

# Performance evaluation of solar assisted half effect Li/Br vapour absorption refrigeration system cascaded with vapour compression refrigeration system using eco-friendly refrigerants

RS Mishra

Department of Mechanical Engineering, Delhi Technological University, New Delhi, India

## Article Info

Article history:

Received 22 April 2019

Received in revised form

20 May 2019

Accepted 28 May 2019

Available online 15 June 2019

**Keywords:** Thermodynamic analysis, Half effect cascaded vapour compression-absorption system, performance prediction

## Abstract

In the most of industrial process the waste heat energy increases the production cost. Using this waste heat to produce power or cooling can decrease the costs and increases the thermal efficiency of the systems. A growing need for refrigeration in industry and for building cooling is well known due to the main cause of growing the demands of higher living standards, by the increasing requirements for comfort, by increasing thermal load of buildings. Using LiBr-H<sub>2</sub>O solution in the vapour absorption refrigeration systems offers very good thermodynamic efficiency for cooling at over 0 °C temperature than the other solutions. In this paper, we analyzed solar assisted half effect vapour absorption refrigeration system cascaded by vapour compression refrigeration system using ecofriendly refrigerants and developed thermodynamic model to predict the variation of generator, absorber, condenser temperatures on first and second law efficiencies and to predict the solar collector area required.

## 1. Introduction

Absorption cooling cycles are environmental, clean and economically driven cycles. By consuming very small electric power, they can use waste heat or solar energy for cooling. The half effect absorption systems have the advantage of using low temperature heat energy for cooling. Karaali [1] presented exergy analysis of a half effect absorption system developed computer program in FORTRAN codes for the thermodynamic properties of lithium bromide-water solutions effect absorption system. he numerical computation was carried out for developed model for computing exergy losses in each component of the system. The computed coefficient performance (COP) of the half effect absorption system is 0.45 and the exergetic coefficient performance (ECOP) is 0.24. and concluded that most of the irreversibilities are in the evaporator and in the absorbers. Kaushik and Arrora A [2] carried out energy and exergy analysis of single effect and series flow double effect water–lithium bromide absorption systems and developed computational model for the parametric investigation of these systems. The performance parameters computed such as coefficient of performance, exergy destruction, efficiency defects and exergetic efficiency which take into account, the effects of pressure drop between evaporator and absorber, and effectiveness of heat exchangers, effects of generator, absorber and evaporator temperatures. The first law efficiency in terms of coefficient of performance of the single effect system ranges from 0.6–0.75 and double effect system coefficient of performance for the series flow ranges from 1–1.28 have been predicted and found the highest irreversibility is in the absorber in both refrigeration systems.

Kaushik et.al [3] carried out thermodynamic analysis of a parallel flow double effect absorption refrigeration system maximum COP and maximum exergetic efficiency and developed model for double effect parallel flow LiBr/H<sub>2</sub>O absorption refrigeration system. This model takes into account of the effect of generator, absorber and evaporator temperatures the maximum COP and maximum exergetic efficiency. Inzunza et.al [4] compared performance of four vapour absorption refrigeration systems and found that the highest coefficient of performance of double effect vapour absorption refrigeration system ranging between 1.1 and 1.75 followed by the generator temperature above 150°C and generators are connected in series combination while lowest COP are found using half effect vapour absorption refrigeration systems between 0.32 to 0.45 for generator temperature 60°C to 80°C while COP of single effect vapour absorption system is found between 0.65 to 0.92 while single effect vapour absorption system, the generator temperature between 80°C to 110°C and suggested that series combination in double effect vapour absorption system is

more efficient than parallel combination double effect vapour absorption system is that the utility of half effect Li/Br that the system required low temperature in generator can operate in the hot climate and also found that in all four combinations of vapour absorption refrigeration systems, the single effect vapour absorption system is simple because this system required minimum number of components to operate and has less expensive. Gomri and Hakimi [5] carried out second law analysis of double effect vapor absorption cooler system and found that by increasing low pressure generator temperature increases the performance of the system and the highest exergy losses occurs in high pressure generator and absorber. Wang and Zheng [6] studied the performance of one and half effect absorption cooling cycle of H<sub>2</sub>O/LiBr system and found that the 1.5-effect cycles gives better performance due to the advantages of the single-effect and half-effect absorption cooling cycles. Colorado and Rivera [7] have obtained the performance comparison between a conventional vapor compression and compression-absorption single-stage and double-stage systems used for refrigeration and concluded that the compression power of the cascade cycles was 45 % lower than in compression cycles.

Jain [8] carried out the performance of a four types of vapour compression–absorption cascaded refrigeration system (CRS) under fouled conditions and found that the main effect of fouling is to decrease the effectiveness of the heat exchanger.

