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Comparison of thermal performances of single effect, double effect and triple effect LiBr-H_2O absorption system cascaded with vapour compression refrigeration systems using ecofriendly refrigerants

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Abstract

This paper mainly deals with comparisons of 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) and energy and exergy analysis of all three systems were carried out because exergy (Second law) analysis used to facilitates the identification of the system components with high exergy loss. The performance parameters have been compared with three cascade vapour absorption-compression refrigeration system and it was observed that 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 reduction is 56.60% using triple effect VARS cascaded with VCRS and 25.9% reduction using double effect VARS cascaded with VCRS An Similarly performance parameters have been compared with three cascade vapour absorption-compression refrigeration system and it was observed that 22.87% first law efficiency enhancement using triple effect VARS cascaded with VCRS and 46.3% enhancement in second law efficiency using triple effect VARS cascaded with VCRS as compared with double effect vapour absorption refrigeration cascaded with vapour compression refrigeration system. Similarly exergy reduction is 41.4% using triple effect VARS cascaded with VCRS as compared to double effect VARS cascaded with VCRS.

Keywords: Thermodynamic Analysis, Energy-Exergy Analysis, Entropy Generation principle, Irreversibility Analysis

1. Introduction

Refrigeration and air conditioning (RAC) plays very importance role in our day to day working for cooling and heating requirements. Refrigeration systems are widely used for controlling temperature in working/living environment to provide thermal comfort to mankind. The use of refrigeration technology for cooling is not new; however, air-conditioning technology is required to evolve due to many environmental regulations. Its applications are many in different fields and sectors. Refrigeration systems also used for storages of perishable food, and pharmaceutical formulations. Conventional systems of refrigeration and air conditioning consume a huge amount of (high-grade) electrical energy produced by burning of fossil fuels. The prices of fossil fuels are increasing day by day and source availability is also declining due to huge consumption. The concerns of increasing fuel price for electricity generation, environmental pollution & environmental damage in terms of global warming is a world –wide concern. Key reasons attributing to this increasing power consumption include: 75% Growth in population 75% Greater demand for building services 75% Need for better comfort levels 75%. Longer duration of occupants spent time inside buildings. It is not only in the developed but also in the developing countries.

The vapour absorption refrigeration system is one of the oldest methods of producing refrigeration effect. The principle of vapour absorption was discovered by the Micheal Faraday in 1824 while performing a set of experiments to liquify certain gases. The first vapour absorption refrigeration machine using NH3-H_2O was developed by a French scientist, Ferd Carre in 1860 and this system was used in both domestic and large

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industrial plants. The vapour absorption system uses heat energy instead of mechanical energy as in vapour compression refrigeration system. In the vapour absorption refrigeration system, the compressor is replaced by an absorber, pump, generator and pressure reducing valves. These components in vapour absorption system perform the same function as that of a compressor in vapour compression refrigeration system. In the vapour absorption refrigeration system, the vapour refrigerant from evaporator is drawn into an absorber where it is absorbed by the weak solution of refrigerant forming strong solution. This strong solution is pumped to the generator where it is heated by some solar energy source. During the heating process, the vapour refrigerant is driven off by the solution and enters into the condenser where it is liquified. The liquid refrigerant then flows into the evaporator and thus the cycle is completed. The LiBr-H_2O vapour absorption system can achieve temperature not below (5^0C) as required while NH_3-H_2O can be used up to 5^0 C are required [1].

This paper mainly deals with comparisons of 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) and energy and exergy analysis of all three systems were carried out because exergy (Second law) analysis used to facilitates the identification of the system components with high exergy loss.

2. Literature Review

S.C. Kaushik and Akhilesh Arora [2] carried out , the energy and exergy analysis of single effect and series flow double effect water–lithium bromide absorption systems and developed computational model by using property equations of water lithium bromide solution and found that the effects of generator, and effectiveness of heat exchangers absorber and evaporator temperatures, the effects of pressure drop between evaporator and absorber, on the energetic and exergetic performances in terms of coefficient of performance, exergy destruction, efficiency defects and exergetic efficiency found Irreversibility highest occurred in the absorber in both systems when compared to other system components. Their results indicate that coefficient of performance of the single effect system lies in range of 0.6–0.75 and double effect system lies in the range 1–1.28 respectively.

