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

Thermal performance of cascaded vapour compression absorption systems

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Abstract

In this paper, we propose four cascaded half effect, single effect, double effect and triple effect Lithium/Bromide vapour absorption–compression refrigeration systems using fifteen ecofriendly refrigerants such as hydrocarbons, HFC and HFO refrigerants and natural refrigerants to produce cooling capacity at -30 °C. The comparison of four cascaded systems were also carried out at -55ºC using HFC refrigerants with R717 refrigerant. It is found that cascaded vapour compression absorption systems significantly improve first and second law performances as compared to simple vapour absorption refrigeration system.

Keywords: Cascaded Vapour Absorption Compression Refrigeration Systems, Performance Evaluation.

1. Introduction

The use of vapour absorption refrigeration system is a talented way towards utilizing waste heat from industrial processes. LiBr absorption refrigeration system and ammonia–water absorption refrigeration systems are commonly used for low temperature applications. Even though ammonia–water absorption refrigeration system is commonly used for freezing applications with temperatures lower than 0 °C [10-11].
The performance of NH_3H_2O system has low first law efficiency. When the refrigeration temperature is lower than -25 °C, the thermal performance dramatically decreases. We proposed cascaded half effect, single effect, double effect and triple effect Lithium/Bromide vapour absorption–compression refrigeration systems using fifteen ecofriendly refrigerants such as hydrocarbons, HFC and HFO refrigerants and natural refrigerants to produce cooling capacity at -30 °C.
The comparison of four cascaded systems were also carried out at -55ºC using HFC refrigerants with R717 refrigerant. It is found that cascaded vapour compression absorption systems significantly improve first and second law performances as compared to simple vapour absorption refrigeration systems.

2. Literature Review

A number of research work is devoted to thermodynamic, analyses of vapour absorption refrigeration systems

S.B. Riffat N. Shankland [1] described the integration of different types of absorption systems with vapour-compression systems. The performances of the single-effect and double-effect series and the double-effect parallel continuous absorption systems and their integration with vapour-compression systems have been carried out.
Kaushik and Arora [2-3] carried out the energy and energy analysis of single effect and series flow double effect water–lithium bromide absorption system and developed thermal computational model for parametric investigation. Their analysis involves the effect of generator, absorber and evaporator temperatures on the energetic and energetic performance. They concluded that the irreversibility is highest in the absorber in both systems as compared to other systems
Gomri [4] carried out comparative thermodynamic analysis between single effect and double effect absorption refrigeration systems and developed the computer program using thermodynamic properties based on energy balance equations and found that for each condenser and evaporator temperature, there is an optimum generator temperature where change in energy of single effect and double effect absorption refrigeration system is minimum. They also found that the COP of double effect system is approximately twice the COP of single effect system but there is marginal difference between the energetic efficiency of the system.
Yi Chena, et.al. [5] proposed a new absorption–compression refrigeration system to produce cooling energy at -30 °C to -

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40 °C and showed that the coefficient of performance of 0.277, which was approximately 50% higher than that of a conventional two-stage absorption refrigeration system. Fernández–Seara et al. [6] studied a cascade refrigeration system with a CO_2 compression vapour refrigeration system and an NH_3/H_2O absorption system at an evaporation temperature of -45°C. and found its first law efficiency in terms of COP. Garimella and Brown [7] developed a novel cascaded absorption–compression system that coupled a single-effect $LiBr/H_2O$ absorption cycle and a subcritical CO_2 vapor–compression cycle to generate low-temperature refrigerant (-40 °C). Rogdakis and Antonopoulos [8] studied a NH_3/H_2O absorption refrigeration system driven by waste heat and predicted the theoretical COP below 0.40 when the lowest temperature is in the range of -64 °C to -30 °C.