The solar assisted half effect vapour absorption refrigerationsystem cascaded with vapour compression refrigeration system using ecofriendly refrigerants have not been studied in detail. In this paper we investigate the performance of above system along with variation of performance parameters and its effect on system performances in terms of exergetic efficiency, coefficient of performance aalong with exergy destruction ratio based on exergy of product.

## 2. Results and Discussions

Following input variables have been chosen for validation of model Evaporator Temperature of Half effect Li/Br vapour absorption refrigeration system= 8°C, Generator temperature=80°C.

Evaporator Temperature of vapour compression refrigeration system= -50°C, Temperature overlapping (Approach)=10 Refrigerating Capacity=29.09 “kW”

Condenser temperature =35°C,

Absorber Temperature=35°C, Compressor Efficiency=0.80,

Thermal performance of half effect vapourabsorption refrigeration systemwas computed by developed model is given below.

- (i) First law efficiency of vapour absorption refrigeration system is (COP\_VARS) =0.4255,
- (ii) The second law efficiency of vapour absorption refrigeration system is the exergetic\_efficiency= 0.1558.
- (iii) The exergy destruction ratio based on out put

**Corresponding Author,**

**E-mail address:** hod.mechanical.rsm@dtu.ac.in

**All rights reserved:** <http://www.ijari.org>

- (iv) The exergy destruction ratio based on input (exergy of exergy of fuel) is  $EDR_{Input} = 0.8442$ .
- (v) The solar Collector/absorber area required to run that system is  $89.37 \text{ m}^2$

**Table-1(a):** Performance variation with temperature over lapping of Half effect LiBrVapour absorption refrigeration system cascaded with Vapour compression refrigeration system using R134a eco-friendly refrigerant

| Effect of Approach (°C) | COP_Cascade-Cascade COP_R134a | EDR_Cascade | Exergetic Efficiency |
|-------------------------|-------------------------------|-------------|----------------------|
| 0                       | 0.6452                        | 1.976       | 0.3361               |
| 5                       | 0.6303                        | 2.262       | 0.3065               |
| 10                      | 0.6155                        | 2.581       | 0.2793               |
| 15                      | 0.6009                        | 2.938       | 0.2540               |

Fig-1(a) shows the variation of approach of Combined Half effect LiBrVapour absorption refrigeration system cascaded with Vapour compression refrigeration system using R134a eco-friendly refrigerant and it was observed that as temperature overlapping in increasing, the first law efficiency (COP) and second law efficiency (exergetic efficiency) Cascade system of cascaded system are decreasing as temperature overlapping is increasing. Similarly exergy destruction ratio based on exergy of product is also decreasing as temperature overlapping is increased.

**Table-1(b):** Performance variation with temperature over lapping of Half effect LiBrVapour absorption refrigeration system cascaded with Vapour compression refrigeration system using R134a eco-friendly refrigerant

| Effect of Approach (°C) | COP_R134a_VCRS | EDR_VCR | Exergetic Efficiency |
|-------------------------|----------------|---------|----------------------|
| 0                       | 2.402          | 0.2376  | 0.8080               |
| 5                       | 2.144          | 0.3871  | 0.721                |
| 10                      | 1.92           | 0.5487  | 0.6457               |
| 15                      | 1.734          | 0.7250  | 0.5797               |

Fig-1(b) shows the variation of approach of Combined Half effect Li/BrVapour absorption refrigeration system cascaded with Vapour compression refrigeration system using R134a eco-friendly refrigerant and it was observed that as temperature overlapping in increasing, the first law efficiency (COP) and second law efficiency (exergetic efficiency) VCRS of cascaded system are decreasing as temperature overlapping is increasing. Similarly exergy destruction ratio based on exergy of product is also decreasing as temperature overlapping (approach) is increased.

**Table-2(a):** Effect of Thermodynamic performances (First law Performance (COP\_Cascade), Second law performance (Exergetic efficiency) and system exergy destruction Ratio with Absorber temperature of Vapour compression Refrigeration System coupled with single Effect vapour Absorption Refrigeration LiBrSystem using 134a ecofriendly refrigerant

| Absorber Temperature (°C) | COP_Cascade | EDR_Cascade | Exergetic Efficiency - Cascade | Solar collector area (m <sup>2</sup> ) |
|---------------------------|-------------|-------------|--------------------------------|--|
| 30                        | 0.6309      | 2.54        | 0.2825                         | 86.88                                  |
| 35                        | 0.6155      | 2.581       | 0.2793                         | 89.57                                  |
| 40                        | 0.6038      | 2.613       | 0.2768                         | 91.36                                  |
| 45                        | 0.5942      | 2.64        | 0.2747                         | 93.05                                  |
| 50                        | 0.5860      | 2.644       | 0.2729                         | 94.53                                  |

Fig-2(a) shows the variation of absorber temperature of Combined Half effect LiBrVapour absorption refrigeration system cascaded with Vapour compression refrigeration system using R134a eco-friendly refrigerant and it was observed that as absorber temperature increasing, the first law efficiency (COP) and second law efficiency (exergetic efficiency) VCRS of cascaded system are decreasing as absorber temperature is increasing. Similarly exergy destruction

ratio based on exergy of product is also increasing as absorber temperature is increased. Similarly solar collector area is also increasing as absorber temperature is increasing.

