International Journal of Research in Engineering and Innovation (IJREI)
journal home page: http://www.ijrei.com
ISSN (Online): 2456-6934

Thermodynamic performance evaluation of single effect Li/Br H_2O vapour absorption refrigeration system cascaded with vapour compression system using ecofriendly HFC-134a and HFO-1234yf refrigerants

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Abstract

Vapour Absorption system is an attractive method for using the low grade energy directly for cooling. In this paper the effect of performance parameters on the thermodynamic performances of two single effect Li/Br H_2O systems cascaded by vapour compression refrigeration cycle at -53°C of evaporator temperature have been studied in detailed. The comparisons were made for two systems in terms of thermal performances. System-1: consisting of single effect vapour absorption refrigeration system cascaded with vapour compression system using ecofriendly refrigerant (i.e.HFC-134a) and system-2 consisting of single effect vapour absorption refrigeration system cascaded with vapour compression system using ecofriendly refrigerant (HFO-1234yf) (system-2). Numerical computation was carried out using thermal model developed for -53°C of low temperature evaporator circuit by varying various thermodynamic parameters (i.e. such as effect of temperature overlapping (i.e. approach) , generator temperature, absorber temperature, evaporator temperature of single effect Li/Br VARS cycle and evaporator temperature of VCRS cycle, etc.) and it is found that single effect cascade vapour absorption system using HFO-1234yf (System-2) has slightly lower thermodynamic performances in terms of overall coefficient of performances, and exergetic efficiency around 3% lower than single effect Li/Br H_2O vapour absorption refrigeration system cascaded with vapour compression system using ecofriendly HFC-134a refrigerant (system-1). On first law efficiency ($COP_{Cascade}$) and exergetic efficiency of overall system have been presented and found that there is significant effect of performance parameters on overall coefficient of performance and exergetic efficiency of cascade system, i.e. COP is 1.434%, exergetic efficiency is 3.2156% and both types-EDRs is 5.922 lower than using HFC-134a (in system-1)

Keywords: Thermo-dynamic performance Comparison, Ecofriendly refrigerants, Cascade single effect VAR System

1. Introduction

Vapour Absorption system is an attractive method for using the low grade energy directly for cooling. Simple vapour absorption system consists of an absorber, a pump, a generator and a pressure reducing valve to replace the compressor of vapour compression system. This is an important advantage as compared to the conventional vapour compression system which operates on high grade energy. Another important feature of these systems is that they do not use any moving component except for a very small liquid pump. Vapour absorption system consists of four basic components viz. an evaporator, an absorber (located on low pressure side), a generator and a compressor (located on high pressure side). Refrigerant flows from the condenser to the evaporator, then through absorber to the generator and back to condenser, while the absorbent passes from absorber to the generator and back to absorber. For maximum efficiency, the pressure difference between the low pressure side and high pressure side is maintained as small as possible. In some places there is a fluctuation in the amount of heat availability which generates cyclic temperature changes in the cooling volume. This change alters the quality of the stored materials like fruits, meat, bakery products etc. The simple vapour absorption system consists of an absorber, a pump, a generator and a pressure reducing valve to replace the compressor of vapour

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compression system. The other components of the system are condenser, receiver, expansion valve and evaporator as in the vapour compression system. In Lithium bromide absorption system, a solution of lithium bromide and water is used. Water is being used as the refrigerant and Lithium bromide acts as an absorbent. Lithium bromide is a hydroscopic salt with high affinity for water vapour due to its very low vapour pressure. This system is generally used in air conditioning systems due to not very low temperature (above 0˚C) requirements.

In a Li/Br-H_2O bromide vapour absorption system. The absorber and the evaporator are placed in one compartment which operates at the same low pressure of the system. The generator and condenser are placed together in another chamber that operates at the same high pressure of the system. In the absorber, the lithium bromide solution absorbs the water refrigerant, which creates a weak solution of water and lithium bromide. This weak solution is pumped by the pump to the generator where the solution is heated by the available waste heat. The water refrigerant gets vapourized and flows to the condenser where it is cooled while the strong solution of lithium bromide flows back to the absorber where it further absorbs water coming from the Evaporator. In condenser, water refrigerant loses heat and changes its phase into liquid. Then it passes to the evaporator through an expansion valve where pressure is reduced drastically. In evaporator water is sprayed at low pressure which absorbs the heat from the area to be cooled and gets converted into vapour state. The effect of various thermodynamic parameters (such as effect of temperature overlapping i.e. approach , generator temperature, absorber temperature, evaporator temperature of VCRS cycle, Evaporator temperature of single effect Li/Br VARS cycle, heat exchanger effectiveness, etc.) have been presented.

2. Literature Review

Getu and Bansal [1] carried out thermodynamic analysis of cascade refrigeration system using carbon dioxide–ammonia (R744–R717) to optimize operating parameters of the system

Kilicarslan [2] carried out theoretical and experimental investigation of a two-stage vapor compression cascade refrigeration system using R-134a as the refrigerant.

Lee et al. [3] studied carbon dioxide and ammonia as refrigerants in the cascade refrigeration system and carried out thermodynamic analysis to determine the optimal condensing temperature of the cascade condenser to maximize the COP and minimize the exergy destruction of the system

Arora et.al. [4-5] developed energy and exergy analysis of single effect and series flow double effect water– lithium bromide absorption system and found that the irreversibility is highest in the absorber in both systems as compared to other systems.

Gomri [6] developed the thermal models of single effect and double effect absorption refrigeration systems and found the best possible generator temperature and also observed that the first law efficiency (COP) of double effect system is around twice the first law efficiency (COP) of single effect system.

Kilic and Kaynakli [7] carried out energy analysis for finding the performance of a single stage water lithium bromide absorption refrigeration system by varying inputs parameters and found that that the maximum energy loss occurs in generator of the system. S.B. Riffat N. Shankland [8] designed the different types of absorption systems integration with vapour-compression systems. The double-effect parallel continuous absorption systems and their integration with vapour compression systems have been carried out.

Garimella and Brown [9] studied a NH3/H2O cascaded absorption–compression system coupled with subcritical CO2 vapor–compression cycle to breed low-temperature refrigerant. Cimsit and Ozturk [8] carried out thermodynamic analysis of vapour compression absorption cascaded refrigeration system (VCACRS) with H_2O-LiBr and NH_3-H_2O and improved the system performances with lesser amount of energy input. Chinnappa et al. [9] developed a compression-absorption cascaded refrigeration system which consist a conventional refrigerants with a solar operated, NH_3-H_2O, VARS for air conditioning application. Rogdakis and Antonopoulos [10] carried out absorption refrigeration system NH_3/H_2O running by waste heat and found COP lower as compared LiBr absorption refrigeration system. Fernández–Seara et al. [11] proposed a cascaded vapor NH_3/H_2O absorption refrigeration system with a CO2 compression vapour refrigeration system at an evaporation temperature of -45°C and found its COP using energy and exergy analysis.

Mishra [12-15] modelled the cascaded half effect vapour absorption refrigeration cycle coupled with vapour compression cycle. He has improved COP by 40% using the half effect LiBr/H_2O vapour absorption refrigeration cascaded with vapour compression cycle using HFC-134a. It was evidenced that the performances of single effect cascaded vapour absorption refrigeration system coupled with vapour compression cycle significantly higher than that of existing cycle. Thermodynamic analysis of cascade single effect ammonia-water (NH_3-H_20) vapour absorption refrigeration system coupled with vapour compression refrigeration using ecofriendly refrigerants in the low temperature cycle of VCRS system have been carried out and it is found that the dichloro-1-fluoroethane and Penta-fluoro-propane gives improved thermodynamic performances. The method for enhancement in the thermal performances of vapour absorption refrigeration system by using heat pipes developed by Mishra and Dewedi [16] by utilizing the waste heat in the condenser and found increase in COP of vapour absorption refrigeration system.

The above investigators have not gone through detailed analysis for finding performance improvement and the effect of performance parameters using HFC/ 134A and HFO/1234yf refrigerants in vapour compression refrigeration cycle cascaded with single effect LiBr/ H_2O vapour absorption system.

3. Results and Discussions

Following input data have been taken for numerical computation of single effect Li/Br vapour absorption refrigeration system cascaded with vapour compression refrigeration systems using HFC-134a (system-1) and HFO-

1234yf (system-2) refrigerants**.**

(i) Effect of temperature overlapping (Approach= Temperature of cascade condenser vapour compression refrigeration cycle- cascade evaporator temperature of vapour absorption refrigeration cycle) variation from 0 to 18 using HFC-134a and HFO-1234yf refrigerants

(ii) Compressor efficiency= 0.80

(iii) Generator temperature variation single effect Li//Br vapour absorption refrigeration from 70 ºC to 115 ºC,

(iv) Evaporator temperature vapour compression refrigeration system from $T_{\_EVA\_VCRS}$ = - 53ºC.

(v) Evaporator temperature vapour absorption refrigeration system $T_{\_EVA\_VARS}$= 05ºC,

(vi) Refrigeration effect of vapour absorption refrigeration system =29.167 "kW'

3.1 Effect of temperature overlapping(approach =$T_{\_Cond\_VCRS}$ -$T_{\_Eva\_VARS}$)

Table-1 (a-b) shows the variation of approach with variation of thermal performances such as first law efficiency in terms of coefficient of performance (COP) of cascaded vapour absorption system & second law efficiency in terms of exergetic efficiency and exergy destruction ratio based on exergy of fuel of single effect Li/Br-H_2O vapour absorption refrigeration system cascaded with vapour compression refrigeration using HFC-134a refrigerant and it is found that when temperature overlapping in terms of approach (means condenser temperature of vapour compression refrigeration minus evaporator temperature of vapour absorption refrigeration system) is increasing , the thermodynamic performances in terms of ($COP_{\_Cascade}$, exergetic efficiency $_{Cascade\ System}$) is decreasing and EDR_ is increasing. Similarly exergy destruction ratio based on the exergy of product (EDR_Cascade) is also decreasing as shown in table-1(b) respectively.

Table-1 (c) shows the variation of approach with variation of thermal performances such as first law efficiency in terms of coefficient of performance (COP) of cascaded single effect vapour absorption system & second law efficiency in terms of exergetic efficiency and exergy destruction ratio based on exergy of fuel of single effect Li/Br-H_2O vapour absorption refrigeration system cascaded with vapour compression refrigeration using HFO-1234yf refrigerant and it is found that when temperature overlapping in terms of approach (means condenser temperature of vapour compression refrigeration minus evaporator temperature of vapour absorption refrigeration system) is increasing, the thermodynamic performances in terms of ($COP_{\_Cascade}$, Exergetic efficiency$_{_Cascade\ System}$) is decreasing and $EDR_{\_Rational}$ is increasing. Similarly exergy destruction ratio based on the exergy of product ($EDR_{\_Cascade}$) is also decreasing as shown in table-1(d) respectively.

