gowda [9]. It was observed that a cooling effect was obtained at the evaporator and that the absorption refrigeration can offer solutions to refrigeration requirements.

In the present work, the effectiveness, otherwise known as coefficient of performance (COP), of a vapour absorption refrigeration system which utilizes a binary mixture of ammonia and water, and sourced its power supply from solar energy was analysed.

## Schematic Assembly of Solar-Powered Vapour Absorption Refrigeration System

The assembly of the solar-powered ammonia-water vapour absorption refrigeration system is shown schematically in **Fig. 1**. Ammonia is used as the refrigerant and water is used as the absorbent. As shown in the figure, low temperature and low pressure ammonia enters the evaporator and vaporizes by producing useful refrigeration. From the evaporator, the low temperature, low pressure ammonia vapour enters the absorber where it comes in contact with a solution of ammonia and water that is weak in ammonia. The weak solution absorbs the ammonia and becomes strong in ammonia. The heat of absorption is rejected to the external heat sink.

The solution that is now rich in ammonia is pumped to high pressure using a solution pump and fed to the generator. In the generator, heat at high temperature is supplied, which results in generation of ammonia vapour at high pressure. This high pressure vapour is then condensed in the condenser by rejecting heat of condensation to the external heat sink. The condensed ammonia liquid is then throttled in the expansion device and is then fed to the evaporator to complete the refrigerant cycle. On the solution side, the hot, high-pressure solution that is weak in ammonia is throttled to the absorber pressure in the solution expansion valve and fed to the absorber where it comes in contact with the ammonia vapour from evaporator. Thus, continuous refrigeration is produced at the evaporator, while heat at high temperature is continuously supplied to the generator. Heat rejection to the external heat sink takes place at absorber and condenser. A small amount of mechanical energy (which may be negligible) is required to run the solution pump.