**Table-2(b):** Effect of Thermodynamic performances (First law Performance (COP\_VARS), Second law performance (Exergetic efficiency) and system exergy destruction ratio with absorber temperature of vapour compression refrigeration system coupled with single effect vapour absorption refrigeration LiBr system using 134a ecofriendly refrigerant

| Absorber Temperature (°C) | COP_VARS | EDR_VARS | Exergetic Efficiency | Solar collector area (m <sup>2</sup> ) |
|---------------------------|----------|----------|----------------------|--|
| 30                        | 0.4377   | 5.24     | 0.1603               | 86.88                                  |
| 35                        | 0.4255   | 5.419    | 0.1558               | 89.57                                  |
| 40                        | 0.4162   | 5.562    | 0.1524               | 91.36                                  |
| 45                        | 0.4087   | 5.683    | 0.1496               | 93.05                                  |
| 50                        | 0.4023   | 5.789    | 0.1473               | 94.53                                  |

Fig-2(b) shows the variation of absorber temperature of Combined Half effect LiBrVapour absorption refrigeration system cascaded with Vapour compression refrigeration system using R134a eco-friendly refrigerant and it was observed that as absorber temperature increasing, the first law efficiency (COP) and second law efficiency (exergetic efficiency) VARS system are decreasing as absorber temperature is increasing. solar collector area is also increasing as absorber temperature is increasing Similarly exergy destruction ratio based on exergy of product is also increasing as absorber temperature is increased.

**Table-3(a):** Effect of Thermodynamic performances (First law Performance (COP\_Cascade), Second law performance (Exergetic efficiency) and system exergy destruction Ratio with condenser temperature of Vapour compression Refrigeration System coupled with single Effect vapour Absorption Refrigeration LiBrSystem using 134a ecofriendly refrigerant

| Condenser Temperature (°C) | COP_Cascade | EDR_Cascade | Exergetic Efficiency | Solar collector area (m <sup>2</sup> ) |
|----------------------------|-------------|-------------|----------------------|--|
| 30                         | 0.6176      | 2.575       | 0.2797               | 89.04                                  |
| 35                         | 0.6155      | 2.581       | 0.2793               | 89.37                                  |
| 40                         | 0.6136      | 2.586       | 0.2789               | 89.7                                   |
| 45                         | 0.6116      | 2.591       | 0.2784               | 90.03                                  |
| 50                         | 0.6096      | 2.597       | 0.2780               | 90.37                                  |

Fig-3(a) shows the variation of condenser temperature of Combined Half effect LiBrVapour absorption refrigeration system cascaded with Vapour compression refrigeration system using R134a eco-friendly refrigerant and it was observed that as condenser temperature increasing, the first law efficiency (COP) and second law efficiency (exergetic efficiency) of combined system is decreasing as absorber temperature is increasing. solar collector area is also increasing as condenser temperature is increasing Similarly exergy destruction ratio based on exergy of product is also increasing as condenser temperature is increased.

**Table-3(b):** Effect of Thermodynamic performances (First law Performance (COP\_VARS), Second law performance (Exergetic efficiency) and system exergy destruction Ratio with condenser temperature of Vapour compression Refrigeration System coupled with single Effect vapour Absorption Refrigeration LiBrSystem using 134a ecofriendly refrigerant

| Condenser Temperature (°C) | COP_VARS | EDR_VARS | Exergetic Efficiency | Solar collector area (m <sup>2</sup> ) |
|----------------------------|----------|----------|----------------------|--|
| 30                         | 0.4271   | 5.395    | 0.1564               | 89.04                                  |
| 35                         | 0.4255   | 5.419    | 0.1558               | 89.37                                  |
| 40                         | 0.4239   | 5.433    | 0.1552               | 89.7                                   |
| 45                         | 0.4224   | 5.467    | 0.1546               | 90.03                                  |
| 50                         | 0.4208   | 5.491    | 0.1541               | 90.37                                  |