Rabah Gomri [3-4] carried out exergy analysis and thermo-economic optimization of the triple-effect LiBr-water absorption refrigerating system and found maximum exergetic efficiency of triple effect refrigeration system is about 35.1 % for condenser 30°C , absorber cooling water temperature (25°C/) and chilled water temperature (12°C/7°C) respectively Thermax's [5] developed the world's greenest and highest efficiency absorption machine using Triple effect vapour absorption chiller known as absorption chiller as a viable energy efficient alternative with a COP of 1.8 as against double effect vapour absorption chiller (1.4) is driven by various heat sources such as hot water, steam, exhaust and direct fuel fired, by using high pressure steam (15-25 bar) for optimum utilization of heat source. The system utilizes smaller size cooling tower due to lower heat load and also ensures water saving by reducing evaporation loss (10-12%)enabled 25-30% more output from engine exhaust, 25-30% lower fuel consumption for direct fired and reduction in $C0_2$ emission by 30%. In the U.S Patent [6] , the inventor to provide an absorption chiller method by utilizing two separate singe-effect absorption refrigeration circuits operating at relatively higher and lower temperatures, respectively, in which the external heat input is effectively utilized three times to thereby improve the coefficient of performance. This is achieved by an absorption apparatus comprising: a first absorption system circuit for operation within a first temperature range, a second absorption system circuit for operation within a second lower temperature range relative to the first circuit, the first circuit having generator means, condenser means, evaporator means, and absorber means operatively connected together, the second circuit having generator means, condenser means, evaporator means, and absorber means operatively connected together, the first circuit condenser means and the first circuit absorber means being in heat exchange communication with the second circuit generator means, and the first and second evaporator means being in heat exchange communication with an external heat load. Performance can be improved by using the double-effect evaporation principle. With a water lithium bromide pair, two generators can be used. One, at high temperature and pressure, is heated by an external source of thermal energy. A second, at lower pressure and temperature, is heated by condensation of the vapor from the first generator. Condensate from both generators moves to the evaporator. This enables the external thermal energy to be effectively utilized twice in the high and low temperature generators, thereby increasing the overall thermal efficiency as compared to single effect absorption systems. The cooling thermal efficiency (COP) of a single effect cycle is typically about 0.5 to 0.7. The thermal efficiency of double-effect cycles is typically about 1.0 to 1.2, while the 1.3 COP reported for double-effect absorption machine. Ravi Kumar T.S., Suganthi S, Anand A.S [7] carried out Exergy analysis of solar assisted double effect water lithium bromide absorption refrigeration system and found 60% higher COP than Single effect LiBR-H_2O system with optimized generation temperature of 150ºC in double effect VARS and 91^0C generator temperature using found using energy analysis in single effect LIBr-H_2O system along with highest exergy destruction in high pressure generator and also found using exergy analysis, the optimum generator temperature of 130ºC in double effect LiBr-H_20 System and 80ºC in single effect LiBr -H_20 System .

A.K. Prithar, S.C. Kaushika , R.S. Agrawal [8] carried out the Simulation of an Ammonia water compression absorption refrigeration system and found that 16% enhancement of COP by increasing 30% of solution heat exchanger area using R22 in the vapour compression refrigeration system.

Vaibahv Jain , S.S. Kachhawaha, Gulson Sachdeva [9]

Developed thermodynamic model for cascade vapour compression single effect absorption refrigeration and found around 61% of reduction in power consumption by using R410a, R407c and R134a refrigerants in VCRS and observed reduction in total irreversibility by reducing condenser temperature and also reduction in irreversibilities by increasing evaporator temperature. M Dixit, SC Kaushik, A Arora [10] studied, the absorption-Compression Cascade Refrigeration, comprising of a VCR system in low temperature stage and a vapour absorption refrigeration system at the high temperature stage, is analyzed. CO_2, NH_3 and R134a have been considered as refrigerants in the compression stage and the H_2O-LiBr refrigerant absorbent pair in the absorption stage. The analysis has been realized by means of a mathematical model of the refrigeration system. The study presents the results obtained regarding the performance of the refrigeration system based on energy and exergy analysis. The comparative study helps to find out the best refrigerant and appropriate operation parameters. It is found in the study that cascade condenser, compressor and refrigerant throttle valve are the major source of exergy destruction.

3. Result and Discussion

Following numerical values have been taken for validatation of thermal models for cascade vapour compression-absorption refrigeration systems .