Kilic and Kaynakli [9] carried out first and second law thermodynamic analysis to analyze the performance of a single stage water lithium bromide absorption refrigeration system by varying some working parameters and developed a mathematical model based on energy method and found that the performance of the ARS increases with increasing generator and evaporator temperatures but decreases with increasing condenser and absorber temperatures. Also concluded that the highest energy loss occurs in generator regardless of operating conditions and therefore it is most important component of the system. R.S. Mishra [12] compared three cascade vapour compression systems cascaded with evaporator of LiBr-H_2O vapour absorption refrigeration system cascaded by condenser of vapour compression refrigeration system using ecofriendly refrigerants (i.e. R1234yf, R134a, R-32, R507a, R227ea, R236fa, R245fa , R717) carried out energy and exergy analysis of all three systems and found 122% first law efficiency enhancement using triple effect VARS cascaded with VCRS and 79.45% enhancement in second law efficiency using triple effect VARS cascaded with VCRS. Similarly exergy destruction is 56.60% using triple effect VARS cascaded with VCRS and 25.9% reduction using double effect VARS cascaded with VCRS as compared with single effect. R.S. Mishra [2019] carried out Thermal performances (first law efficiency, exergy destruction ratio & exergetic efficiency) of cascade single effect ammonia-water (NH3-H_20) vapour absorption refrigeration system coupled with vapour compression refrigeration using ecofriendly refrigerants in the low temperature cycle of VCRS system, The combined thermodynamic first law efficiency in terms of coefficient of performance ($COP_{\_Overall}$), second law efficiency in terms of exergetic efficiency and exergy destruction ratio working with each of the following refrigerants in the cascaded vapour compression cycle R1234yf, R227ea, R236fa, R245fa, R143a,R134a, R32, R507 operating at (- 223 K) of evaporator temperature with temperature overlapping and evaporator temperature of vapour absorption refrigeration cycle working at 13.5 bar of highest generator pressure and 1.75 bar as lowest evaporator pressure have been presented and it is found thatR141b and R245fa gives better performance.

R.S. Mishra [13] found that the thermodynamic performances in the case of cascaded half effect vapour absorption refrigeration system coupled with vapour compression cycle is improved by 44.6% increment of first law efficiency (i.e. over all COP), 172.87% increment of second law efficiency (i.e. exergetic efficiency) of the half effect vapour absorption refrigeration cascaded with vapour compression cycle using HFC-134a, 42.87% enhancement in first law efficiency (COP) of 142.73% increment of second law efficiency using HFO-1234yf for -50ºC of evaporator temperature of VCRS. Similarly 72% reduction in exergy destruction ratio based on exergy of output of the half effect vapour absorption refrigeration cascaded with vapour compression cycle using HFC-134a and 70.4% reduction in exergy destruction ratio using HFO-1234yf ecofriendly refrigerant for -50ºC of evaporator temperature of VCRS. The performances of single effect cascaded vapour absorption refrigeration system coupled with vapour compression cycle significantly higher than cascaded half effect vapour absorption refrigeration coupled with vapour compression cycle.

3. Results and Discussions

Performance of four cascaded vapour compression-absorption refrigeration systems have been carried out using following input data.

Table-1(a) shows the thermal performances of simple half effect vapour absorption system with half effect cascade vapour absorption system using R134a,and it was found that Cascaded half effect gives better first law thermodynamic performance (COP) and second law thermodynamic performance in terms of exergetic efficiency than simple half effect vapour absorption refrigeration system. Table-1(b) shows the thermal performances of simple single effect vapour absorption system with single effect cascade vapour absorption system using R134a,and it was found that Cascade single effect gives better first law thermodynamic performance (COP) and second law thermodynamic performance in terms of exergetic efficiency than simple single effect vapour absorption refrigeration system. Table-1(c) shows the thermal performances of simple double effect vapour absorption system with double effect cascade vapour absorption system using R134a,and it was found that Cascade double effect gives better first law thermodynamic performance (COP) and second law thermodynamic performance in terms of exergetic efficiency than simple double effect vapour absorption refrigeration system

Table-1(a): Comparison between performance parameters of simple half effect VARS and half effect VARS with cascading.