Fig-3(b) shows the variation of condenser temperature of Combined Half effect LiBrVapour absorption refrigeration system cascaded with Vapour compression refrigeration system using R134a eco-friendly refrigerant and it was observed that as condenser temperature increasing, the first law efficiency (COP) and second law efficiency (exergetic efficiency) of half effect vapour absorption refrigeration system is decreasing as absorber temperature is increasing. Similarly exergy destruction ratio based on exergy of product is also increasing as condenser temperature is increased

**Table-4(a):**Effect of Thermodynamic performances (First law Performance (COP\_VCRS), Second law performance (Exergetic efficiency) and system exergy destruction Ratio with generator temperature of Vapour compression Refrigeration System coupled with single Effect vapourAbsorption Refrigeration LiBrSystem using 134a ecofriendly refrigerant

| Generator Temperature (°C) | COP_Cascade | EDR_Cascade | Exergetic Efficiency _ Cascade | Solar collector area (m <sup>2</sup> ) |
|----------------------------|-------------|-------------|--------------------------------|--|
| 60                         | 0.6335      | 1.751       | 0.3636                         | 86.47                                  |
| 65                         | 0.6283      | 1.965       | 0.3373                         | 87.29                                  |
| 70                         | 0.6236      | 2.175       | 0.3149                         | 88.05                                  |
| 75                         | 0.6194      | 2.381       | 0.2958                         | 88.74                                  |
| 80                         | 0.6155      | 2.581       | 0.2793                         | 89.37                                  |
| 85                         | 0.6121      | 2.773       | 0.2650                         | 89.94                                  |
| 90                         | 0.6091      | 2.959       | 0.2526                         | 90.45                                  |

Fig-4(a) shows the variation of generator temperature of CombinedHalf effect LiBrVapour absorption refrigeration system cascaded with Vapour compression refrigeration system using R134a eco-friendly refrigerant and it was observed that as generator temperature increasing, the first law efficiency (COP) and second law efficiency (exergetic efficiency) of combined vapour absorption cascaded refrigeration system is decreasing as generator temperature is increasing. solar collector area is also increasing as generator temperature is increasing. Similarly exergy destruction ratio based on exergy of product is also increasing as condenser temperature is increased.

**Table-4(b):**Effect of Thermodynamic performances (First law Performance (COP\_VCRS), Second law performance (Exergetic efficiency) and system exergy destruction Ratio with generator temperature of Vapour compression Refrigeration System coupled with single Effect vapourAbsorption Refrigeration LiBrSystem using 134a ecofriendly refrigerant

| Generator Temperature (0C) | COP_VAR S | EDR_VAR S | Exergetic Efficiency | Solar collector area (m <sup>2</sup> ) |
|----------------------------|-----------|-----------|----------------------|--|
| 60                         | 0.4397    | 3.190     | 0.2387               | 86.47                                  |
| 65                         | 0.4356    | 3.762     | 0.210                | 87.29                                  |
| 70                         | 0.4319    | 4.325     | 0.1878               | 88.05                                  |
| 75                         | 0.4285    | 4.876     | 0.1701               | 88.74                                  |
| 80                         | 0.4255    | 5.419     | 0.1558               | 89.37                                  |
| 85                         | 0.4228    | 5.949     | 0.1439               | 89.94                                  |
| 90                         | 0.4204    | 6.467     | 0.1339               | 90.45                                  |

Fig-4(b) shows the variation of generator temperature of CombinedHalf effect LiBrVapour absorption refrigeration system cascaded with Vapour compression refrigeration system using R134a eco-friendly refrigerant and it was observed that as generator temperature increasing, the first law efficiency (COP) and second law efficiency (exergetic efficiency) of half effect vapour absorption refrigeration system is decreasing as generator temperature is increasing. solar collector area is also increasing as generator temperature is increasing. Similarly exergy destruction ratio based on exergy of product is also increasing as condenser temperature is increased

**Table-5(a):**Effect of Thermodynamic performances (First law Performance (COP\_VCRS), Second law performance (Exergetic efficiency) and system exergy destruction Ratio with generator temperature of Vapour compression Refrigeration System coupled with Half Effectvapour Absorption Refrigeration Li/BrSystem using following ecofriendly refrigerants