The performance of single effect Li/Br-H_2O vapour absorption system cascaded with vapour compression system using HFC-134a and HFO-1234yf for low temperature circuit evaporator at -53ºC and generator temperature at 110ºC have been compared and also shown in Tables-1 to Tables-2 respectively and it is found that thermodynamic performances using HFO-1234yf in cascaded vapour absorption system (system-2) in terms of COP is 1.434% lower and exergetic efficiency is 3.2156% lower than using HFC-134a For both type of EDRs 5.922% decreasing as temperature overlapping approach is increasing.

(A) Input Parameters for vapour single effect Li/Br-H_2O refrigeration system

- Generator temperature= 110 ºC,
- $T_{\_EVA\_VARS}$= 5ºC,
- Refrigerating Effect=35.167 "kW'
- Condenser temperature ($T_{\_Cond}$)=35ºC
- Absorber temperature ($T_{\_Cond}$)=35ºC

(B) Performance of single effect Vapour Absorption System using energy-exergy method

- First law Efficiency (COP_VARS) =0.741,
- Exergy Destruction Ratio (EDR)=3.412, ,
- Exergetic Efficiency_VARS=0.2241,

(C) PerforCmance of single effect Vapour Absorption System using entropy generation method

- First law Efficiency (COP_VARS) =0.741,
- Exergy Destruction Ratio (EDR)=3.759, ,
- Exergetic Efficiency_VARS=0.2101,

(D) *Input Parameters for vapour compression refrigeration system using HFC-134a*

- Compressor efficiency= 0.80
- $T_{\_EVA\_VCRS}$ = - 53ºC.
- Effect of Approach; 0 to 20

Table-1(a) Effect of approach on exergy destruction ratio ($EDR_{\_Rational}$) of single effect vapour absorption refrigeration cascaded with vapour compression refrigeration system

Temperature overlapping / Approach(ºC)	$COP_{\_Cascade}$	$EDR_{\_Cascade}$	Cascaded System Second Law Efficiency
0	1.036	0.8522	0.5399
2	1.024	0.9024	0.5256
4	1.012	0.9530	0.5118
6	1.0	1.006	0.4984
8	0.9888	1.06	0.4854
10	0.9774	1.116	0.4727
12	0.9660	1.172	0.4603
14	0.9548	1.231	0.4483
16	0.9436	1.291	0.4365
18	0.9325	1.353	0.4251

(A) Input Parameters for vapour Double effect Li/Br-H_2O refrigeration system

- Generator temperature= 110 ^oC,
- $T_{\_EVA\_VARS}$= 5^oC,
- RE=35.167 "kW'
- Condenser temperature (T_ Cond)=35^oC
- Absorber temperature ($T_{\_ Absorber}$)=35^oC

(B) Performance of single effect Vapour Absorption System

- First law Efficiency (COP_VARS) =0.741,
- Exergy Destruction Ratio (EDR)=3.412, ,
- Exergetic Efficiency_VARS=0.2241,

(C) Performance of single effect Vapour Absorption System using entropy generation method

- First law Efficiency (COP_VARS) =0.741,
- Exergy Destruction Ratio (EDR)=3.759, ,
- Exergetic Efficiency_VARS=0.2101,

(D) Input Parameters for vapour compression refrigeration system

- Effect of Approach; 0 to 20 using HFO-1234yf,
- Compressor efficiency= 0.80
- $T_{\_EVA\_VCRS}$ = - 53^oC.

Table-1(b) Effect of approach on exergy destruction ratio ($EDR_{\_Rational}$) of single effect vapour absorption refrigeration cascaded with vapour compression refrigeration system

Temperature overlapping / Approach(^oC)	$COP_{\_VCRS}$	$EDR_{\_VCRS}$	VCRS Second Law Efficiency
0	2.378	0.1862	0.8431
2	2.271	0.2418	0.8053
4	2.171	0.2991	0.7698
6	2.077	0.3581	0.7363
8	1.988	0.419	0.747
10	1.903	0.4819	0.6748
12	1.823	0.5470	0.6464
14	1.747	0.6143	0.6195
16	1.675	0.6841	0.5938
18	1.606	0.7566	0.5693

- Effect of Approach; 0 to 20 using HFO-1234yf, Compressor efficiency= 0.80
- Generator temperature= 110 ^oC, $T_{\_EVA\_VCRS}$ = - 53^oC. $T_{\_EVA\_VARS}$= 5^oC, RE=35.167 "kW'
- Performance of Vapour Absorption System: COP_VARS=1.121, EDR=3.241,
- Exergetic Efficiency_VARS=0.2358,

Table-1(c) Effect of Approach on exergy Destruction Ratio (EDR) of single effect vapour absorption refrigeration cascaded with vapour compression refrigeration system

Temperature overlapping / Approach(^oC)	$COP_{\_Cascade}$	$EDR_{\_Cascade}$	Cascaded System Second Law Efficiency
0	1.027	0.8893	0.5293
2	1.014	0.9448	0.5142
4	1.001	1.002	0.4995
6	0.9886	1.061	0.4852
8	0.9760	1.122	0.4712
10	0.9634	1.186	0.4575
12	0.9509	1.252	0.44441
14	0.9383	1.320	0.4311
16	0.9258	1.391	0.4182
18	0.9133	1.465	0.4057

- Effect of Approach; 0 to 20 using HFO-1234yf, Compressor efficiency= 0.80
- Generator temperature= 110 ^oC, $T_{\_EVA\_VCRS}$ = - 53^oC. $T_{\_EVA\_VARS}$= 5^oC, RE=35.167 "kW'
- Performance of Vapour Absorption System:
- $COP_{\_VARS}$=1.121, EDR $_{VARS}$=3.241,
- $ExergeticEfficiency_{\_VARS}$=0.2358

Table-1(d) Effect of Approach on exergy Destruction Ratio (EDR) of single effect vapour absorption refrigeration cascaded with vapour compression refrigeration system

Temperature overlapping / Approach(^oC)	$COP_{\_VCRS}$	$EDR_{\_VCRS}$	VCRS Second Law Efficiency
0	2.298	0.2273	0.8148
2	2.188	0.2891	0.7758
4	2.084	0.3533	0.7390
6	1.986	0.420	0.7042
8	1.893	0.4897	0.6713
10	1.805	0.5624	0.6401
12	1.722	0.6384	0.6101
14	1.641	0.7181	0.5821
16	1.565	0.8017	0.5550
18	1.493	0.8898	0.5292

3.2 Effect of of low temperature evaporator temperature of vapour compression refrigeration cycle on thermal performances of single effect vapour absorption refrigeration cascaded with vapour compression refrigeration system

Table-2 (a) shows the variation of low temperature evaporator circuit temperature with variation of thermal performances such as first law efficiency in terms of coefficient of performance (COP) of cascaded vapour absorption system & second law efficiency in terms of exergetic efficiency and exergy destruction ratio based on exergy of fuel of single effect Li/Br-H_2O vapour absorption refrigeration system cascaded with vapour compression refrigeration using HFC-134a refrigerant and it is found that when low temperature evaporator circuit temperature of vapour absorption refrigeration system is increasing, the thermodynamic performances in terms of (COP_{Cascad},) is decreasing and exergetic efficiency$_{Cascade\ System}$ is also decreasing and $EDR_{Rational}$ is increasing . Similarly exergy destruction ratio based on the exergy of product ($EDR_{Cascade}$) is also decreasing and exergetic efficiency is increasing.as shown in table-2(b) respectively. The optimum values of single effect vapour absorption refrigeration cycle cascaded with vapour compression cycle for generator temperature of 110ºC and condenser temperature and absorber temperature of 35ºC by using HFO-1234yf refrigerant(system-2) has 1.353% lower COP and 3.036% lower exergetic efficiency and 5.703% higher EDR than System-1 using HFC-134a

(A) Input Parameters for vapour single effect Li/Br-H_2O refrigeration system

- Generator temperature= 110 ºC,
- T_{EVA_VARS}= 5ºC,
- RE=29.167 "kW'
- Condenser temperature (T_ Cond)=35ºC
- Absorber temperature ($T_{Absorber}$)=35ºC

(B) Performance of single effect Vapour Absorption System

- COP_VARS=0.7410, (vii) EDR=3.462,
- ExergeticEfficiency_VARS=0.2241

(C) Performance of single effect Vapour Absorption System using entropy generation method

- COP_VARS=0.7410, (vii) Irreversibility Ratio=3.759.
- Exergetic Efficiency_VARS=0.2101

(D) Performance of single effect Vapour Absorption System

- COP_VARS=0.7410,
- Maximum COP_VARS=1.815
- Exergetic Efficiency_VARS=0.4083

(E) Input Parameters for vapour compression refrigeration system

- Effect of Approach; 10 using HFC-134a,
- Compressor efficiency= 0.80
- T_{EVA_VCRS} = - 53ºC.

Table-2(a) Effect of evaporator Temperature VCRS Evaporator on thermal performances of single effect vapour absorption refrigeration cascaded with vapour compression refrigeration system

Temperature VCRS Evaporator $T_{\_Evaporator}$(ºC)	$COP_{\_Cascade}$	$EDR_{\_Cascade}$	Cascaded System Second Law Efficiency
- 40	0.9774	1.116	0.4727
- 45	0.9839	1.112	0.4735
-50	0.9904	1.108	0.4743
-51	0.9970	1.105	0.4751
-52	1.030	1.092	0.4781
-53	1.099	1.083	0.4802

(A) Input Parameters for vapour ***single*** *effect Li/Br-H_2O refrigeration system*

- Generator temperature= 110 ºC,
- T_{EVA_VARS}= 5ºC,
- RE=35.167 "kW'
- Condenser temperature (T_ Cond)=35ºC
- Absorber temperature ($T_{Absorber}$)=35ºC

(B) Performance of single effect Vapour Absorption System

- COP_VARS=07410, (vii) EDR=3.759,
- ExergeticEfficiency_VARS=0.2101,

(C) Performance of single effect Vapour Absorption System

- COP_VARS=07410, (vii) EDR=3.462
- ExergeticEfficiency_VARS=0.2241

(D) Performance of single effect Vapour Absorption System

- COP_VARS=07410, (vii) EDR=3.759,
- ExergeticEfficiency_VARS=0.2101,

(E) Input Parameters for vapour compression refrigeration system

- Effect of Approach; 10 using HFC-134a,
- Compressor efficiency= 0.80
- T_{EVA_VCRS} = - 53ºC.