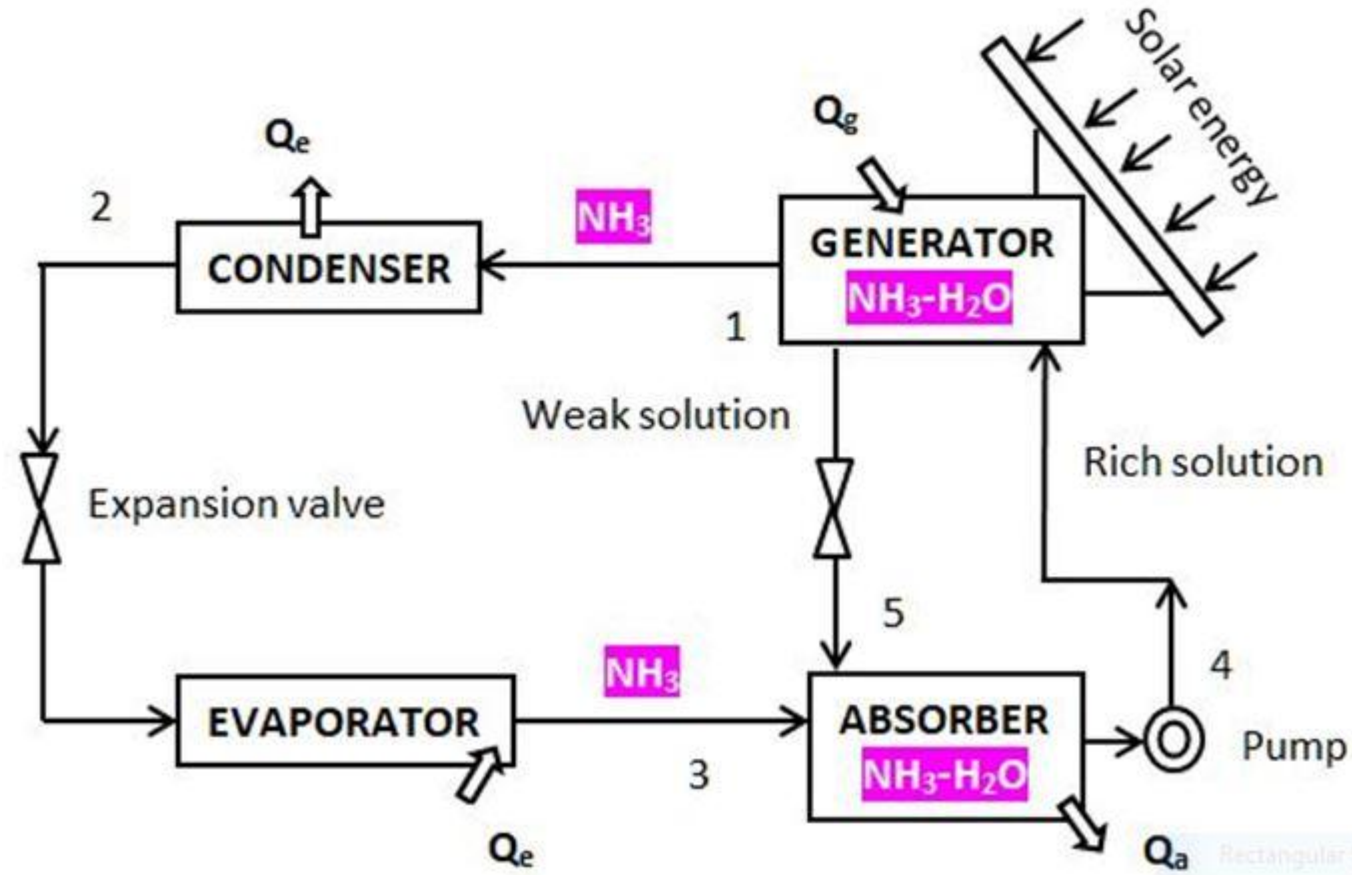


**Fig. 1**. Schematic assembly of solar-powered ammonia-water vapour absorption refrigeration system

## Design Parameters of the $NH_3$-$H_2O$ VARS

The evaporator of the ammonia-water vapour absorption refrigeration system operated at a temperature between 267K and 283K, the condenser and absorber operated at a temperature between 303K and 313K, while the temperature of the generator was between 343K and 388K. Considering mass flow rate, m (kg/s); enthalpy, h (kJ/kg); heat rejected by the absorber to the surrounding, $Q_a$ (W); heat input to the generator, $Q_g$ (W); heat rejected by the condenser to the surrounding, $Q_c$ (W); and heat input to the evaporator, $Q_e$ (W), conservation laws were applied to each of the components as follows:

Generator: (1a)

$$m_1 + m_5 = m_4$$

$$m_1 h_1 + m_5 h_5 = m_4 h_4 + Q_g \quad (1b)$$

Condenser:

$$m_1 = m_2 \quad (2a)$$

$$m_1 h_1 = m_2 h_2 + Q_c \quad (2b)$$

Evaporator:

$$m_2 = m_3 \quad (3a)$$

$$m_3 h_3 = m_2 h_2 + Q_e \quad (3b)$$

Absorber:

$$m_3 + m_5 = m_4 \quad (4a)$$

$$m_3 h_3 = m_3 h_5 = m_4 h_4 + Q_a \quad (4b)$$

Coefficient of performance (COP):

$$COP = \frac{Q_e}{Q_g} = \frac{m_3 h_3 - m_2 h_2}{m_1 h_1 + m_5 h_5 - m_4 h_4} \quad (5)$$

**Results and Discussions**

This section presents the results of the work. The COP for different evaporator temperatures but fixed generator and absorber temperatures can be seen in **Table 1** and **Fig. 2**. The temperature of the evaporator ($T_e$) was increased from 267K to 383K, but the temperatures of the generator ($T_g$) and absorber ($T_a$) was fixed at 343K and 303K, respectively. It can be inferred from Fig. 2 that the COP increased from 0.86 to 1.65 as the evaporator temperature was increased. Quantitatively, for the case considered, the COP increased by 10.32% from $T_e$ = 267K to $T_e$ = 270K and by 90.79% from $T_e$ = 267K to $T_e$ = 283K. This is a corresponding increase of 1.12% and 6.0%, respectively, in the evaporating temperature.