| Performance Parameters | COP_cascade | EDR_cascade | Exergetic Efficiency _ Cascade |
|------------------------|-------------|-------------|--------------------------------|
| R134a                  | 0.6155      | 2.581       | 0.2793                         |
| R1234yf                | 0.6079      | 2.762       | 0.2658                         |
| R152a                  | 0.6216      | 2.445       | 0.2902                         |
| R 245fa                | 0.6196      | 2.490       | 0.2866                         |
| R236fa                 | 0.6084      | 2.749       | 0.2668                         |
| R 227ea                | 0.5956      | 3.076       | 0.2453                         |
| R290                   | 0.6151      | 2.59        | 0.2786                         |
| R600a                  | 0.6144      | 2.606       | 0.2773                         |
| R600                   | 0.6203      | 2.474       | 0.2878                         |
| R141b                  | 0.6296      | 2.277       | 0.3052                         |
| R143a                  | 0.6068      | 2.789       | 0.2639                         |
| R32                    | 0.6138      | 2.62        | 0.2763                         |
| R507a                  | 0.6042      | 2.852       | 0.2596                         |
| R125                   | 0.5951      | 3.091       | 0.2445                         |
| R404a                  | 0.6011      | 2.931       | 0.2544                         |
| R717                   | 0.6157      | 2.577       | 0.2795                         |
| R123                   | 0.6238      | 2.398       | 0.2943                         |
| R410a                  | 0.6142      | 2.613       | 0.2768                         |
| R407c                  | 0.5956      | 3.078       | 0.2452                         |

Fig-5(a) shows the effect of various ecofriendly refrigerants of Combined Half effect Li/BrVapour absorption refrigeration system cascaded with Vapour compression refrigeration system and it was observed that as the first law efficiency (COP\_Cascade) and second law efficiency (exergetic efficiency) of half effect vapour absorption-compression refrigeration system using R141b is higher and lower first and second law efficiencies when R125 is used. . Similarly exergy destruction ratio based on exergy of product is also increased using R125.

**Table-5(b):**Effect of Thermodynamic performances (First law Performance (COP\_VCRS), Second law performance (Exergetic efficiency) and system exergy destruction Ratio with generator temperature of Vapour compression Refrigeration System coupled with Half Effect vapourAbsorption Refrigeration Li/BrSystem using following ecofriendly refrigerants

| Performance Parameters | COP_VCRS | EDR_VCRS | Exergetic Efficiency _ Cascade |
|------------------------|----------|----------|--------------------------------|
| R134a                  | 1.92     | 0.5487   | 0.6457                         |
| R1234yf                | 1.814    | 0.5419   | 0.6102                         |
| R152a                  | 2.008    | 0.4806   | 0.6757                         |
| R245fa                 | 1.976    | 0.5030   | 0.6653                         |
| R236fa                 | 1.821    | 0.5419   | 0.6126                         |
| R227ea                 | 1.659    | 0.7921   | 0.5580                         |
| R290                   | 1.914    | 0.5534   | 0.6437                         |
| R600a                  | 1.904    | 0.5615   | 0.6404                         |
| R600                   | 1.989    | 0.4952   | 0.6688                         |
| R141b                  | 2.132    | 0.3946   | 0.7171                         |
| R143a                  | 1.80     | 0.6522   | 0.6053                         |
| R32                    | 1.896    | 0.5683   | 0.6376                         |
| R507a                  | 1.766    | 0.6835   | 0.5940                         |
| R125                   | 1.653    | 0.7991   | 0.5558                         |

|       |       |        |        |
|-------|-------|--------|--------|
| R404a | 1.727 | 0.7217 | 0.5808 |
| R717  | 1.922 | 0.5471 | 0.6464 |
| R123  | 2.041 | 0.4566 | 0.6865 |
| R410a | 1.90  | 0.5647 | 0.6391 |
| R407c | 1.658 | 0.793  | 0.5577 |

Fig-5(b) shows the effect of various ecofriendly refrigerants of Combined Half effect Li/BrVapour absorption refrigeration system cascaded with Vapour compression refrigeration system and it was observed that as the first law efficiency (COP\_VCRS) and second law efficiency (exergetic efficiency) of half effect vapour absorption refrigeration system using R141b is higher and lower first and second law efficiencies when R125 is used. Similarly exergy destruction ratio based on exergy of product is also increased using R125.

**Table-6(a):**Effect of Thermodynamic performances (First law Performance (COP\_Cascade), Second law performance (Exergetic efficiency) and system exergy destruction Ratio with generator temperature of Vapour compression Refrigeration System coupled with half EffectvapourAbsorption Refrigeration Li/BrSystem using 134a ecofriendly refrigerant

| Low temperature circuit evaporator Temperature (°C) | COP_Cascade Using R134a | EDR_Cascade | Exergetic Efficiency |
|---|-------------------------|-------------|----------------------|
| -35   | 0.6662                  | 2.919       | 0.2552               |
| -40   | 0.6491                  | 2.765       | 0.2656               |
| -45   | 0.6322                  | 2.655       | 0.2736               |
| -50   | 0.6155                  | 2.581       | 0.2793               |
| -55   | 0.5991                  | 2.534       | 0.2830               |
| -60   | 0.5829                  | 2.510       | 0.2849               |
| -65   | 0.5669                  | 2.507       | 0.2852               |
| -70   | 0.5513                  | 2.521       | 0.2844               |