Table-2(b) Effect of evaporator Temperature VCRS Evaporator on thermal performances of single effect vapour absorption refrigeration cascaded with vapour compression refrigeration system

Temperature VCRS Evaporator $T_{\_Evaporator}$(ºC)	$COP_{\_VCRS}$	$EDR_{\_VCRS}$	VCRS Second Law Efficiency
- 40	1.903	0.4819	0.6748
- 45	1.951	0.4713	0.6797
-50	2.0	0.4607	0.6846
-51	2.05	0.4501	0.6896
-52	2.33	0.3981	0.7153
-53	3.063	0.2952	0.7721

(A) Input Parameters for vapour single effect Li/Br-H_2O refrigeration system:

- Generator temperature= 110 ºC,
- T_{EVA_VARS}= 5ºC,
- RE=29.167 "kW'
- Condenser temperature (T_ Cond)=35ºC
- Absorber temperature ($T_{Absorber}$)=35ºC

(B) Performance of single effect Vapour Absorption System using entropy generation method

- COP_VARS=07410, (vii) EDR=3.759,
- ExergeticEfficiency_VARS=0.2101,

(C) Performance of single effect Vapour Absorption System

- COP_VARS=07410, (vii) EDR=3.462,
- ExergeticEfficiency_VARS=0.2241,

(D) Performance of single effect Vapour Absorption System

- COP_VARS=07410, (vii) EDR=3.759,
- ExergeticEfficiency_VARS=0.2101,

(E) Input Parameters for vapour compression refrigeration system

- Effect of Approach; 10 using HFO-1234yf,
- Compressor efficiency= 0.80
- $T_{\_EVA\_VCRS}$ = - 53°C.

Table-2(b) Effect of evaporator Temperature VCRS Evaporator on thermal performances of single effect vapour absorption refrigeration cascaded with vapour compression refrigeration system

Temperature VCRS Evaporator $T_{\_Evaporator}$ (°C)	$COP_{\_Cascade}$	$EDR_{\_Cascade}$	Cascaded System Second Law Efficiency
- 40	0.9634	1.186	0.4575
- 45	0.9702	1.180	0.4587
-50	0.9770	1.175	0.4599
-51	0.9839	1.169	0.4610
-52	1.019	1.147	0.4658
-53	1.054	1.131	0.4692

(A) Input Parameters for vapour single effect Li/Br-H_2O refrigeration system

- Generator temperature= 110 °C,
- $T_{\_EVA\_VARS}$= 5°C,
- RE= 35.167"kW'
- Condenser temperature (T_ Cond)=35°C
- Absorber temperature ($T_{\_ Absorber}$)=35°C

(B) Performance of single effect Vapour Absorption System using entropy generation method

- COP_VARS=0.7410, (vii) EDR=3.759,
- ExergeticEfficiency_VARS=0.2101,

(C) Performance of single effect Vapour Absorption System

- COP_VARS=07410, (vii) EDR=3.462,
- ExergeticEfficiency_VARS=0.2241.

(D) Performance of single effect Vapour Absorption System

- COP_VARS=07410, (vii) EDR=3.759,
- Exergetic Efficiency_VARS=0.2101,

(E) Input Parameters for vapour compression refrigeration system

- Effect of Approach; 10 using HF-134a,
- Compressor efficiency= 0.80
- $T_{\_EVA\_VCRS}$ = - 53°C.

Table-2(b) Effect of evaporator Temperature VCRS Evaporator on thermal performances of single effect vapour absorption refrigeration cascaded with vapour compression refrigeration system

Temperature VCRS Evaporator $T_{\_Evaporator}$(°C)	$COP_{\_VCRS}$	$EDR_{\_VCRS}$	VCRS Second Law Efficiency
- 40	1.805	0.5624	0.6401
- 45	1.852	0.5496	0.6453
-50	1.901	0.5369	0.6507
-51	1.951	0.5243	0.6560
-52	2.227	0.4626	0.6837
-53	2.553	0.4023	0.7131

The optimum value of second law efficiency of single effect Li/Br H_2O vapour absorption refrigeration system at 5°C of VARS evaporator temperature using HFO-1234yf occurred between VCRS evaporator temperature -30°C to -34°C (i.e. -31°C, -32°C and -33°C. The optimum exergetic efficiency is 46.67% with exergy destruction ratio is 1.143 and rational exergy destruction ratio is 0.5333) and similar second law performance (exergetic efficiency= 46.66%) which is less than optimum exergetic efficiency occurred at -30°C and -34°C. Table-2 (b) shows the variation of low temperature evaporator circuit temperature with variation of thermal performances such as first law efficiency in terms of coefficient of performance (COP) of cascaded vapour absorption system & second law efficiency in terms of exergetic efficiency and exergy destruction ratio based on exergy of fuel of single effect Li/Br-H_2O vapour absorption refrigeration system cascaded with vapour compression refrigeration using HFO-1234yf refrigerant and it is found that when low temperature evaporator circuit temperature of single effect Li/Br H_2O vapour absorption is increasing, the thermodynamic performances in terms of ($COP_{\_Cascade}$) &Exergetic $efficiency_{\_Cascade\ System}$ is decreasing and $EDR_{\_Rational}$ is increasing. Similarly exergy destruction ratio based on the exergy of product ($EDR_{\_Cascade}$) is also decreasing and low temperature evaporator circuit temperature increasing along with exergetic efficiency of cascaded system is increasing as shown in table-2(d) respectively. The performance of single effect Li/Br-H_2O vapour absorption system cascaded with vapour compression system using HFC-134a and HFO-1234yf for low temperature circuit evaporator at -53°C have been compared and also shown in Table-2(a) & Table-2(d) respectively and it is found that thermodynamic performances using HFO-1234yf in cascaded vapour absorption system in terms of COP is 1.643 % and exergetic efficiency is 3.201% lower than using HFC-134a.

3.3 Comparison between VCRS performance using HFC-134a and HFO-1234yf refrigerants at $T_{\_Evaporator}$ = -30 (°C)

(A) Input Parameters for vapour single effect Li/Br-H_2O refrigeration system

- Generator temperature= 110 °C,
- $T_{\_EVA\_VARS}$= 5°C,
- RE=35.167 "kW'
- Condenser temperature (T_ Cond)=35°C
- Absorber temperature ($T_{\_ Absorber}$)=35°C

(B) Performance of single effect Vapour Absorption System

- COP_VARS=0.7410, (vii) EDR=3.462,
- Exergetic Efficiency_VARS=0.2241,

(C) Performance of single effect Vapour Absorption System using entropy generation method

- COP_VARS=0.7410, (vii) EDR=3.759,
- Exergetic Efficiency_VARS=0.2101,

(D) Performance of single effect Vapour Absorption System

- COP_VARS=0.7410, (vii) Maximum $COP_{\_VARS}$=1.815
- Second law (Exergetic) $Efficiency_{\_VARS}$=0.4083,

(E) Input Parameters for vapour compression refrigeration system

- Using HFC-134a, R1234ze and R-1234yf
- Effect of Approach; 10
- Compressor efficiency= 0.80
- $T_{\_EVA\_VCRS}$ = - 30°C.

Table-3(a) Effect of ecofriendly refrigerants in the VCRS on thermal performances of single *effect vapour absorption refrigeration cascaded with vapour compression refrigeration system*

Ecofriendly Refrigerants	$COP_{Cascade}$	Rational $EDR_{\_Cascade}$	Cascaded System Second Law Efficiency
R134a	1.135	1.088	0.4790
R1234ze	1.133	1.094	0.4776
R1234yf	1.127	1.121	0.4716

(A) Input Parameters for vapour single effect Li/Br-H_2O refrigeration system

- Generator temperature= 110 °C,
- $T_{\_EVA\_VARS}$= 5°C,
- RE=29.167 "kW'
- Condenser temperature (T_ Cond)=35°C
- Absorber temperature ($T_{\_ Absorber}$)=35°C

(B) Performance of single effect Vapour Absorption System

- COP_VARS=1.121, (vii) EDR=3.24,
- Exergetic Efficiency_VARS=0.2358,

(C) Input Parameters for vapour compression refrigeration system

- Using HFC-134a, R1234ze and R-1234yf
- Effect of Approach; 10
- Compressor efficiency= 0.80
- $T_{\_EVA\_VCRS}$ = - 30°C.

Table-3(b) Effect of ecofriendly refrigerants in the VCRS on VCRS thermal performances of vapour compression refrigeration system cascaded with single *effect vapour absorption refrigeration system.*

Ecofriendly Refrigerants	COP_{VCRS}	Rational $EDR_{\_Cascade}$	Cascaded System Second Law Efficiency
R134a	3.555	0.2428	0.8046
R1234ze	3.535	0.2499	0.8001
R1234yf	3.444	0.2829	0.7795

Table-3(a) and Table-3(b) show, the effect of ecofriendly HFC-134a and HFO refrigerants in low temperature circuit with variation of thermal performances such as first law efficiency in terms of coefficient of performance (COP) of cascaded vapour absorption system & second law efficiency in terms of exergetic efficiency and exergy destruction ratio based on exergy of fuel of single effect Li/Br-H_2O vapour absorption refrigeration system cascaded with vapour compression refrigeration at -30°C and it is found that the performance of HFC-134a refrigerant and HFO-1234ze are nearly similar with the variation of 0.5626% in first law efficiency and 0.559% in second law efficiency while the performance of HFC-134a is superior than HFO- 1234yf refrigerant. Therefore both HFO refrigerants can replace HFC-134a refrigerant in near future due to its very low global warming potential (i.e. GWP of R1234ze is 6 and GWP of R1234yf is 4 respectively as compared to GWP of HFC-134a is 1360).