Performance Parameters	Simple Half Effect VARS	Half Effect VARS with VCRS cascade using R134a
COP	0.4255	0.7152
EDR	5.419	1.257
Exergetic Efficiency	0.1558	0.4439

Table-1(b): Comparison between performance parameters of simple single effect VARS and single effect VARS with cascading

Performance Parameters	Simple Single Effect VARS	Single Effect VARS with VCRS cascade using R134a
COP	0.7496	1.193
EDR	4.19	1.862
Exergetic Efficiency	0.3628	0.3494

Table-1(c): Comparison between performance parameters of simple double effect VARS and double effect VARS with cascading.

Performance Parameters	Simple Double Effect VARS	Double Effect VARS with VCRS cascade using R134a
COP	1.201	1.781
$EDR\_{Rational}$	2.802	0.4243
Exergetic Efficiency	0.263	0.5757

Table-2: Comparison between performance Parameters of Simple tripple effect VARS and tripple effect VARS with Cascading.

Refrigerants	Simple Tripple Effect VARS	Tripple Effect VARS with VCRS cascade using R134a
COP	1.786	2.432
EDR	2.166	1.05
Exergetic Efficiency	0.3158	0.4879

Table-2 shows the thermal performances of triple effect vapour absorption system. it was found that triple effect gives better first law thermodynamic performance (COP) and second law thermodynamic performance in terms of exergetic efficiency than double effect and single effect & half effect vapour absorption refrigeration systems. Table-3(a) shows the thermal performances of simple half effect vapour absorption system with half effect cascade vapour absorption system using following eco-friendly refrigerants ,and it was found that cascade half effect gives better first law thermodynamic performance (COP) and second law thermodynamic performance in terms of exergetic efficiency than simple half effect vapour absorption refrigeration system the thermodynamic performances (i.e. coefficient of performance (COP) and exergetic efficiency (second law efficiency) using R245fa gives better thermodynamic performances as compared to R134a and R236fa used in cascade vapour compression-absorption refrigeration systems.