3.1 Tripple Effect Cascade vapour compression-absorption refrigeration system using ecofriendly refrigerants.

$T_{\_Generator}$=180⁰C.T_Cond=30ºC,$T_{\_Eva}$=5⁰C,T_absorber=30⁰C , Compressor Efficiency=0.80, T_Eva_LTC=-50⁰C, Approach (Temperature Overlapping)=10⁰C) Table-1 shows the variation of thermal performance parameters of triple effect cascade vapour absorption refrigeration system using lithium bromide water solution coupled with vapour compression refrigeration system using 10 tons of load. The evaporator of VARS is cascaded with condenser of vapour compression refrigeration systems using following nine ecofriendly refrigerants. It is found that overall first law efficiency in terms of coefficient of performance (COP) of cascade refrigeration system using R245fa refrigerant is highest and lowest by using R227ea as shown in fig-1 .while exergy destruction of cascade system is lowest by using R141b and highest while using R227ea as shown in Fig-2. The cascade system exergetic efficiency is highest by using R141b and lowest by using R227ea as shown in Fig-3. The thermal performances using ecofriendly refrigerants in the low temperature circuit of vapour compression refrigeration system is shown in Table-1 and it is found that maximum coefficient of performance (COP)of vapour compression refrigeration system by using R141b and lower COP by using R227ea respectively as shown in Fig-4. Similarly exergy destruction of vapour compression refrigeration system is lowest by using R141b and highest while using R227ea as shown in Fig-5. The exergetic efficiency of vapour compression of refrigeration system is highest by using R141b and lowest by using R227ea as shown in Fig-6.

3.2 Double Effect Cascade vapour compression-absorption refrigeration system using ecofriendly refrigerants

$T_{\_Generator}$=150ºC,T_Cond=30ºC,$T_{\_Eva}$=10ºC,T_absorber=30⁰C, Compressor Efficiency=0.80, T_Eva_LTC=-50⁰C, Approach (Temperature Overlapping) =10⁰C)

Table-2 shows the variation of thermal performance parameters of double effect cascade vapour absorption refrigeration system using lithium bromide -water solution coupled with vapour compression refrigeration system using 10 tons of load. The evaporator of VARS is cascaded with condenser of vapour compression refrigeration systems using nine ecofriendly refrigerants. It is found that overall first law efficiency in terms of coefficient of performance (COP) of cascade refrigeration system using R245fa refrigerant is highest and lowest by using R227ea as shown in fig-7 .while exergy destruction of cascade system is lowest by using R141b and highest while using R227ea as shown in Fig-8. The cascade system exergetic efficiency is highest by using R141b and lowest by using R227ea as shown in Fig-9. The thermal performances using ecofriendly refrigerants in the low temperature circuit of vapour compression refrigeration system is shown in Table-2 and it is found that maximum coefficient of performance (COP)of vapour compression refrigeration system by using R141b and lower COP by using R227ea respectively as shown in Fig-10. Similarly exergy destruction of vapour compression refrigeration system is lowest by using R141b and highest while using R227ea as shown in Fig-11. The exergetic efficiency of vapour compression of refrigeration system is highest by using R141b and lowest by using R227ea as shown in Fig-12.

3.3 Single Effect Cascade vapour compression-absorption refrigeration system using ecofriendly refrigerants

$T_{\_Generator}$=110⁰C.T_Cond=35⁰C, $T_{\_Eva}$=10⁰C, T_absorber =30⁰C, Compressor Efficiency=0.80, T_Eva _LTC =-50⁰C, Approach (Temperature Overlapping) =10⁰C)

Table-3 shows the variation of thermal performance parameters of single effect cascade vapour absorption refrigeration system using lithium bromide-water solution coupled with vapour compression refrigeration system using 10 tons of load. The evaporator of VARS is cascaded with condenser of vapour compression refrigeration systems using nine ecofriendly refrigerants. It is found that overall first law efficiency in terms of coefficient of performance (COP) of cascade refrigeration system using R245fa refrigerant is highest and lowest by using R227ea as shown in fig-13 .while exergy destruction of cascade system is lowest by using R141b and highest while using R227ea as shown in Fig-14. The cascade system exergetic efficiency is highest by using R141b and lowest by using R227ea as shown in Fig-15. The thermal performances using ecofriendly refrigerants in the low temperature circuit of vapour compression refrigeration system is shown in Table-3 and it is found that maximum coefficient of performance (COP)of vapour compression refrigeration system by using R141b and lower COP by using R227ea respectively as shown in Fig-16. Similarly exergy destruction of vapour compression refrigeration system is lowest by using R141b and highest while using R227ea as shown in Fig-17. The exergetic efficiency of vapour compression of refrigeration system is highest by using R141b and lowest by using R227ea as shown in Fig-18.