3.4 Variation of vapour absorption refrigeration system evaporator temperature of vapour absorption system, when absorber temperature is same as condenser temperature

- Evaporator temperature (T_{EVA_VARS}) varying from 5ºC to 10ºC
- Generator temperature =110 ºC
- VCRS using HFC-134a , Compressor efficiency= 0.80
- Approach=10, T_{EVA_VCRS} = - 53ºC. T_{EVA_VARS}= 5ºC, RE=35.167 "kW'
- Performance of Vapour compression System COP_VCRS=1.71, EDR=,0.6492
- Exergetic Efficiency_VCRS=0.6064, $EDR_{Rational}$ =0.3936

Table-5(a) Effect of vapour absorption refrigeration system evaporator temperature on thermal performances of single effect vapour absorption refrigeration cascaded with vapour compression refrigeration system

Vapour absorption system evaporator temperature (ºC)	$COP\_{Cascade}$	$EDR\_{Cascade}$	Cascaded System Second Law Efficiency
05	0.9773	1.116	0.4726
06	0.9745	1.168	0.4613
07	0.9717	1.222	0.4501
08	0.9891	1.277	0.4391
09	0.9665	1.335	0.4283
10	0.9641	1.394	0.4177

- Evaporator temperature (T_{EVA_VARS}) varying from 5ºC to 10ºC
- Generator temperature =110 ºC
- VCRS using HFC-134a , Compressor efficiency= 0.80
- Approach=10, T_{EVA_VCRS} = - 53ºC. T_{EVA_VARS}= 5ºC, RE=35.167 "kW'
- Performance of Vapour compression System: COP_VCRS=1.71, EDR=,0.6492
- Exergetic efficiency_VCRS=0.6064, $EDR_{Rational}$ =0.3936

Table-5(b) Effect of Vapour absorption system evaporator temperature ($T\_{evaporator}$)*on thermal performances of single e effect vapour absorption refrigeration cascaded with vapour compression refrigeration system*

Vapour absorption system evaporator temperature ($T\_{evaporator}$)	COP_{VARS}	EDR_{VARS}	VARS Second Law Efficiency
05	0.7410	3.462	0.2241
06	0.7438	3.68	0.2137
07	0.7466	3.921	0.2032
08	0.7496	4.19	1.927
09	0.7527	4.491	1.821
10	0.7560	4.832	0.1715

- Evaporator temperature (T_{EVA_VARS}) varying from 5ºCto 10ºC
- Generator temperature =110 ºC
- VCRS using HFC-134a , Compressor efficiency= 0.80
- Approach=10, T_{EVA_VCRS} = - 53ºC. T_{EVA_VARS}= 5ºC, RE=35.167 "kW'
- Performance of Vapour compression System: COP_VCRS= 1.71, EDR=,0.6492
- Exergetic Efficiency_VCRS=0.6064, $EDR_{Rational}$ =0.3936.

Table-5(d) Effect of generator temperature on thermal performances of single effect vapour absorption refrigeration cascaded with vapourcompression refrigeration system

Vapour absorption system evaporator temperature ($T\_{evaporator}$)	COP_{VARS}	EDR_{VARS}	VARS Second Law Efficiency
05	0.7410	3.759	0.2101
06	0.7438	3.939	0.2025
07	0.7466	4.36	0.1946
08	0.7496	4.19	1.866
09	0.7527	4.609	1.783
10	0.7560	4.89	0.1698

- Evaporator temperature (T_{EVA_VARS}) varying from 5ºCto 10ºC
- Generator temperature =110 ºC
- VCRS using HFC-134a , Compressor efficiency= 0.80
- Approach=10, T_{EVA_VCRS} = - 53ºC. T_{EVA_VARS}= 5ºC, RE=35.167 "kW'
- Performance of Vapour compression System: COP_VCRS=1.71, EDR=,0.6492
- Exergetic Efficiency_VCRS=0.6064, $EDR_{Rational}$ =0.3936.

Table-5(d) Effect of generator temperature on thermal performances of single effect vapour absorption refrigeration cascaded with vapou rcompression refrigeration system

Vapour absorption system evaporator temperature ($T\_{evaporator}$)	COP_{VARS}	Maximum COP_VARS	VARS Second Law Efficiency
05	0.7410	1.815	0.4083
06	0.7438	1.884	0.3947
07	0.7466	1.959	0.3812
08	0.7496	2.038	0.3678
09	0.7527	2.124	0.3543
10	0.7560	2.217	0.3410

- Evaporator temperature (T_{EVA_VARS}) varying from 5ºC to 10ºC
- Generator temperature =110 ºC
- VCRS using HFC-1234yf , Compressor efficiency= 0.80
- Approach=10, T_{EVA_VCRS} = - 53ºC. T_{EVA_VARS}= 5ºC, RE=35.167 "kW'
- Performance of Vapour compression System: COP_VCRS=1.588, EDR=,0.7759
- Exergetic Efficiency_VCRS=0.5631, $EDR_{Rational}$ =0.4369.

Table-5(c) Effect of Vapour absorption system evaporator temperature ($T_{\_evaporator}$) *on thermal performances of single effect vapour absorption refrigeration cascaded with vapour compression refrigeration system*

Vapour absorption system evaporator temperature ($T_{\_evaporator}$) (°C)	COP_ Cascade	EDR_ Cascade	Cascaded System Second Law Efficiency
05	0.9613	1.197	0.4552
06	0.9577	1.255	0.4434
07	0.9542	1.316	0.4317
08	0.9508	1.379	0.4203
09	0.9474	1.445	0.4090
10	0.9441	1.513	0.3979

- Evaporator temperature ($T_{\_EVA\_VARS}$) varying from 5°Cto 10°C
- Generator temperature =110 °C
- VCRS using HFC-1234yf , Compressor efficiency= 0.80
- Approach=10, $T_{\_EVA\_VCRS}$ = - 53°C. $T_{\_EVA\_VARS}$= 5°C, RE=35.167 "kW'
- Performance of Vapour compression System:COP_VCRS=1.588, EDR=,0.7759
- ExergeticEfficiency_VCRS=0.5631, $EDR_{\_Rational}$ =0.4369.

Table-5(d) Effect of generator temperature on thermal performances of single effect vapour absorption refrigeration cascaded with vapour compression refrigeration system

Vapour absorption system evaporator temperature ($T_{\_evaporator}$)	$COP_{\_VARS}$	EDR_ VARS	VARS Second Law Efficiency
05	0.7410	3.462	0.2241
06	0.7438	3.68	0.2137
07	0.7466	3.921	0.2032
08	0.7496	4.19	1.927
09	0.7527	4.491	1.821
10	0.7560	4.832	0.1715

- Evaporator temperature ($T_{\_EVA\_VARS}$) varying from 5°Cto 10°C
- Generator temperature =110 °C
- VCRS using HFC-1234yf , Compressor efficiency= 0.80
- Approach=10, $T_{\_EVA\_VCRS}$ = - 53°C. $T_{\_EVA\_VARS}$= 5°C, RE=35.167 "kW'
- Performance of Vapour compression System:COP_VCRS=1.588, EDR=,0.7759
- ExergeticEfficiency_VCRS=0.5631, $EDR_{\_Rational}$ =0.4369 .

Table-5(d) Effect of generator temperature on thermal performances of single effect vapour absorption refrigeration cascaded with vapourcompression refrigeration system using entropy generation method

Vapour absorption system evaporator temperature ($T_{\_evaporator}$)	$COP_{\_VARS}$	EDR_ VARS	VARS Second Law Efficiency
05	0.7410	3.759	0.2101
06	0.7438	3.939	0.2025
07	0.7466	4.36	0.1946
08	0.7496	4.19	1.866
09	0.7527	4.609	1.783
10	0.7560	4.89	0.1698

- Evaporator temperature ($T_{\_EVA\_VARS}$) varying from 5°Cto 10°C
- Generator temperature =110 °C
- VCRS using HFC-1234yf , Compressor efficiency= 0.80
- Approach=10, $T_{\_EVA\_VCRS}$ = - 53°C. $T_{\_EVA\_VARS}$= 5°C, RE=35.167 "kW'
- Performance of Vapour compression System:COP_VCRS=1.588, EDR=,0.7759
- Exergetic Efficiency_VCRS=0.5631, $EDR_{\_Rational}$ = 0.4369.

Table-5(d) Effect of generator temperature on thermal performances of single effect vapour absorption refrigeration cascaded with vapour compression refrigeration system

Vapour absorption system evaporator temperature	COP_VA RS	Maximum COP_VARS	VARS Second Law Efficiency
05	0.7410	1.815	0.4083
06	0.7438	1.884	0.3947
07	0.7466	1.959	0.3812
08	0.7496	2.038	0.3678
09	0.7527	2.124	0.3543
10	0.7560	2.217	0.3410

Table-5 (a) shows the variation of Vapour absorption system evaporator temperature ($T_{\_evaporator}$)with variation of thermal performances such as first law efficiency in terms of coefficient of performance (COP) of cascaded vapour absorption system & second law efficiency in terms of exergetic efficiency and exergy destruction ratio based on exergy of fuel of single effect Li/Br-H_2Ovapour absorption refrigeration system cascaded with vapour compression refrigeration using HFC-134a refrigerant and it is found that when Vapour absorption system evaporator temperature ($T_{\_evaporator}$)of vapour absorption refrigeration system is increasing, the thermodynamic performances in terms of ($COP_{\_Cascad}$,) is decreasing and Exergetic efficiency $_{\_CascadeSystem}$ is increasing and $EDR_{\_Rational}$ is decreasing . Similarly exergy destruction ratio based on the exergy of product ($EDR_{\_Cascade}$) is also decreasing and exergetic efficiency is increasing.as shown in table-5(b) respectively. Table-5 (c) shows the variation of generator temperature with variation of thermal performances such as first law efficiency in terms of coefficient of performance (COP) of cascaded vapour absorption system & second law efficiency in terms of exergetic efficiency and exergy destruction ratio based on exergy of fuel of single effect Li/Br-H_2O vapour absorption refrigeration system cascaded with vapour compression refrigeration using HFO-1234yf refrigerant and it is found that when generator temperature of tripple effect Li/Br H_2O vapour absorption is increasing , the thermodynamic performances in terms of ($COP_{\_Cascade}$) &$EDR_{\_Rational}$ is decreasing and Exergetic efficiency$_{_Cascade\ System}$) is increasing. Similarly exergy destruction ratio based on the exergy of product ($EDR_{\_Cascade}$) is also decreasing and generator temperature increasing along with exergetic efficiency of cascaded system is increasing as shown in table-5(d) respectively.

The performance of single effect Li/Br-H_2O vapour absorption system cascaded with vapour compression system using HFC-134a and HFO-1234yf for low temperature circuit evaporator at -53°C and Vapour absorption system evaporator temperature at 5°C have been compared and also shown in Table-5(a) to Tables-5(d) respectively and it is found that thermodynamic performances using HFO-1234yf (system-2)in cascaded vapour absorption system in terms of COP is 3.87223% and exergetic efficiency is 4.2815 % lower than using HFC-134a (system-1)with increasing 7.9875% at 8°C of evaporator of single effect vapour absorption systems. .