The thermodynamic performance performances using R227ea is found to be lowest in vapour -compression-absorption LiBr refrigeration system. Table-3(b) shows the thermal performances of simple single effect vapour absorption system with single effect cascade vapour absorption system using following eco-friendly refrigerants ,and it was found that cascade single effect gives better first law thermodynamic exergetic efficiency of cascaded triple effect vapour absorption-vapour compression refrigeration system is decreasing along with increasing exergy destruction ratio. Similarly the first law efficiency in terms of coefficient of performance (COP_VARS) is decreasing and second law efficiency in terms of exergetic efficiency of the triple effect performance (COP) and second law thermodynamic performance in terms of exergetic efficiency than simple single effect vapour absorption refrigeration system. The thermodynamic performances (i.e. coefficient of performance (COP) and exergetic efficiency (second law efficiency) using R245fa gives better thermodynamic performances as compared to R134a and R236fa used in single effect cascade vapour compression-absorption refrigeration systems. The thermodynamic performance performances using R227ea is found to be lowest in single effect vapour -compression-absorption LiBr refrigeration system. Table-3(c) shows the thermal performances of simple double effect vapour absorption system with double effect cascade vapour absorption system using following eco-friendly refrigerants ,and it was found that cascade double effect gives better first law thermodynamic performance (COP) and second law thermodynamic performance in terms of exergetic efficiency than simple double effect vapour absorption refrigeration system. The thermodynamic performances (i.e. coefficient of performance (COP) and exergetic efficiency (second law efficiency) using R245fa gives better thermodynamic performances as compared to R134a and R236fa used in double effect cascade vapour compression-absorption refrigeration systems. The thermodynamic performance performances using R227ea is found to be lowest in double effect vapour compression-absorption LiBr refrigeration system. Table-3(d) to Table-3(g) show the thermal performances of simple triple effect vapour absorption system with triple effect cascade vapour absorption system using twenty eco-friendly refrigerants ,and it was found that cascade triple effect gives better first law thermodynamic performance (COP) and second law thermodynamic performance in terms of exergetic efficiency than simple triple effect vapour absorption refrigeration system. The thermodynamic performances (i.e. coefficient of performance (COP) and exergetic efficiency (second law efficiency) using R245fa gives better thermodynamic performances as compared to R134a and R236fa used in double effect cascade vapour compression-absorption refrigeration systems. The thermodynamic performance performances using R407c is found to be lowest in triple effect vapour -compression-absorption LiBr refrigeration system. Table-4 shows the effect of condenser/absorber/ temperatures on thermal performances of cascaded vapour compression – triple effect vapour absorption refrigeration system using R134a eco-friendly refrigerants and simple triple effect LiBr vapour absorption refrigeration system and it is found that as condenser/absorber/ temperatures of triple effect vapour absorption is increasing, the first law efficiency in terms of coefficient of performance (COP) is decreasing and second law efficiency in terms of vapour absorption refrigeration system is decreasing along with increasing exergy destruction ratio of triple effect VARS as increasing generator temperature of vapour compression – triple effect vapour absorption refrigeration systemTable-5 shows the effect of generator temperature on thermal performances of cascaded vapour compression – triple effect vapour absorption refrigeration system using R134a eco-friendly refrigerants and simple triple effect LiBr vapour absorption refrigeration system and it is found that as generator temperature of triple effect vapour absorption is increasing, the first law efficiency in terms of coefficient of performance (COP) is increasing and second law efficiency in terms of exergetic efficiency of cascaded triple effect vapour absorption-vapour compression refrigeration system is decreasing along with increasing exergy destruction ratio. Similarly the first law efficiency in terms of coefficient of performance (COP_VARS) is increasing and second law efficiency in terms of exergetic efficiency of the triple effect vapour absorption refrigeration system is increasing along with increasing exergy destruction ratio of triple effect vapour compression triple effect vapour absorption refrigeration system as increasing generator temperature of vapour compression triple effect vapour absorption refrigeration system. Table-6 shows the effect of evaporator temperature on thermal performances of cascaded vapour compression – triple effect vapour absorption refrigeration system using R134a eco-friendly refrigerants and simple triple effect LiBr vapour absorption refrigeration system and it is found that as evaporator temperature of triple effect vapour absorption is increasing, the first law efficiency in terms of coefficient of performance (COP) and second law efficiency in terms of exergetic efficiency of cascaded triple effect vapour absorption-vapour compression refrigeration system are increasing with increasing exergy destruction ratio . Similarly the first law efficiency in terms of coefficient of performance (COP_VARS) and second law efficiency in terms of exergetic efficiency of the triple effect vapour absorption refrigeration system are increasing with decreasing exergy destruction ratio of triple effect VARS as increasing evaporator temperature of vapour compression triple effect vapour absorption refrigeration system. The optimum exergetic efficiency of triple effect vapour absorption refrigeration system is to be found as 35.4% at 3ºC evaporator temperature while optimum exergetic efficiency of cascaded triple effect vapour absorption-compression refrigeration system is to be found as 35.4% at 4ºC evaporator temperature while the first law efficiency in terms of coefficient of performance (COP) cascaded system is found at 5^0 evaporator temperature. Table-7 shows the variation of effectiveness of heat exchanger with first law efficiency, second law efficiency and exergy destruction ratio of triple effect vapour absorption refrigeration system and cascaded vapour compression - triple effect absorption refrigeration system, and it is found that first law efficiency in terms of coefficient of performance (COP) and second law efficiency in terms of exergetic efficiency of vapour absorption refrigeration system are increasing with increasing effectiveness of heat exchanger and exergy destruction ratio of vapour absorption refrigeration system is decreasing with increasing effectiveness of heat exchanger. Similarly that first law efficiency in terms of coefficient of performance (COP) and second law efficiency in terms of exergetic efficiency of cascaded-vapour compression triple stage vapour absorption refrigeration system are increasing with increasing effectiveness of heat exchanger and exergy destruction ratio of cascaded-vapour compression triple stage vapour absorption refrigeration system is decreasing with increasing effectiveness of heat exchanger. Table-8 shows the variation of temperature overlapping (Approach) with first law efficiency, second law efficiency and exergy destruction ratio of triple effect vapour absorption refrigeration system and cascaded vapour compression triple effect absorption refrigeration system, and it is found that first law efficiency in terms of coefficient of performance (COP) and second law efficiency in terms of exergetic efficiency of vapour absorption refrigeration system are decreasing with increasing temperature overlapping (Approach) and exergy destruction ratio of vapour absorption refrigeration system is increasing with increasing temperature overlapping (Approach).