**Table 1**. COP for different evaporating temperatures but fixed generator and absorber temperatures

| **$T_e$ (K)** | 267 | 270 | 273 | 276 | 279 | 283 |
|---|---|---|---|---|---|---|
| **COP** | 0.86 | 0.95 | 1.06 | 1.19 | 1.36 | 1.65 |

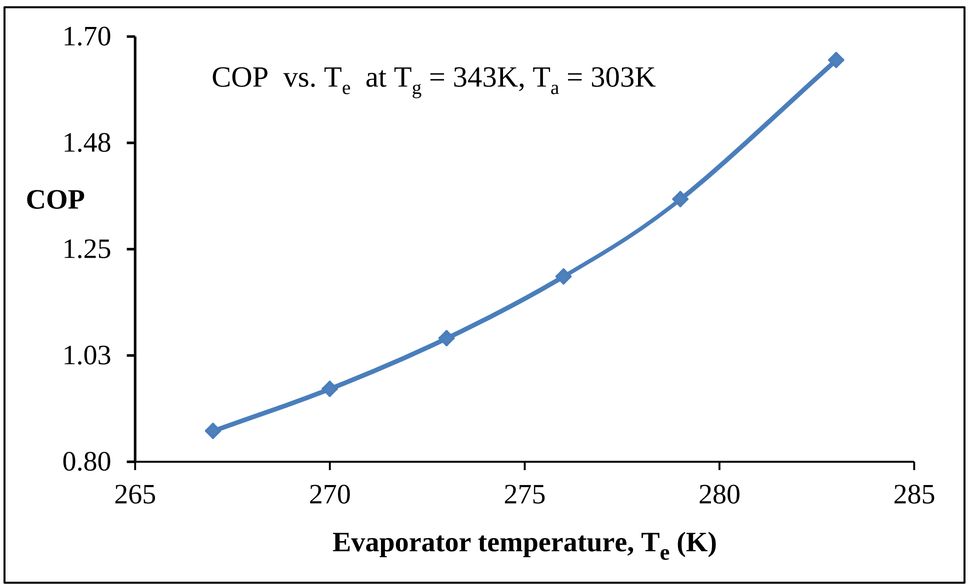


**Fig. 2**. COP for different evaporating temperatures but fixed generator and absorber temperatures

The effect which constant generator temperature and constant evaporator temperature but different absorber temperatures has on COP is demonstrated in **Table 2** and **Fig. 3**. It was revealed through the results that the behavior exhibited was the opposite of the case in which the evaporator temperature varied in value. Interestingly, as depicted in **Fig. 3**, as the temperature of the absorber ($T_a$) was increased from 303K to 305K and 313K, while keeping the temperatures of the generator ($T_g$) and the evaporator ($T_e$) constant at 343K and 267K, respectively, the COP decreased by 10% to 41.3% from 0.86 to 0.78 and 0.51, respectively.

**Table 2**. COP for different absorber temperatures but fixed generator and evaporator temperatures

| **$T_a$ (K)** | 303 | 305 | 307 | 309 | 311 | 313 |
|---|---|---|---|---|---|---|
| **COP** | 0.86 | 0.78 | 0.70 | 0.63 | 0.57 | 0.51 |