3.5 Variation of generator temperature of vapour absorption system, when absorber temperature is same as condenser temperature

Table-6 (a) shows the variation of generator temperature with variation of thermal performances such as first law efficiency in terms of coefficient of performance (COP) of cascaded vapour absorption system & second law efficiency in terms of exergetic efficiency and exergy destruction ratio based on exergy of fuel of single effect Li/Br-H_2Ovapour absorption refrigeration system cascaded with vapour compression refrigeration using HFC-134a refrigerant and it is found that when generator temperature of vapour absorption refrigeration system is increasing , the thermodynamic performances in terms of (COP_{Cascad}) is decreasing and Exergetic $efficiency\_{Cascade\ System}$ is increasing and $EDR\_{Rational}$ is decreasing . Similarly exergy destruction ratio based on the exergy of product ($EDR\_{Cascade}$) is also decreasing and exergetic efficiency is increasing.as shown in table-6(b) respectively. Table-6 (c) shows the variation of generator temperature with variation of thermal performances such as first law efficiency in terms of coefficient of performance (COP) of cascaded vapour absorption system & second law efficiency in terms of exergetic efficiency and exergy destruction ratio based on exergy of fuel of single effect Li/Br-H_2O vapour absorption refrigeration system cascaded with vapour compression refrigeration using HFO-1234yf refrigerant and it is found that when generator temperature of single effect Li/Br H_2O vapour absorption is increasing , the thermodynamic performances in terms of ($COP\_{Cascade}$) &$EDR\_{Rational}$ is decreasing and Exergetic $efficiency\_{Cascade\ System}$) is increasing. Similarly exergy destruction ratio based on the exergy of product ($EDR\_{Cascade)}$ is also decreasing and generator temperature increasing along with exergetic efficiency of cascaded system is increasing as shown in table-6(b) respectively. The performance of single effect Li/Br-H_2O vapour absorption system cascaded with vapour compression system using HFC-134a and HFO-1234yf for low temperature circuit evaporator at -53°C and generator temperature at 110°C have been compared and also shown in Table-6(a) to Tables-6(d) respectively and it is found that thermodynamic performances using HFO-1234yf (system-2) in cascaded vapour absorption system in terms of COP is 1.4322% lower and exergetic efficiency is 3.3044 % lower than using HFC-134a(System-1).

- Generator temperature varing from 80 to 115 °C
- VCRS using HFC-134a , Compressor efficiency= 0.80
- Approach=10, T_{EVA_VCRS} = - 53°C. T_{EVA_VARS}= 5°C, RE=29.167 "kW'
- Performance of Vapour compression System: COP_VCRS=1.903,
- Exergetic $Efficiency\_{VCRS}$=0.6748 , $EDR\_\_{VCRS}$=0.4819.

Table-6(a) Effect of generator temperature on thermal performances of single effect vapour absorption refrigeration cascaded with vapour compression refrigeration system

$T\_{generator}$ (°C)	$COP\_{Cascade}$	Rational $EDR\_{Cascade}$	Cascaded System Second Law Efficiency
80	1.013	0.792	0.5580
85	1.004	0.8497	0.5406
90	0.9968	0.9062	0.5246
95	0.9901	0.9614	0.5099
100	0.9845	1.015	0.4963
105	0.9802	1.067	0.4839
110	0.9774	1.116	0.4727
115	0.975	1.163	0.4623

- Generator temperature varing from 80 to 115 °C
- VCRS using HFC-134a , Compressor efficiency= 0.80
- Approach=10, T_{EVA_VCRS} = - 53°C. T_{EVA_VARS}= 5°C, RE = 35.167 "kW'
- Performance of Vapour compression System: COP_VCRS =1.903,
- Exergetic $Efficiency\_{VCRS}$=0.6748 , $EDR\_\_{VCRS}$=0.4819.

Table-6(b) Effect of generator temperature on thermal performances of single effect vapour absorption refrigeration cascaded with vapour compression refrigeration system

$T\_{generator}$ (°C)	COP_{VARS}	EDR_{VARS}	VARS Second Law Efficiency
80	0.7752	1.995	0.3339
85	0.7669	2.256	0.3071
90	0.7596	2.513	0.2847
95	0.7532	2.763	0.2658
100	0.7479	3.006	0.2496
105	0.7438	3.24	0.2359
110	0.7410	3.462	0.2241
115	0.7388	3.678	0.2138

- Generator temperature varing from 80 to 115 °C
- VCRS using HFC-134a , Compressor efficiency= 0.80
- Approach=10, T_{EVA_VCRS} = - 53°C. T_{EVA_VARS}= 5°C, RE= 35.167 "kW'
- Performance of Vapour compression System: COP_VCRS= 1.903,
- $ExergeticEfficiency\_{VCRS}$=0.6748 ,
- $EDR\_\_{VCRS}$=0.4819.

Table-6(b) Effect of generator temperature on thermal performances of single effect vapour absorption refrigeration cascaded with vapour compression refrigeration system using entropy generation method

$T_{\_generator}$ (°C)	COP_{VARS}	Irreversibility Coefficient	VARS Second Law Efficiency
80	0.7752	3.555	0.2195
85	0.7669	3.603	0.2172
90	0.7596	3.646	0.2152
95	0.7532	3.684	0.2135
100	0.7479	3.717	0.2120
105	0.7438	3.742	0.2109
110	0.7410	3.759	0.2101
115	0.7388	3.773	0.2095

- Generator temperature varing from 80 to 115 °C
- VCRS using HFC-134a , Compressor efficiency= 0.80
- Approach=10, $T_{\_EVA\_VCRS}$ = - 53°C. $T_{\_EVA\_VARS}$= 5°C, RE=35.167 “kW’
- Performance of Vapour compression System: COP_VCRS=1.903,
- Exergetic $Efficiency_{\_VCRS}$=0.6748 , $EDR_{\_\_VCRS}$=0.4819.

Table-6(b) Effect of generator temperature on thermal performances of single effect vapour absorption refrigeration cascaded with vapour compression refrigeration system

$T_{\_generator}$ (°C)	COP_{VARS}	Maximum COP_VARS	VARS Second Law Efficiency
80	0.7752	1.181	0.6562
85	0.7669	1.294	0.5925
90	0.7596	1.404	0.5409
95	0.7532	1.511	0.4985
100	0.7479	1.615	0.463
105	0.7438	1.716	0.4334
110	0.7410	1.815	0.4083
115	0.7388	1.911	0.3866

- Generator temperature varing from 80 to 115 °C
- VCRS using HFO-1234yf , Compressor efficiency= 0.80
- Approach=10, $T_{\_EVA\_VCRS}$ = - 53°C. $T_{\_EVA\_VARS}$= 5°C, RE=35.167 “kW’
- Performance of Vapour compression System:COP_VCRS=1.805, EDR=,1.117
- ExergeticEfficiency_VCRS=0.5624, EDR_{VCRS}=0.6401 .

Table-6(c) Effect of generator temperature on thermal performances of single *effect vapour absorption refrigeration cascaded with vapour compression refrigeration system*

$T_{\_generator}$ (°C)	$COP\_{Cascade}$	$EDR\_{Cascade}$	Cascaded System Second Law Efficiency
80	0.9983	0.8575	0.5383
85	0.9898	0.9160	0.5219
90	0.9824	0.9733	0.5088
95	0.9759	1.029	0.4928
100	0.9704	1.084	0.4799
105	0.9662	1.136	0.4682
110	0.9634	1.186	0.4575
115	0.9601	1.234	0.4476

- Generator temperature varing from 80 to 115 °C
- VCRS using HFC-1234yf , Compressor efficiency= 0.80
- Approach=10, $T_{\_EVA\_VCRS}$ = - 53°C. $T_{\_EVA\_VARS}$= 5°C, RE=35.167 “kW’
- Performance of Vapour compression System: COP_VCRS=1.805,
- Exergetic $Efficiency_{\_VCRS}$=0.6748 , $EDR_{\_\_VCRS}$=0.6401.

Table-6(b) Effect of generator temperature on thermal performances of triple effect vapour absorption refrigeration cascaded with vapour compression refrigeration system

$T_{\_generator}$ (°C)	COP_{VARS}	EDR_{VARS}	VARS Second Law Efficiency
80	0.7752	1.995	0.3339
85	0.7669	2.256	0.3071
90	0.7596	2.513	0.2847
95	0.7532	2.763	0.2658
100	0.7479	3.006	0.2496
105	0.7438	3.24	0.2359
110	0.7410	3.462	0.2241
115	0.7388	3.678	0.2138

- Generator temperature varying from 80 to 115 ºC
- VCRS using HFC-134a , Compressor efficiency= 0.80
- Approach=10, $T_{\_EVA\_VCRS}$ = - 53°C. $T_{\_EVA\_VARS}$= 5°C, RE=35.167 “kW’
- Performance of Vapour compression System: COP_VCRS=1.805,
- Exergetic $Efficiency_{\_VCRS}$=0.6748, $EDR_{\_\_VCRS}$=0.6401.

Table-6(b) Effect of generator temperature on thermal performances of single *effect vapour absorption refrigeration cascaded with vapour compression refrigeration system*

$T_{\_generator}$ (°C)	COP_{VARS}	Irreversibility Coefficient	VARS Second Law Efficiency
80	0.7752	3.555	0.2195
85	0.7669	3.603	0.2172
90	0.7596	3.646	0.2152
95	0.7532	3.684	0.2135
100	0.7479	3.717	0.2120
105	0.7438	3.742	0.2109
110	0.7410	3.759	0.2101
115	0.7388	3.773	0.2095

- Generator temperature varing from 80 to 115 °C
- VCRS using HFC-1234yf , Compressor efficiency= 0.80
- Approach=10, $T_{\_EVA\_VCRS}$ = - 53°C. $T_{\_EVA\_VARS}$= 5°C, RE=29.167 “kW’
- Performance of Vapour compression System: COP_VCRS=1.805,
- $ExergeticEfficiency_{\_VCRS}$=0.6748 , $EDR_{\_\_VCRS}$=0.6401.