Fig-6(a) shows the variation of Low temperature circuit evaporator Temperature of combined Half effect Li/BrVapour absorption refrigeration system cascaded with Vapour compression refrigeration system using R134a eco-friendly refrigerant and it was observed that as Low temperature circuit evaporator Temperature is increasing from (-70oC to -30oC), the first law efficiency(COP\_Cascade) of cascaded vapour compression -half effect vapour absorption system is increasing while and second law efficiency (exergetic efficiency) of Cascaded vapour compression half effect vapour absorption refrigeration system is decreasing as generator temperature is increasing. Similarly exergy destruction ratio based on exergy of product is also increasing as Low temperature circuit evaporator Temperature of combined Half effect Li/BrVapour absorption refrigeration system cascaded with Vapour compression refrigeration system using R134a eco-friendly refrigerant is increased.

**Table-6(b):**Effect of Thermodynamic performances (First law Performance (COP\_Cascade), Second law performance (Exergetic efficiency) and system exergy destruction Ratio with generator temperature of Vapour compression Refrigeration System coupled with half EffectvapourAbsorption Refrigeration Li/BrSystem using 1234yf ecofriendly refrigerant

| Low temperature circuit evaporator Temperature (°C) | COP_Cascade Using R1234yf | EDR_Cascade | Exergetic Efficiency |
|---|---------------------------|-------------|----------------------|
| -30   | 0.6791                    | 3.249       | 0.2354               |
| -35   | 0.6611                    | 3.048       | 0.2471               |
| -40   | 0.6432                    | 2.909       | 0.2558               |
| -45   | 0.6254                    | 2.817       | 0.2620               |

|     |        |       |        |
|-----|--------|-------|--------|
| -50 | 0.6079 | 2.762 | 0.2658 |
|-----|--------|-------|--------|

Fig-6(b) shows the variation of Low temperature circuit evaporator Temperature of combined Half effect Li/BrVapour absorption refrigeration system cascaded with Vapour compression refrigeration system using R1234yf eco-friendly refrigerant and it was observed that as Low temperature circuit evaporator Temperature is increasing from (-50oC to -30oC), the first law efficiency(COP\_Cascade) of cascaded vapour compression -half effect vapour absorption system is increasing while and second law efficiency (exergetic efficiency) of Cascaded vapour compression half effect vapour absorption refrigeration system is decreasing as generator temperature is increasing. Similarly exergy destruction ratio based on exergy of product is also increasing as Low temperature circuit evaporator Temperature of combined Half effect Li/BrVapour absorption refrigeration system cascaded with Vapour compression refrigeration system using R1234yf eco-friendly refrigerant is increased.

**Table-6(c):**Effect of Thermodynamic performances (First law Performance (COP\_VCRS), Second law performance (Exergetic efficiency) and system exergy destruction Ratio with generator temperature of Vapour compression Refrigeration System coupled with HalfEffectvapourAbsorption Refrigeration Li/BrSystem using R134a ecofriendly refrigerant

| Low temperature circuit evaporator Temperature (°C) | COP_VCRS Using R134a | EDR_VCRS | Exergetic Efficiency |
|---|----------------------|----------|----------------------|
| -35   | 2.836                | 0.3985   | 0.7151               |
| -40   | 2.476                | 0.4476   | 0.6908               |
| -45   | 2.175                | 0.4975   | 0.6678               |
| -50   | 1.92                 | 0.5487   | 0.6457               |
| -55   | 1.701                | 0.6018   | 0.6243               |
| -60   | 1.517                | 0.6572   | 0.6034               |
| -65   | 1.347                | 0.7154   | 0.5830               |
| -70   | 1.203                | 0.7769   | 0.5628               |

Fig-6(c) shows the variation of Low temperature circuit evaporator Temperature of combined Half effect Li/BrVapour absorption refrigeration system cascaded with Vapour compression refrigeration system using R134a eco-friendly refrigerant and it was observed that as Low temperature circuit evaporator Temperature is increasing from (-70oC to -30oC), the first law efficiency(COP\_VCRS) of cascaded vapour compression system is increasing while and second law efficiency (exergetic efficiency) of Cascaded vapour compression half effect vapour absorption refrigeration system is increasing as Low temperature circuit evaporator Temperature is increasing. Similarly exergy destruction ratio based on exergy of product is also increasing as Low temperature circuit evaporator Temperature of combined Half effect Li/BrVapour absorption refrigeration system cascaded with Vapour compression refrigeration system using R134a eco-friendly refrigerant is decreased.