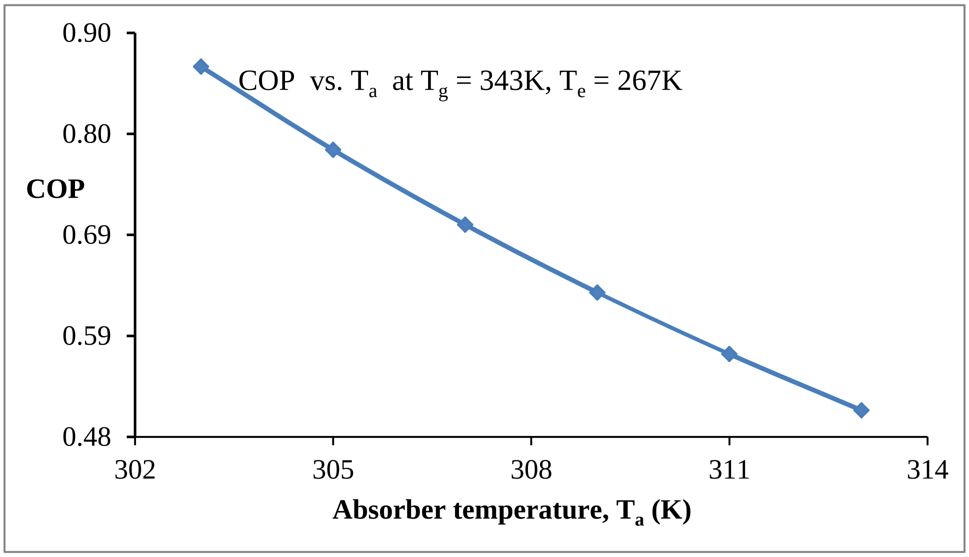


**Fig. 3**. COP for different absorber temperatures but fixed generator and evaporator temperatures

The COP for different values of temperature of the generator but fixed values of temperatures of the evaporator and absorber is shown in **Table 3** and **Fig. 4**. The temperature of the evaporator ($T_g$) was increased from 343K to 388K, but the temperatures of the evaporator ($T_e$) and absorber ($T_a$) was fixed at 267K and 303K, respectively. Relying on the findings detailed in **Fig. 4**, it is evident that as the generator temperature was increased, the COP increased by 19.37% from 0.86 to 1.03 to 87.85% from 0.86 to 1.62.

**Table 3**. COP for different generator temperatures but fixed evaporator and absorber temperatures

| **$T_g$ (K)** | 343 | 352 | 361 | 370 | 379 | 388 |
|---|---|---|---|---|---|---|
| **COP** | 0.86 | 1.03 | 1.19 | 1.34 | 1.49 | 1.62 |

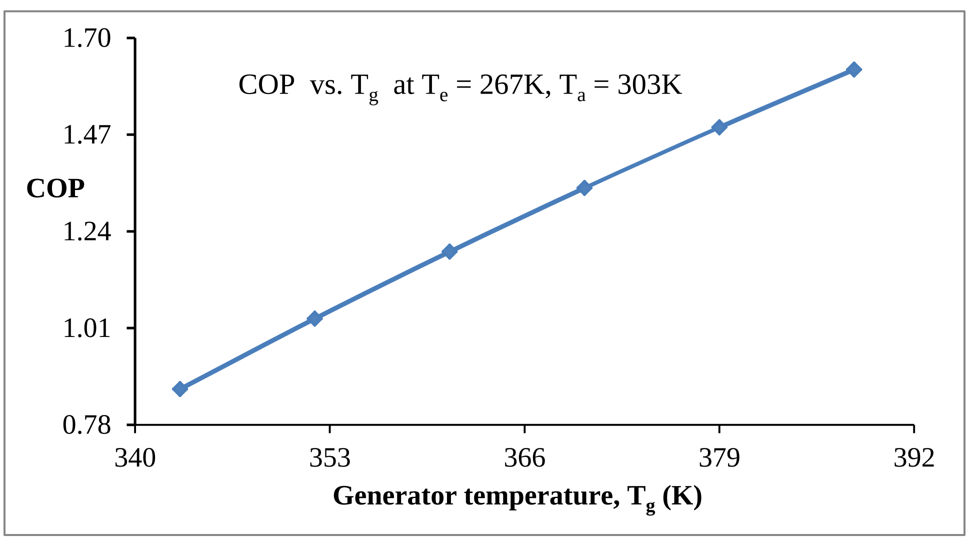


**Fig. 4**. COP for different generator temperatures but fixed evaporator and absorber temperatures

**Fig. 5** displays the values of the COP for different generator temperatures ($T_g$) between 343K and 388K, fixed evaporator temperature ($T_e$) at 267K, but two different values of absorber temperature ($T_a$) at 303K and 313K. The COP increased in both cases (that is, $T_a$ = 301K and $T_a$ = 313K). Importantly, it was observed that the increase in the COP in the case of $T_a$ = 313K was less than that of $T_a$ = 303K by 30.95% at $T_g$ = 388K up to 41.3% at $T_g$ = 343K.