Table-6(b) Effect of generator temperature on thermal performances of single *effect vapour absorption refrigeration cascaded with vapour compression refrigeration system*

$T_{\_generator}$ (°C)	COP_{VARS}	Maximum COP_VARS	VARS Second Law Efficiency
80	0.7752	1.181	0.6562

85	0.7669	1.294	0.5925
90	0.7596	1.404	0.5409
95	0.7532	1.511	0.4985
100	0.7479	1.615	0.463
105	0.7438	1.716	0.4334
110	0.7410	1.815	0.4083
115	0.7388	1.911	0.3866

3.6 Variation of condenser temperature of vapour absorption system, when absorber temperature is same as condenser temperature

- Evaporator temperature of VARS using HFC-134a = -53ºC, Compressor efficiency= 0.80
- Single effect Li/Br-H_2O VARS
- Approach=10, $T_{\_generator}$= 110ºC. $T_{\_EVA\_VARS}$= 05ºC, RE =29.167 "kW', T_Absorber=T_Cond
- Performance of Vapour compression System: COP_VCRS=1.903,
- Exergetic Efficiency$_{_VCRS}$=,0.2630, $EDR_{\_VCRSI}$=0.4822.

Table-7(a) Effect of condenser temperature of VARS on thermal performances of single effect vapour absorption refrigeration cascaded with vapour compression refrigeration system when $T_{\_Cond}$=$T_{\_Absorber}$

T_Cond	$COP_{\_Cascade}$	$EDR_{\_Cascade}$	Cascaded System Second Law Efficiency
31	0.9827	1.109	0.4741
32	0.9414	1.111	0.4738
33	0.9801	1.112	0.4734
34	0.9787	1.114	0.4730
35	0.9773	1.116	0.4726
36	0.9760	1.118	0.4722
37	0.9747	1.119	0.4719
38	0.9735	1.121	0.4715
39	0.9724	1.222	0.4712
40	0.9713	1.123	0.4709

- Evaporator temperature of VARS using HFC-134a = -53ºC, Compressor efficiency= 0.80
- Double effect Li/Br-H_2O VARS
- Approach=10, $T_{\_generator}$= 110ºC. $T_{\_EVA\_VARS}$= 05ºC, RE=35.167 "kW', T_Absorber=T_Cond
- Performance of Vapour compression System:COP_VCRS=1.903,
- ExergeticEfficiency$_{_VCRS}$=,0.2630, $EDR_{\_VCRSI}$=0.4822.

Table-7(b) Effect of condenser temperature of VARS on thermal performances of single *effect vapour absorption refrigeration cascaded with vapour compression refrigeration system when $T_{\_Cond}$=$T_{\_Absorber}$*

T_Cond	$COP_{\_VARS}$	$EDR_{\_VARS}$	VARS Second Law Efficiency
31	0.7461	3.432	0.2256
32	0.7449	3.439	0.2253
33	0.7437	3.447	0.2249
34	0.7423	3.455	0.2245
35	0.7410	3.759	0.2241
36	0.7398	3.47	0.2237
37	0.7385	3.478	0.2233
38	0.7374	3.484	0.2230
39	0.7363	3.491	0.2227
40	0.7353	3.497	0.2224-

- Evaporator temperature of VARS using HFC-134a = - 53 ºC, Compressor efficiency= 0.80
- Double effect Li/Br-H_2O VARS
- Approach=10, $T_{\_generator}$= 110ºC. $T_{\_EVA\_VARS}$= 05ºC, RE= 35.167 "kW', T_Absorber=T_Cond
- Performance of Vapour compression System: COP_VCRS=1.903,
- Exergetic Efficiency$_{_VCRS}$= 0.2630, $EDR_{\_VCRSI}$= 0.4822.

Table-7(b) Effect of condenser temperature of VARS on thermal performances of single *effect vapour absorption refrigeration cascaded with vapour compression refrigeration system when $T_{\_Cond}$=$T_{\_Absorber}$ using entropy generation method*

T_Cond	$COP_{\_VARS}$	$EDR_{\_VARS}$	VARS Second Law Efficiency
31	0.7461	3.327	0.2126
32	0.7449	3.734	0.2112
33	0.7437	3.742	0.2109
34	0.7423	3.750	0.2105
35	0.7410	3.759	0.2101
36	0.7398	3.767	0.2098
37	0.7385	3.774	0.2095
38	0.7374	3.782	0.2091
39	0.7363	3.788	0.2088
40	0.7353	3.94	0.2086

- Evaporator temperature of VARS using HFC-134a = - 53 ºC, Compressor efficiency= 0.80
- Double effect Li/Br-H_2O VARS
- Approach=10, $T_{\_generator}$= 110ºC. $T_{\_EVA\_VARS}$= 05ºC, RE=35.167 "kW', T_Absorber=T_Cond
- Performance of Vapour compression System: COP_VCRS=1.903,
- Exergetic Efficiency$_{_VCRS}$=,0.2630, $EDR_{\_VCRSI}$=0.4822.

Table-7(b) Effect of condenser temperature of VARS on thermal performances of single *effect vapour absorption refrigeration cascaded with vapour compression refrigeration system when $T_{\_Cond}$=$T_{\_Absorber}$*

T_Cond	$COP_{\_VARS}$	Maximum $COP_{\_VARS}$	VARS Second Law Efficiency
31	0.7461	2.206	0.3383
32	0.7449	2.097	0.3552
33	0.7437	1.996	0.3725
34	0.7423	1.903	0.3902
35	0.7410	1.815	0.4083
36	0.7398	1.733	0.4269
37	0.7385	1.656	0.4460
38	0.7374	1.584	0.4656
39	0.7363	1.516	0.4857
40	0.7353	1.791	0.5065

- Evaporator temperature of VARS using HFO-1234yf = -53°C, Compressor efficiency= 0.80
- Single effect Li/Br-H_2O VARS
- Approach=10, $T_{\_generator}$= 110°C. $T_{\_EVA\_VARS}$= 05°C, RE=35.167 "kW', T_Absorber=T_Cond
- Performance of Vapour compression System: COP_VCRS=1.791,
- Exergetic efficiency$_{_VCRS}$=0.6349,EDR$_{_VCRSl}$=0.5751.

Table-7(c) Effect of condenser temperature of VARS on thermal performances of single *effect vapour absorption refrigeration cascaded with vapour compression refrigeration system when $T_{\_Cond}$=$T_{\_Absorber}$*

T_Cond	COP$_{_Cascade}$	EDR$_{_Cascade}$	Cascaded System Second Law Efficiency
31	0.9665	1.190	0.4566
32	0.9653	1.192	0.4563
33	0.9640	1.193	0.4559
34	0.9626	1.195	0.4556
35	0.9613	1.197	0.4552
36	0.960	1.199	0.4548
37	0.9587	1.20	0.4545
38	0.9575	1.202	0.4542
39	0.9564	1.203	0.4539
40	0.9554	1.205	0.4536

- Evaporator temperature of VARS using HFO-1234yf = -53 °C, Compressor efficiency= 0.80
- Double effect Li/Br-H_2O VARS
- Approach=10, $T_{\_generator}$= 110°C. $T_{\_EVA\_VARS}$= 05°C, RE=35.167 "kW', T_Absorber=T_Cond
- Performance of Vapour compression System:COP_VCRS=1.791,
- Exergetic Efficiency$_{_VCRS}$=0.6349, EDR$_{_VCRSl}$=0.3630,

Table-7(d) Effect of condenser temperature of VARS on thermal performances of single *effect vapour absorption refrigeration cascaded with vapour compression refrigeration system when $T_{\_Cond}$=$T_{\_Absorber}$*

T_Cond	COP$_{_VARS}$	EDR$_{_VARS}$	VARS Second Law Efficiency
31	0.7461	3.432	0.2256
32	0.7449	3.439	0.2253
33	0.7437	3.447	0.2249
34	0.7423	3.455	0.2245
35	0.7410	3.759	0.2241
36	0.7398	3.47	0.2237
37	0.7385	3.478	0.2233
38	0.7374	3.484	0.2230
39	0.7363	3.491	0.2227
40	0.7353	3.497	0.2224-

- Evaporator temperature of VARS using HFO-1234yf = -53 °C, Compressor efficiency= 0.80
- Double effect Li/Br-H_2O VARS
- Approach=10, $T_{\_generator}$= 110°C. $T_{\_EVA\_VARS}$= 05°C, RE=35.167 "kW', T_Absorber=T_Cond
- Performance of Vapour compression System: COP_VCRS=1.791,
- Exergetic Efficiency$_{_VCRS}$=0.6349, EDR$_{_VCRSl}$=0.3630,

Table-7(d) Effect of condenser temperature of VARS on thermal performances of single *effect vapour absorption refrigeration cascaded with vapour compression refrigeration system when $T_{\_Cond}$=$T_{\_Absorber}$*

T_Cond	COP$_{_VARS}$	EDR$_{_VARS}$	VARS Second Law Efficiency
31	0.7461	3.327	0.2126
32	0.7449	3.734	0.2112
33	0.7437	3.742	0.2109
34	0.7423	3.750	0.2105
35	0.7410	3.759	0.2101
36	0.7398	3.767	0.2098
37	0.7385	3.774	0.2095
38	0.7374	3.782	0.2091
39	0.7363	3.788	0.2088
40	0.7353	3.94	0.2086

- Evaporator temperature of VARS using HFC-134a = - 53 °C, Compressor efficiency= 0.80
- Double effect Li/Br-H_2O VARS
- Approach=10, $T_{\_generator}$= 110°C. $T_{\_EVA\_VARS}$= 05°C, RE=35.167 "kW', T_Absorber=T_Cond
- Performance of Vapour compression System: COP_VCRS=
- Exergetic Efficiency$_{_VCRS}$=,EDR$_{_VCRSl}$=0.