**Table-6(d):**Effect of Thermodynamic performances (First law Performance (COP\_VCRS), Second law performance (Exergetic efficiency) and system exergy destruction Ratio with generator temperature of Vapour compression Refrigeration System coupled with HalfEffectvapourAbsorption Refrigeration Li/BrSystem using 1234yf ecofriendly refrigerant

| Low temperature circuit evaporator Temperature (°C) | COP_VCRS using R1234yf | EDR_VCRS | Exergetic Efficiency |
|---|------------------------|----------|----------------------|
| -30   | 3.157                  | 0.3995   | 0.7145               |

|     |       |        |        |
|-----|-------|--------|--------|
| -35 | 2.722 | 0.4573 | 0.6862 |
| -40 | 2.365 | 0.5158 | 0.6597 |
| -45 | 2.067 | 0.5761 | 0.6345 |
| -50 | 1.814 | 0.6388 | 0.6102 |

Fig-6(d) shows the variation of Low temperature circuit evaporator Temperature of combined Half effect Li/Br Vapour absorption refrigeration system cascaded with Vapour compression refrigeration system using R1234yf eco-friendly refrigerant and it was observed that as Low temperature circuit evaporator Temperature is increasing from (-70oC to -30oC), the first law efficiency (COP\_VCRS ) of vapour compression system is increasing while and second law efficiency (exergetic efficiency) of Cascaded vapour compression half effect vapour absorption refrigeration system is increasing as Low temperature circuit evaporator Temperature is increasing. Similarly exergy destruction ratio based on exergy of product is also increasing as Low temperature circuit evaporator Temperature of combined Half effect Li/Br Vapour absorption refrigeration system cascaded with Vapour compression refrigeration system using R134a eco-friendly refrigerant is decreased.

**Table-7(a):** Comparison between HFC-134a ecofriendly refrigerant with HFO-1234yf in terms of Thermodynamic performances (First law Performance (COP\_Cascade), Second law performance (Exergetic efficiency) and system exergy destruction Ratio of Vapour compression Refrigeration System coupled with half Effect vapourAbsorption Refrigeration LiBrSystem using HFC-134a and HFO-1234yf ecofriendly refrigerants

| Low temperature circuit evaporator Temperature (°C) | First Law Efficiency of cascaded vapour compression Absorption system using R134a) (COP_Cascade) | First Law Efficiency of cascaded vapour compression Absorption system using R1234yf COP_Cascade | Exergetic Efficiency of cascaded vapour compression Absorption system using R134a | Exergetic Efficiency of cascaded vapour compression Absorption system using R1234yf |
|---|--|---|---|---|
| -35   | 0.6662   | 0.6611  | 0.2552  | 0.2471  |
| -40   | 0.6491   | 0.6432  | 0.2656  | 0.2558  |
| -45   | 0.6322   | 0.6254  | 0.2736  | 0.2620  |
| -50   | 0.6155   | 0.6079  | 0.2793  | 0.2658  |

Table-7(a) shows the comparison between HFC-134a ecofriendly refrigerant with HFO-1234yf in terms of Thermodynamic performances (First law Performance (COP\_Cascade), Second law performance (Exergetic efficiency) and system exergy destruction Ratio of Vapour compression Refrigeration System coupled with half Effect vapourAbsorption Refrigeration LiBrSystem using HFC-134a and HFO-1234yf ecofriendly refrigerants and it is found that the first and second law performances of Cascaded vapour compression -vapour half effect absorption system is higher by using HFC-134a and slightly lower by using HFO-1234yf.

**Table-7(b):** Comparison between HFC-134a ecofriendly refrigerant with HFO-1234yf in terms of Thermodynamic performances (First law Performance (COPVCRS), Second law performance (Exergetic efficiency) and system exergy destruction Ratio of Vapour compression Refrigeration System coupled with half Effect vapourAbsorption Refrigeration LiBrSystem using HFC-134a and HFO-1234yf ecofriendly refrigerants

| Low temperature circuit evaporator Temperature (oC) | First Law Efficiency of cascaded vapour compression | First Law Efficiency of cascaded vapour compression | Exergetic Efficiency of cascaded vapour compression | Exergetic Efficiency of cascaded vapour compression |
|---|---|---|---|---|
| -35   | 0.6662  | 0.6611  | 0.2552  | 0.2471  |
| -40   | 0.6491  | 0.6432  | 0.2656  | 0.2558  |
| -45   | 0.6322  | 0.6254  | 0.2736  | 0.2620  |
| -50   | 0.6155  | 0.6079  | 0.2793  | 0.2658  |

|     | Absorption system using R134a) (COP_VCRS) | on Absorption system using R1234yf COP_VCRS | on Absorption system using R134a | on Absorption system using R1234yf |
|-----|---|---|----------------------------------|------------------------------------|
| -35 | 2.836                                     | 2.722                                       | 0.7151                           | 0.6862                             |
| -40 | 2.476                                     | 2.365                                       | 0.6908                           | 0.6597                             |
| -45 | 2.175                                     | 2.067                                       | 0.6678                           | 0.6345                             |
| -50 | 1.92                                      | 1.814                                       | 0.6457                           | 0.6102                             |