Table-3(a): Comparison between thermal performances various eco-friendly refrigerants in half effect LiBr cascade vapour absorption refrigeration system.

Performance parameters	Simple Half Effect VARS	Half Effect VARS with VCRS cascade using R134a	Half Effect VARS with VCRS cascade using R1234ze	Half Effect VARS with VCRS cascade using R227ea	Half Effect VARS with VCRS cascade using R236fa	Half Effect VARS with VCRS cascade using R245fa
COP	0.4255	0.7152	0.7150	0.7133	0.7173	0.7175
EDR	5.419	1.257	1.291	1.306	1.274	1.237
Exergetic Efficiency	0.1558	0.4439	0.4366	0.4336	0.4398	0.4407

Table-3(b): Comparison between thermal performances various eco-friendly refrigerants in Single effect LiBr cascade vapour absorption refrigeration system.

Performance parameters	Simple Single Effect VARS	Single Effect VARS with VCRS cascade using R134a	Single Effect VARS with VCRS cascade using R1234ze	Single Effect VARS with VCRS cascade using R227ea	Single Effect VARS with VCRS cascade using R236fa	Single Effect VARS with VCRS cascade using R245fa
COP	0.7496	1.193	1.193	1.18	1.189	1.198
EDR	4.19	1.862	1.865	1.972	1.896	1.824
Exergetic Efficiency	0.3628	0.3494	0.3490	0.3378	0.3454	0.3541

Table-3(c): Comparison between thermal performances various eco-friendly refrigerants in Double effect LiBr cascaded vapour absorption refrigeration system.

Performance parameters	Simple Double Effect VARS	Double Effect VARS with VCRS cascade using R134a	Double Effect VARS with VCRS cascade using R1234ze	Double Effect VARS with VCRS cascade using R236fa	Double Effect VARS with VCRS cascade using R245fa
COP	1.201	1.781	1.780	1.773	1.79
$EDR_{\_Rational}$	2.802	0.4243	0.4248	0.4294	0.1182
Exergetic Efficiency	0.263	0.5757	0.5752	0.5706	0.5818

Table-3(d): Comparison between thermal performances various eco-friendly refrigerants in triple effect LiBr cascaded vapour absorption refrigeration system

Performance parameters	Simple Tripple Effect VARS	Tripple Effect VARS with VCRS cascade using R134a	Tripple Effect VARS with VCRS cascade using R1234ze	Tripple Effect VARS with VCRS cascade using R245fa	Tripple Effect VARS with VCRS cascade using R236fa	Tripple Effect VARS with VCRS cascade using R227ea
COP	1.786	2.432	2.431	2.447	2.419	2.391
EDR	2.166	1.05	1.052	1.025	1.071	1.122
Exergetic Efficiency	0.3158	0.4879	0.4874	0.4939	0.4827	0.4718

Table-3(e): Comparison between thermal performances various eco-friendly refrigerants in triple effect LiBr cascade vapour absorption refrigeration system.

Performance parameters	R404a	R410a	R407c	R290	R600a	R600	R507a
COP	2.384	2.425	2.291	2.428	2.431	2.445	2.401
EDR	1.135	1.061	1.315	1.056	1.051	1.027	1.105
Exergetic Efficiency	0.4684	0.4851	0.4320	0.4863	0.4875	0.4933	0.4751

Table-3(f): Comparison between thermal performances various eco-friendly refrigerants in triple effect LiBr cascade vapour absorption refrigeration system.

Performance parameters	R123	R143a	R141b	R744	R717	R125	R1234yf
COP	2.455	2.406	2.469	2.299	2.429	2.381	2.420
EDR	1.01	1.096	0.9864	1.297	1.055	1.141	1.055
Exergetic Efficiency	0.4975	0.4773	0.4034	0.4353	0.4856	0.4670	0.4870

Table-3(g): Comparison between thermal performances various eco-friendly refrigerants in triple effect LiBr cascade vapour absorption refrigeration system.