Table-7(b) Effect of condenser temperature of VARS on thermal performances of single *effect vapour absorption refrigeration cascaded with vapour compression refrigeration system when $T_{\_Cond}$=$T_{\_Absorber}$*

T_Cond	COP$_{_VARS}$	Maximum COP$_{_VARS}$	VARS Second Law Efficiency
31	0.7461	2.206	0.3383
32	0.7449	2.097	0.3552
33	0.7437	1.996	0.3725
34	0.7423	1.903	0.3902
35	0.7410	1.815	0.4083
36	0.7398	1.733	0.4269
37	0.7385	1.656	0.4460
38	0.7374	1.584	0.4656
39	0.7363	1.516	0.4857
40	0.7353	1.791	0.5065

Table-7 (a) shows the variation of condenser temperature with variation of thermal performances such as first law efficiency in terms of coefficient of performance (COP) of cascaded vapour absorption system & second law efficiency in terms of exergetic efficiency and exergy destruction ratio based on exergy of fuel of single effect Li/Br-H_2Ovapour absorption refrigeration system cascaded with vapour compression refrigeration using HFC-134a refrigerant and it is found that when condenser temperature of vapour absorption refrigeration system is increasing, the thermodynamic performances in terms of (COP$_{_Cascad}$,) and Exergetic efficiency_Cascade System both are decreasing and EDR_Rational is increasing . Similarly exergy destruction ratio based on the exergy of product (EDR_Cascade) is also increasing as exergetic efficiency is decreasing. Table-7 (b) shows the variation of low temperature evaporator circuit temperature with variation of thermal performances such as first law efficiency in terms of coefficient of performance (COP) of cascaded vapour absorption system & second law efficiency in terms of exergetic efficiency and exergy destruction ratio based on exergy of fuel of single effect Li/Br-H_2O vapour absorption refrigeration system cascaded with vapour compression refrigeration using HFO-1234yf refrigerant and it is found that when absorber temperature of double effect Li/Br H_2O vapour absorption is increasing , the thermodynamic performances in terms of (COP_Cascade) &Exergetic efficiency_Cascade System is decreasing and EDR_Rational is increasing. Similarly exergy destruction ratio based on the exergy of product (EDR_Cascade) is also increasing .Table-7 (c) shows the variation of condenser temperature with variation of thermal performances such as first law efficiency in terms of coefficient of performance (COP) of cascaded vapour absorption system & second law efficiency in terms of exergetic efficiency and exergy destruction ratio based on exergy of fuel of single effect Li/Br-H_2Ovapour absorption refrigeration system cascaded with vapour compression refrigeration using HFC-134a refrigerant and it is found that when condenser temperature of vapour absorption refrigeration system is increasing , the thermodynamic performances in terms of (COP_Cascad,) and Exergetic efficiency_Cascade System both are decreasing and EDR_Rational is increasing . Similarly exergy destruction ratio based on the exergy of product (EDR_Cascade) is also increasing and exergetic efficiency is decreasing. The performance of single effect Li/Br-H_2O vapour absorption system cascaded with vapour compression system using HFC-134a and HFO-1234yf for low temperature circuit evaporator at -53°C and generator temperature at 110°C have been compared and also shown in Table-7(a) to Table7(d) respectively and it is found that thermodynamic performances using HFO-1234yf (ystem-2) in cascaded vapour absorption system in terms of COP, is 1.6372 % lower than using HFC-134a (system-1)at 35°C of condenser temperature and 1.643% lower than using HFC-134a at 35°C of condenser temperature respectively. Similarly. The exergetic efficiency using HFO-1234yf is 3.682% lower than R134a at 35°C and exergy destruction ratio is 7.256% higher than system-1 at 35°C respectively.

3.7 Effect of absorber temperature of single effect vapour absorption cascaded vapour absorption refrigeration system on thermal performances

- Evaporator temperature of VCRS using HFC-134a = -53°C, Compressor efficiency= 0.80
- Single effect Li/Br-H_2O VARS
- Approach=10, T_generator= 110°C. T_EVA_VARS= 05°C, RE=29.167 “kW’, T_Cond=35°C
- Performance of Vapour compression System performance of Vapour compression System: COP_VCRS=1.903, EDR= 0.4822 Exergetic Efficiency_VCRS=,0.6747, EDR_Rational =0.3253.

Table-8(a) Effect of absorber temperature of VARS on thermal performances of single -effect vapour absorption refrigeration cascaded with vapour compression refrigeration system

T_Absorber (°C)	COP_Cascade	EDR_Cascade	Cascaded System Second Law Efficiency
30	0.9853	1.106	0.4749
35	0.9773	1.116	0.4726
40	0.9713	1.124	0.4709
45	0.9669	1.129	0.4697

- Evaporator temperature of VCRS using HFC-134a = -53°C, Compressor efficiency= 0.80
- Single effect Li/Br-H_2O VARS
- Approach=10, T_generator= 110°C. T_EVA_VARS= 05°C, RE=29.167 “kW’, T_Cond=35°C
- Performance of Vapour compression System:Performance of Vapour compression System: COP_VCRS=1.903, EDR= 0.48242 ExergeticEfficiency_VCRS=,0.6747, EDR_Rational =0.3253.

Table-8(b) Effect of absorber temperature of VARS on thermal performances of single effect vapour absorption refrigeration cascaded with vapour compression refrigeration system

T_Absorber (°C)	COP_VARS	EDR_ VARS	VARS Second Law Efficiency
30	0.7486	3.417	0.2264
35	0.7410	3.482	0.2241
40	0.7353	3.497	0.2224
45	0.7312	3.522	0.2211

- Evaporator temperature of VCRS using HFC-134a = -53°C, Compressor efficiency= 0.80
- Single effect Li/Br-H_2O VARS
- Approach=10, T_generator= 110°C. T_EVA_VARS= 05°C, RE=29.167 “kW’, T_Cond=35°C
- Performance of Vapour compression System:Performance of Vapour compression System: COP_VCRS=1.903, EDR= 0.48242ExergeticEfficiency_VCRS=,0.6747, EDR_Rational =0.3253.

Table-8(b) Effect of absorber temperature of VARS on thermal performances of single effect vapour absorption refrigeration cascaded with vapour compression refrigeration system using entropy generation method

T_Absorber (°C)	COP_VARS	Rational EDR_ VARS	VARS Second Law Efficiency
30	0.7486	3.712	0.2122
35	0.7410	3.759	0.2101
40	0.7353	3.795	0.2086
45	0.7312	3.821	0.2074

- Evaporator temperature of VCRS using HFC-134a = -53°C, Compressor efficiency= 0.80

- Single effect Li/Br-H_2O VARS
- Approach=10, $T_{\_generator}$= 110ºC. $T_{\_EVA\_VARS}$= 05ºC, RE=29.167 "kW', T_Cond=35ºC
- Performance of Vapour compression System: COP_VCRS=1.903, EDR= 0.48242Exergetic Efficiency_VCRS=, 0.6747, $EDR_{\_Rational}$ =0.3253.

Table-8(b) Effect of absorber temperature of VARS on thermal performances of single effect vapour absorption refrigeration cascaded with vapour compression refrigeration system

T_Absorber (ºC)	$COP_{\_VARS}$	Maximum COP_VARS	VARS Second Law Efficiency
30	0.7486	1.815	0.4125
35	0.7410	1.815	0.4083
40	0.7353	1.815	0.4051
45	0.7312	1.815	0.4029

Table-8 (a) shows the variation of absorber temperature with variation of thermal performances such as first law efficiency in terms of coefficient of performance (COP) of cascaded vapour absorption system & second law efficiency in terms of exergetic efficiency and exergy destruction ratio based on exergy of fuel of single effect Li/Br-H_2Ovapour absorption refrigeration system cascaded with vapour compression refrigeration using HFC-134a refrigerant and it is found that when absorber temperature of vapour absorption refrigeration system is increasing , the thermodynamic performances in terms of ($COP_{\_Cascad}$,) is decreasing and Exergetic $efficiency_{\_Cascade\ System}$ is increasing and $EDR_{\_Rational}$ is decreasing . Similarly exergy destruction ratio based on the exergy of product (EDR_Cascade) is also decreasing and exergetic efficiency is increasing.as shown in table-8(b) respectively.Table-8 (c) shows the variation of low temperature evaporator circuit temperature with variation of thermal performances such as first law efficiency in terms of coefficient of performance (COP) of cascaded vapour absorption system & second law efficiency in terms of exergetic efficiency and exergy destruction ratio based on exergy of fuel of single effect Li/Br-H_2O vapour absorption refrigeration system cascaded with vapour compression refrigeration using HFO-1234yf refrigerant and it is found that when absorber temperature of single effect Li/Br H_2O vapour absorption is increasing , the thermodynamic performances in terms of ($COP_{\_Cascade}$) & Exergetic $efficiency_{\_Cascade\ System}$ is decreasing and $EDR_{\_Rational}$ is increasing. Similarly exergy destruction ratio based on the exergy of product (EDR_Cascade) is also decreasing and absorber temperature increasing along with exergetic efficiency of cascaded system is increasing as shown in table-8(d) respectively.

The performance of single effect Li/Br-H_2O vapour absorption system cascaded with vapour compression system using HFC-134a and HFO-1234yf for absorber temperature at 35ºC have been compared and also shown in Tables-7 to Tables-8 respectively and it is found that thermodynamic performances using HFO-1234yf in cascaded vapour absorption system in terms of COP is1.637 % lower and , exergetic efficiency is 3.682 % lower than using HFC-134a at 35ºC of vapour compression absorber temperature.

- Evaporator temperature of VCRS using HFO-1234yf = -53 ºC, Compressor efficiency= 0.80
- singleeffect Li/Br-H_2O VARS
- Approach=10, $T_{\_generator}$= 110ºC. $T_{\_EVA\_VARS}$= 05ºC, RE=29.167 "kW', T_Cond=35ºC
- Performance of Vapour compression System:Performance of Vapour compression System:
- Performance of Vapour compression System:
- COP_VCRS=1.791, EDR= 0.5751,
- ExergeticEfficiency_VCRS=, 0.6349, $EDR_{\_Rational}$ =0.3451.

Table-8(c) Effect of absorber temperature of VARS on thermal performances of single effect vapour absorption refrigeration cascaded with vapour compression refrigeration system

T_Absorber (ºC)	$COP_{\_Cascade}$	$EDR_{\_Cascade}$	Cascaded System Second Law Efficiency
30	0.9690	1.187	0.4573
35	0.9613	1.197	0.4552
40	0.9554	1.205	0.4536
45	0.9512	1.210	0.4524

- Evaporator temperature of VCRS using HFO-1234yf = -53 ºC, Compressor efficiency= 0.80
- Single effect Li/Br-H_2O VARS
- Approach=10, $T_{\_generator}$= 110ºC. $T_{\_EVA\_VARS}$= 05ºC, RE=29.167 "kW', T_Cond=35ºC
- Performance of Vapour compression System:
- COP_VCRS=1.791, EDR= 0.5751,
- Exergetic Efficiency_VCRS=,0.6349, $EDR_{\_Rational}$ =0.3451.