**Table 4**. COP for different generator temperatures, fixed evaporator temperature but two different values of absorber temperature

| $T_g$ (K) | 343 | 352 | 361 | 370 | 379 | 388 |
|---|---|---|---|---|---|---|
| **COP @ $T_a$ = 303K** | 0.86 | 1.03 | 1.19 | 1.34 | 1.49 | 1.62 |
| **COP @ $T_a$ = 313K** | 0.51 | 0.64 | 0.77 | 0.89 | 1.01 | 1.12 |

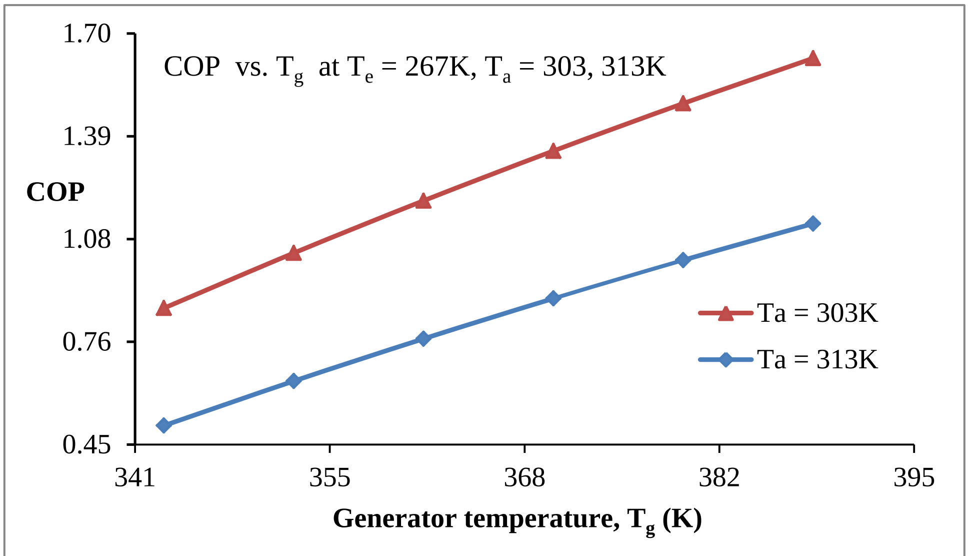


**Fig. 5**. COP for different generator temperatures, fixed evaporator temperature but two different values of absorber temperature

## Conclusion

In this paper, analyses were carried out on the effects of temperatures of absorber, generator, and evaporator on the coefficient of performance of an ammonia-water solar-powered vapour absorption refrigeration system. The results of the analyses indicated that coefficient of performance of the absorption refrigeration system increased as either the generator temperature or the evaporator temperature was increased, but decreased when the absorber temperature was decreased.

## References

[1] T. O. Oni and S. B. Adeyemo, "Tackling the Energy Challenges in Nigeria through Renewable Energy Systems," Proc. Nigerian Soc. of Engineers 2016 National Engineering Conference, 2016.

[2] A. R. Trott and T. Welch, Refrigeration and Air-Conditioning, Oxford: Butterworth-Heinemann, 2000.

[3] S. K. Wang and Z. Lavan, "Air-Conditioning and Refrigeration," Mechanical Engineering Handbook, F. Kreith, ed., Boca Raton: CRC Press LLC, pp. 9.1-9.160, 1999.

[4] K. P. Tyagi, "Ammonia-Salts Vapour Absorption Refrigeration Systems," Heat Recov. Syst., vol. 4, no. 6, pp. 427-431, 1984.

[5] V. Muthu, R. Saravanan, and S. Renganarayanan, "Experimental Studies on R134a- DMAC Hot Water Based Vapour Absorption Refrigeration Systems," Int. J. Therm. Sci., vol. 47, pp. 175–181, 2008.

[6] M. I. Karamangil, S. Coskun, O. Kaynakli, and N. Yamankaradeniz, "A Simulation Study of Performance Evaluation of Single-Stage Absorption Refrigeration System Using Conventional Working Fluids and Alternatives," Renew. Sustain. Energy Rev., vol. 14, pp. 1969–1978, 2010.

[7] V. K. Bajpai, "Design of Solar Powered Vapour Absorption System," Proc. World Congress on Engineering 2012 Vol III, pp., 2012.

[8] C. V. Vazhappilly, T. Tharayil, and A. P. Nagarajan, "Modeling and Experimental Analysis of Generator in Vapour Absorption Refrigeration System," Int. J. Eng. Res. Appl., vol. 3, no. 5, pp. 63-67, 2013.

[9] P. Johnson and K. B. J. Gowda, "Fabrication of Solar Thermalvapour Absorption Refrigeration System," Int. Res. J. Eng. Technol., vol. 2, no. 5, pp. 1106-1111, 2015.