Table 1: thermal performances of triple effect vapour absorption refrigeration system using vapour compression refrigeration system

Refrigerant	COP_Overall	Overall Exergy Destruction Ratio (EDR)	Overall Exergetic Efficiency	COP_VCRS	VCRS Exergy Destruction Ratio (EDR)	VCRS Exergetic Efficiency
R134a	1.782	1.371	0.4218	2.05	0.4501	0.6896
R1234yf	1.754	1.46	0.4065	1.951	0.5243	0.6560
R141b	1.850	1.210	0.4526	2.258	0.3170	0.7593
R717	1.782	1.382	0.4199	2.037	0.4594	0.6852
R32	1.776	1.398	0.4170	2.019	0.4729	0.6789
R-507a	1.738	1.507	0.3988	1.902	0.5634	0.6396
R227ea	1.701	1.616	0.3823	1.796	0.6534	0.6048
R236fa	1.756	1.455	0.4074	1.956	0.5199	0.6579
R245fa	1.805	1.323	0.4305	2.107	0.4109	0.7068

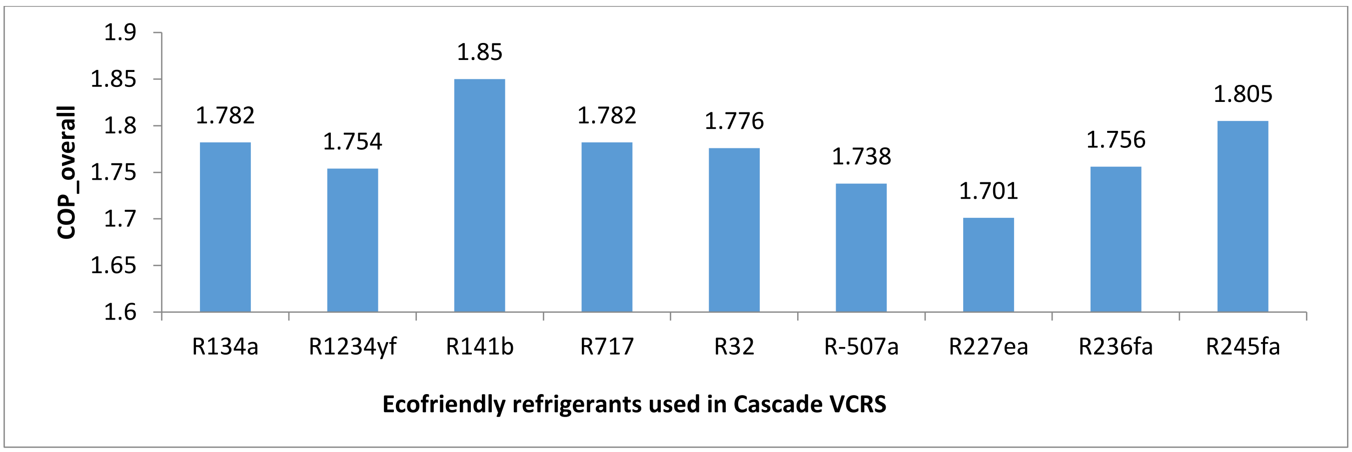

Figure 1: Thermal first law performances (COP_Over all) of cascade triple effect LiBr vapour absorption refrigeration system coupled with vapour compression refrigeration using ecofriendly refrigerants in the low temperature cycle of VCRS system