Table-8(d) Effect of absorber temperature of VARS on thermal performances of single effect vapour absorption refrigeration cascaded with vapour compression refrigeration system

T_Absorber (ºC)	$COP_{\_VARS}$	$EDR_{\_ VARS}$	VARS Second Law Efficiency
30	0.7486	3.417	0.2264
35	0.7410	3.462	0.2241
40	0.7353	3.497	0.2224
45	0.7312	3.522	0.2211

- Evaporator temperature of VCRS using HFO-1234yf = -53 ºC, Compressor efficiency= 0.80
- Single effect Li/Br-H_2O VARS
- Approach=10, $T_{\_generator}$= 110ºC. $T_{\_EVA\_VARS}$= 05ºC, RE=29.167 "kW', T_Cond=35ºC
- Performance of Vapour compression System:
- COP_VCRS=1.791, EDR= 0.5751,
- Exergetic Efficiency_VCRS=,0.6349, $EDR_{\_Rational}$ =0.3451.

Table-8(d) Effect of absorber temperature of VARS on thermal performances of single effect vapour absorption refrigeration cascaded with vapour compression refrigeration system using entropy generation method

T_Absorber (°C)	COP_VARS	EDR_ VARS	VARS Second Law Efficiency
30	0.7486	3.712	0.2122
35	0.7410	3.759	0.2101
40	0.7353	3.795	0.2086
45	0.7312	3.821	0.2074

- Evaporator temperature of VCRS using HFO-1234yf = -53 °C, Compressor efficiency= 0.80
- Single effect Li/Br-H_2O VARS
- Approach=10, $T_{\_generator}$= 110°C. $T_{\_EVA\_VARS}$= 05°C, RE=29.167 "kW', T_Cond=35°C
- Performance of Vapour compression System:
- COP_VCRS=1.791, EDR= 0.5751,
- Exergetic Efficiency_VCRS=,0.6349, $EDR_{\_Rational}$ =0.3451.

Table-8(d) Effect of absorber temperature of VARS on thermal performances of single effect vapour absorption refrigeration cascaded with vapour compression refrigeration system

T_Absorber (°C)	COP_VARS	Maximum COP_VARS	VARS Second Law Efficiency
30	0.7486	1.815	0.4125
35	0.7410	1.815	0.4083
40	0.7353	1.815	0.4051
45	0.7312	1.815	0.4029

4. Conclusions and Recommendations

The following conclusions were drawn from present investigations.

(i) The thermodynamic performances of single effect Li/Br H_2O vapour absorption refrigeration system cascaded with vapour compression system HFO-1234yf refrigerants(system-2) in terms of COP is 1.435% lower and exergetic efficiency is 3.216%lower than The thermodynamic performances of single effect Li/Br H_2O vapour absorption refrigeration system cascaded with vapour compression system using HFC-134a (system-1) For both type of EDRs 5.922% at 10°C approach and also decreases as temperature overlapping (approach) is increasing.

(ii) The thermal performance of single effect Li/Br H_2O vapour absorption refrigeration system cascaded with vapour compression system using HFO -1234yf refrigerant is always than the single effect Li/Br H_2O vapour absorption refrigeration system cascaded with vapour compression system (system-1)using HFC -134a refrigerants. The thermodynamic performances using HFO-1234yf (system-2) in cascaded vapour absorption system in terms of COP is 1.353 % lower and exergetic efficiency is 3.036% lower than using HFC-134a in the vapour compression refrigeration system.

(iii) The variation of low temperature evaporator circuit temperature in single effect Li/Br vapour absorption refrigeration system on thermal performance of single effect Li/Br H_2O vapour absorption refrigeration system cascaded with vapour compression system using HFO - 1234yf refrigerant when low temperature evaporator circuit temperature of vapour absorption refrigeration system is increasing , the thermodynamic performances in terms of ($COP\__{Cascad}$,) is decreasing and Exergeticefficiency$__{Cascade\ System}$ is also decreasing and $EDR\__{Rational}$ is increasing . Similarly exergy destruction ratio based on the exergy of product ($EDR\__{Cascade}$) is also decreasing and exergetic efficiency is increasing; The optimum values of single effect vapour absorption refrigeration cycle cascaded with vapour compression cycle for generator temperature of 110°C and condenser temperature and 35°C of absorber temperature using HFC-134a refrigerant (system-1) comes to be 1.353% COP and 3.036% higher exergetic efficiency) with reduction in 5.702% in exergy destruction ratio of cascade system than cascade vapour absorption Li/Br H2O system using R1234yf refrigerant in compression refrigerating cycle (system-2).

(iv) The variation of temperature of generator in single effect Li/Br vapour absorption refrigeration system on thermal performance of single effect Li/Br H_2O vapour absorption refrigeration system cascaded with vapour compression system using HFO -1234yf refrigerant is 6.0 % to 7% lower than the single effect Li/Br H_2O vapour absorption refrigeration system cascaded with vapour compression system using HFC -134a refrigerants.

(v) For single effect Li/Br-H_2O vapour absorption refrigeration system cascaded with vapour compression refrigeration at -30°C , the performance of HFC-134a refrigerant and HFO-1234ze are nearly similar with the variation of 0.5626% in first law efficiency and 0.559% in second law efficiency while the performance of HFC-134a is 3.1196% superior than HFO- 1234yf refrigerant (system-2) . Therefore both HFO refrigerants can replace HFC-134a refrigerant in near future due to its very low global warming potential (i.e. GWP of R1234ze is 6 and GWP of R1234yf is 4 respectively as compared to GWP of HFC-134a is 1360) (iv) Thermodynamic performances of single effect Li/Br-H_2O vapour absorption refrigeration system cascaded with vapour compression refrigeration using HFO-1234yf in cascaded vapour absorption system in terms of COP is 1.643 % lower and exergetic efficiency is 3.201% lower than using HFC-134a. For both type of EDRs 6.261% decreasing as heat exchanger effectiveness is increasing.

(vi) The performance of single effect Li/Br-H_2O vapour absorption system cascaded with vapour compression system using HFC-134a and HFO-1234yf for low temperature circuit evaporator at -53°C and generator

temperature at 180ºC thermodynamic performances using HFO-1234yf in cascaded vapour absorption system in terms of COP is1.643% lower and exergetic efficiency is 3.201 % lower than using HFC-134a in the vapour compression refrigeration cycle.

(vii) The performance of single effect Li/Br-H_2O vapour absorption system cascaded with vapour compression system using HFC-134a and HFO-1234yf for low temperature circuit evaporator at -53ºC and Vapour absorption system evaporator temperature at 5ºC have been compared and it is found that thermodynamic performances using HFO-1234yf in cascaded vapour absorption system in terms of COP is 1.643% and exergetic efficiency is 3.201 % lower than using HFC-134a.

(viii) The performance of single effect Li/Br-H_2O vapour absorption system cascaded with vapour compression system using HFC-134a and HFO-1234yf for low temperature circuit evaporator at -53ºC and generator temperature at 130ºC have been compared and it is found that thermodynamic performances using HFO-1234yf in cascaded vapour absorption system in terms of COP, is 1.9563 % lower than using HFC-134a at 30ºC of condenser temperature and 1.643% lower than using HFC-134a at 35ºC of condenser temperature respectively. Similarly The exergetic efficiency using HFO-1234yf is 3.5033% lower than R134a at 30ºC and 3.20% lower than HFC-134a at 35ºC respectively.

(ix) The performance of single effect Li/Br-H_2O vapour absorption system cascaded with vapour compression system using HFC-134a and HFO-1234yf for absorber temperature at 40ºC have been compared and it is found that thermodynamic performances using HFO-1234yf in cascaded vapour absorption system in terms of COP is1.637 % lower and , exergetic efficiency is 3.682 % lower than using HFC-134a at 35ºC of vapour compression absorber temperature.

(x) In the single effect Li/Br-H_2Ovapour absorption refrigeration system cascaded with vapour compression refrigeration using HFC-134a refrigerant and it is found that absorber temperature of Tripple effect Li/Br vapour absorption refrigeration system is increasing , the thermodynamic performances in terms of (COP_{Cascad},) is decreasing and Exergetic efficiency$_{Cascade\ System}$ is increasing and EDR_{l} is decreasing.

(xi) In the single effect Li/Br-H_2Ovapour absorption refrigeration system cascaded with vapour compression refrigeration using HFC-134a refrigerant and it is found that when condenser temperature of vapour absorption refrigeration system is increasing , the thermodynamic performances in terms of (COP_{Cascad},) and Exergetic efficiency$_{Cascade\ System}$ both are decreasing and $EDR\_{Rational}$ is increasing.

(xii) In the single effect Li/Br-H_2Ovapour absorption refrigeration system cascaded with vapour compression refrigeration using HFC-134a refrigerant and it is found that when generator temperature of vapour absorption refrigeration system is increasing , the thermodynamic performances in terms of (COP_{Cascad},) is decreasing and Exergetic efficiency$_{Cascade\ System}$ is increasing and $EDR\_{Rational}$ is decreasing.

(xiii) In the single effect Li/Br-H_2Ovapour absorption refrigeration system cascaded with vapour compression refrigeration using HFC-134a refrigerant and it is found that when Vapour absorption system evaporator temperature ($T\_{evaporator}$)of vapour absorption refrigeration system is increasing , the thermodynamic performances in terms of (COP_{Cascad},) is decreasing and Exergetic efficiency$_{Cascade\ System}$ is increasing and $EDR\_{Rational}$ is decreasing . Similarly exergy destruction ratio based on the exergy of product ($EDR\_{Cascade}$) is also decreasing and exergetic efficiency is increasing.

(xiv) In the single effect Li/Br-H_2Ovapour absorption refrigeration system cascaded with vapour compression refrigeration using HFC-134a refrigerant and it is found that when heat exchanger effectiveness of vapour absorption refrigeration system) is increasing , the thermodynamic performances in terms of ($COP\_{Cascade}$) &exergetic efficiency$_{Cascade\ System}$) is increasing and $EDR\_{cascade}$ is decreasing when heat exchanger effectiveness is increasing.

(xv) In the single effect Li/Br-H_2Ovapour absorption refrigeration system cascaded with vapour compression refrigeration using HFC-134a refrigerant and it is found that when temperature overlapping in terms of approach (means condenser temperature of vapour compression refrigeration minus evaporator temperature of vapour absorption refrigeration system) is increasing , the thermodynamic performances in terms of ($COP\_{Cascade}$, Exergetic efficiency$_{Cascade\ System}$) is decreasing and $EDR\_{Rational}$ is increasing.

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Cite this article as: R.S. Mishra, Thermodynamic performance evaluation of single effect Li/Br H_2O vapour absorption refrigeration system cascaded with vapour compression system using ecofriendly HFC-134a and HFO-1234yf refrigerants, International Journal of Research in Engineering and Innovation Vol-3, Issue-3 (2019), 165-182.