Table-7(b) shows the comparison between HFC-134a ecofriendly refrigerant with HFO-1234yf in terms of Thermodynamic performances (First law Performance (COP\_VCRS), Second law performance (Exergetic efficiency) and system exergy destruction Ratio of Vapour compression Refrigeration System coupled with half Effect vapourAbsorption Refrigeration LiBrSystem using HFC-134a and HFO-1234yf ecofriendly refrigerants and it is found that the first and second law performances of Cascaded vapour compression -vapour half effect absorption system is higher by using HFC-134a and slightly lower by using HFO-1234yf

### 3. Conclusions

The following conclusions were drawn from present investigations.

- (i) Thermodynamic performance in terms of first law efficiency (COP\_Cascade\_System) of combined cascaded vapour compression -half effect vapour absorption refrigeration system using HFC-134a is higher than the combined cascaded vapour compression -half effect vapour absorption refrigeration system using HFC-1234yf
- (ii) Thermodynamic performance in terms of second law efficiency (Exergetic Efficiency\_Cascade\_System) of combined cascaded vapour compression -half effect vapour absorption refrigeration system using HFC-134a is higher than the combined cascaded vapour compression -half effect vapour absorption refrigeration system using HFC-1234yf
- (iii) As Low temperature circuit evaporator Temperature is decreasing, the first law performances ((COP\_Cascade\_System) and second law efficiency (Exergetic efficiency) of cascaded vapour compression -half effect vapour absorption refrigeration system is decreasing and exergy destruction ratio of combined vapour compression-half effect vapour absorption system is increasing.
- (iv) The best thermodynamic performances in terms of first and second law efficiencies have been found by using R141b.
- (v) Use of hydrocarbon is also feasible by considering safety measures because hydrocarbons are flammable.
- (vi) Thermodynamic performances in terms of first and second law efficiencies also affected by variation of generator temperature and also decreasing as generator temperature is increasing.
- (vii) Thermodynamic performances in terms of first and second law efficiencies also affected by variation of absorber temperature and also decreasing as absorber temperature is increasing.
- (viii) Thermodynamic performances in terms of first and second law efficiencies also affected by variation of condenser temperature and also decreasing as condenser temperature is increasing.
- (ix) Thermodynamic performances in terms of first and second law efficiencies also affected by variation of approach (temperature over lapping) and also decreasing as temperature over lapping is increasing.

- (x) By increasing generator temperature , the solar collector area is increasing
- (xi) By increasing condenser temperature , the solar collector area is increasing
- (xii) By increasing absorber temperature , the solar collector area is increasing

### References

- [1]. R Karaali. Exergy analysis of half-effect absorption cooling cycles , International Journal of Engineering Sciences & Research Technology, 2016, DOI: 10.5281/zenodo.154222
- [2]. SC Kaushik, A Arora. Energy and exergy analysis of single effect and series flow double effect water–lithium bromide absorption refrigeration systems International Journal of Refrigeration 32(6), 2009, 1247-1258.
- [3]. SC Kaushik , M Dixit, A Arora. Energy and exergy analysis of a double effect parallel flow LiBr/H<sub>2</sub>O absorption refrigeration system, Journal of Thermal Engineering, 2(1), 2015, 541-549,
- [4]. <http://eds.yildiz.edu.tr/journal-of-thermal-engineering/> / Articles Yildiz Technical University Press, Istanbul, Turkey .
- [5]. LA Domenguez-Inzunza et.al. Comparison of performance of single effect, half effect, double effect in series and inverse absorption cooling system operating with mixture H<sub>2</sub>-Li/Br ISES solar world congress-2013 energy Procedia, 57, 2014, 2534-2543
- [6]. Rabah Gomri, and Riad Hakimi. Second law analysis of double effect vapour absorption cooler system, Energy Conversion and Management, 49, 2008, 3343–3348.
- [7]. J Wang, D Zheng. Performance of one and half effect absorption cooling cycle of H<sub>2</sub>O/LiBr system, Energy Conversion and Management, 50, 2009, 3087-3095.
- [8]. D Colorado, W Rivera. Performance comparison between a conventional vapor compression and compression-absorption single-stage and double-stage systems used for refrigeration, Applied Thermal Engineering, 87, 2015, 273-285.
- [9]. V Jain et.al. Performance analysis of a vapour compression-absorption cascaded refrigeration system with undersized evaporator and condenser, Journal of Energy in Southern Africa, 25(4), 2014