Performance parameters	R134a	R1234ze	R245fa	R236fa	R227ea	R152a	R32
COP	2.432	2.431	2.447	2.419	2.391	2.446	2.418
EDR	1.05	1.052	1.025	1.071	1.122	1.026	1.073
Exergetic Efficiency	0.4879	0.4874	0.4939	0.4827	0.4718	0.4936	0.4823

Table-4: Effect of condenser/Absorber on thermal performances using R134a eco-friendly refrigerants in triple effect LiBr cascade vapour absorption refrigeration system.

Effect of condenser/Absorber Temperature	$COP_{\_VARS}$	$EDR_{\_VARS}$	Exergetic Efficiency	$COP_{\_Cascade}$	$EDR_{Cascade}$	Exergetic $Efficiency_{\_Cascade}$	$COP_{\_VCRS}$
30	1.786	2.160	0.3158	1.998	1.044	0.4892	2.402
35	1.479	2.825	0.2614	1.758	1.212	0.4521	2.402

Table-5: Effect of generator temperature on thermal performances using R134a eco-friendly refrigerants in triple effect LiBr cascaded vapour absorption refrigeration system.

Effect of Generator Temperature	$COP_{\_VARS}$	$EDR_{\_VARS}$	Exergetic Efficiency	$COP_{\_Cascade}$	$EDR_{Cascade}$	Exergetic efficiency_ Cascade	COP VCRS
170	1.769	2.058	0.3270	1.986	1.017	0.4958	2.402
175	1.780	2.110	0.3215	1.993	1.030	0.4926	2.402
180	1.786	2.166	0.3158	1.998	1.044	0.4892	2.402
185	1.790	2.225	0.3101	2.011	1.059	0.4856	2.402
190	1.792	2.286	0.3043	2.003	1.075	0.4820	2.402
195	1.793	2.349	0.2986	2.003	1.091	0.4783	2.402
200	1.792	2.413	0.293	2.003	1.107	0.4746	2.402

Table-6: Effect of evaporator temperature on thermal performances using R134a eco-friendly refrigerants in triple effect LiBr cascaded vapour absorption refrigeration system.

Effect of evaporator Temperature	COP_VARS	EDR_VARS	Exergetic Efficiency	COP_Cascade	EDRCascade	Exergetic Efficiency_Cascade	COP VCRS Decreasing
0	1.233	2.081	0.3299	1.636	1.128	0.470	2.916
1	1.348	1.898	0.3451	1.736	1.066	0.4841	2.844
2	1.442	1.838	0.3524	1.810	1.032	0.4921	2.774
3	1.520	1.825	0.3540	1.865	1.015	0.4962	2.706
4	1.586	1.845	0.3515	1.908	1.01	0.4976	2.641
5	1.644	1.892	0.3458	1.989	1.012	0.4971	2.579
6	1.696	1.962	0.3376	1.964	1.019	0.4953	2.518
7	1.743	2.053	0.3275	1.983	1.030	0.4926	2.459
8	1.786	2.166	0.3158	1.998	1.044	0.4892	2.402
9	1.826	2.302	0.3028	2.010	1.061	0.4852	2.347
10	1.864	2.464	0.2887	2.019	1.08	0.4808	2.294
15	2.028	3.86	0.2058	2.037	1.197	0.4553	2.050

Table-7: Effect of Heat Exchanger Effectiveness on thermal performances using R134a eco-friendly refrigerants in triple effect LiBr cascaded vapour absorption refrigeration system.

Effect of Heat Exchanger Effectiveness	COP_VARS	EDR_VARS	Exergetic Efficiency	COP_Cascade	EDRCascade	Exergetic EfficiencyCascade	COPVCRS
0.40	1.719	2.291	0.3039	1.948	1.076	0.4817	2.402
0.45	1.752	2.228	0.3097	1.973	1.060	0.4854	2.402
0.50	1.786	2.166	0.3158	1.998	1.044	0.4892	2.402
0.55	1.822	2.104	0.3222	2.025	1.028	0.4930	2.402
0.60	1.86	2.041	0.3288	2.051	1.012	0.4969	2.402
0.65	1.818	1.979	0.3356	2.079	0.9966	0.5008	2.402

Table-8: Effect of temperature overlapping (Approach) on thermal performances using R134a eco-friendly refrigerant in triple effect LiBr cascaded vapour absorption refrigeration system.

Approach	COP_VARS	EDR_VARS	Exergetic Efficiency	COP_Cascade Decreasing	EDRCascade increasing	Exergetic EfficiencyCascade Decreasing	COP VCRS Decreasing
0	1.786	2.166	0.3158	1.998	1.044	0.4892	2.402
2.5	1.786	2.166	0.3158	1.957	1.132	0.4691	2.268
5.0	1.786	2.166	0.3158	1.916	1.222	0.450	2.144
7.5	1.786	2.166	0.3158	1.876	1.317	0.4317	2.028
10	1.786	2.166	0.3158	1.837	1.815	0.4141	1.920
12.5	1.786	2.166	0.3158	1.799	1.518	0.3972	1.819
15	1.786	2.166	0.3158	1.762	1.625	0.3810	1.724

4. Conclusion

The following conclusions were drawn from present investigations.

(i) Triple effect gives better first law thermodynamic performance (COP) and second law thermodynamic performance in terms of exergetic efficiency than double effect and single effect & half effect vapour absorption refrigeration systems.

(ii) Cascaded half effect gives better first law thermodynamic performance (COP) and second law thermodynamic performance in terms of exergetic efficiency than simple half effect vapour absorption refrigeration system.

(iii) Cascaded single effect gives better first law thermodynamic performance (COP) and second law thermodynamic performance in terms of exergetic efficiency than simple single effect vapour absorption refrigeration system. the thermodynamic performances (i.e. coefficient of performance (COP) and exergetic efficiency (second law efficiency) using R245fa gives better thermodynamic performances as compared to R134a and R236fa used in single effect cascade vapour compression-absorption refrigeration systems.

(iv) The thermodynamic performance performances using R227ea is found to be lowest in single effect vapour -compression-absorption LiBr refrigeration system.

(v) Cascaded half effect gives better first law thermodynamic performance (COP) and second law thermodynamic performance in terms of exergetic efficiency than simple half effect vapour absorption refrigeration system.

(vi) Cascade single effect gives better first law thermodynamic performance (COP) and second law thermodynamic performance in terms of exergetic efficiency than simple single effect vapour absorption refrigeration system.

(vii) Cascade double effect gives better first law thermodynamic performance (COP) and second law thermodynamic performance in terms of exergetic efficiency than simple double effect vapour absorption refrigeration system.

(viii) Cascade triple effect gives better first law thermodynamic performance (COP) and second law thermodynamic performance in terms of exergetic efficiency than simple triple effect vapour absorption refrigeration system.

(ix) The first law efficiency in terms of coefficient of performance (COP_VARS) is increasing and second law efficiency in terms of exergetic efficiency of the triple effect vapour absorption refrigeration system is increasing along with increasing exergy destruction ratio of triple effect vapour compression – triple effect vapour absorption refrigeration system as increasing generator temperature of vapour compression – triple effect vapour absorption refrigeration.

(x) The optimum exergetic efficiency of triple effect vapour absorption refrigeration system is to be found as 35.4% at 3^{o}C evaporator temperature while optimum exergetic efficiency of cascaded triple effect vapour absorption-compression refrigeration system is to be found as 35.4% at 4^{0}C evaporator temperature while the first law efficiency in terms of coefficient of performance (COP) cascaded system is found at 5^{o}C evaporator temperature.

(xi) The first law efficiency in terms of coefficient of performance (COP) and second law efficiency in terms of exergetic efficiency of vapour absorption refrigeration system are increasing with increasing effectiveness of heat exchanger and exergy destruction ratio of vapour absorption refrigeration system is decreasing with increasing effectiveness of heat exchanger.

(xii) The first law efficiency in terms of coefficient of performance (COP) and second law efficiency in terms of exergetic efficiency of cascaded-vapour compression triple stage vapour absorption refrigeration system are increasing with increasing effectiveness of heat exchanger and exergy destruction ratio of cascaded-vapour compression triple stage vapour absorption refrigeration system is decreasing with increasing effectiveness of heat exchanger.

(xiii) The first law efficiency in terms of coefficient of performance (COP) and second law efficiency in terms of exergetic efficiency of cascaded vapour compression-tripple effect absorption refrigeration system are decreasing with increasing temperature overlapping (Approach) and exergy destruction ratio of cascaded vapour absorption-compression refrigeration system is increasing with increasing temperature overlapping.

References

[1] S.B. Riffat N. Shankland [1993] Integration of absorption and vapour-compression systems, Applied Energy, Vol-46, Issue-4,1993, Pages 303-316.

[2] Kaushik, S.C., Arora, A., Energy and Exergy analysis of single effect and series flow double effect waterlithium bromide absorption refrigeration systems, International Journal of Refrigeration, Vol. 32, (2009), pp. (1247-1258)

[3] A Arora and S.C. Kaushik [2009]Theoretical analysis of LiBr/H2O absorption refrigeration system, International Journal of Energy Research, 33(15), page-1321 - 1340

[4] Gomri, R., Second law comparison of single effect and double effect vapour absorption refrigeration systems, Energy Conversion and Management,Vol. 50, (2009), pp.1279-1287).

[5] Yi Chena,b, Wei Hana, Liuli Sunc , Hongguang Jina A new absorption–compression refrigeration system using a mid-temperature heat source for freezing application , The 7th International Conference on Applied Energy – ICAE2015, Energy Procedia 75 (2015) 560 – 565

[6] Fernández-Seara J, Sieres J, Vázquez M. Compression–absorption cascade refrigeration system. Applied Thermal Engineering. 2006;26:502-12.

[7] Garimella S, Brown AM, Nagavarapu AK. Waste heat driven absorption/vapor-compression cascade refrigeration system for megawatt scale, high-flux, low-temperature cooling. International Journal of Refrigeration. 2011;34:1776-85

[8] Rogdakis ED, Antonopoulos KA. Performance of a low- temperature NH_3H_2O absorption-refrigeration system. Energy. 1992;17:477-84.

[9] Kilic, M. and Kaynakli, O., Theoretical study on the effect of operating conditions on performance of absorption refrigeration system, Energy Conversion and Management, Vol. 48, (2007), pp.(599-607).

[10] Lee T-S, Liu C-H, Chen T-W. Thermodynamic analysis of optimal condensing temperature of cascade-condenser in CO_2/NH_3 cascade refrigeration systems. International Journal of Refrigeration. 2006;29:1100-8.

[11] Wu W, Wang B, Shi W, Li X. An overview of ammonia-based absorption chillers and heat pumps. Renewable and Sustainable Energy Reviews. 2014; 31:681-707.

[12] R.S. Mishra (2018) Comparison of thermal performances of single effect, double effect and triple effect LiBr-H2O absorption system cascaded with vapour compression refrigeration systems using ecofriendly refrigerants, International Journal of Research in Engineering and Innovation Vol-2, Issue-6 (2018), 610-621.

[13] R.S. Mishra (2019) Thermal performances (first law efficiency, exergy destruction ratio & exergetic efficiency) of cascade single effect ammonia-water (NH3-H20) vapour absorption refrigeration system coupled with vapour compression refrigeration using ecofriendly refrigerants in the low temperature cycle of VCRS system, International Journal of Research in Engineering and Innovation Vol-3, Issue-1 (2019), 1-5

[14] R.S. Mishra (2019) Comparison of half effect absorption-compression cascaded refrigeration system using thermodynamic (energy-exergy) analysis. International Journal of Research in Engineering and Innovation Vol-3, Issue-1 (2019), 6-11.

Cite this article as: R.S. Mishra, Thermal Performance of Cascaded Vapour Compression Absorption Systems, International journal of research in engineering and innovation (IJREI), vol 3, issue 1 (2019), 48-56.