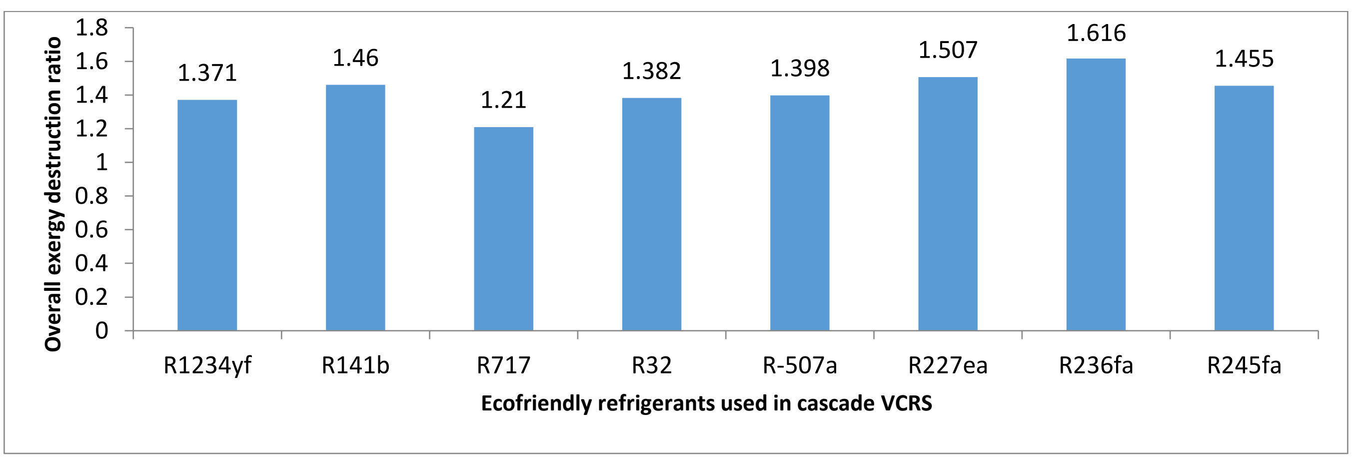

Figure 2: Thermal performances in terms of exergy destruction ratio (EDR_VCRS) of cascade triple effect LiBr vapour absorption refrigeration system coupled with vapour compression refrigeration using ecofriendly refrigerants in the low temperature cycle of VCRS system

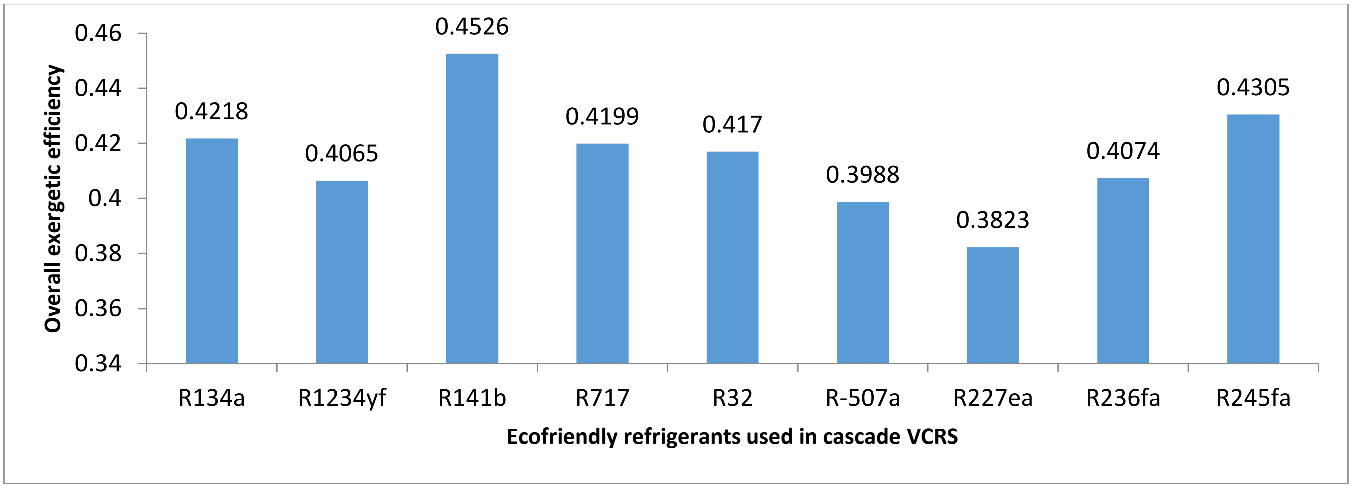

Figure 3: Thermal second law performances (Overall Exergetic Efficiency) of Cascade triple Effect LiBr vapour absorption refrigeration system coupled with vapour compression refrigeration using ecofriendly refrigerants in the low temperature cycle of VCRS system

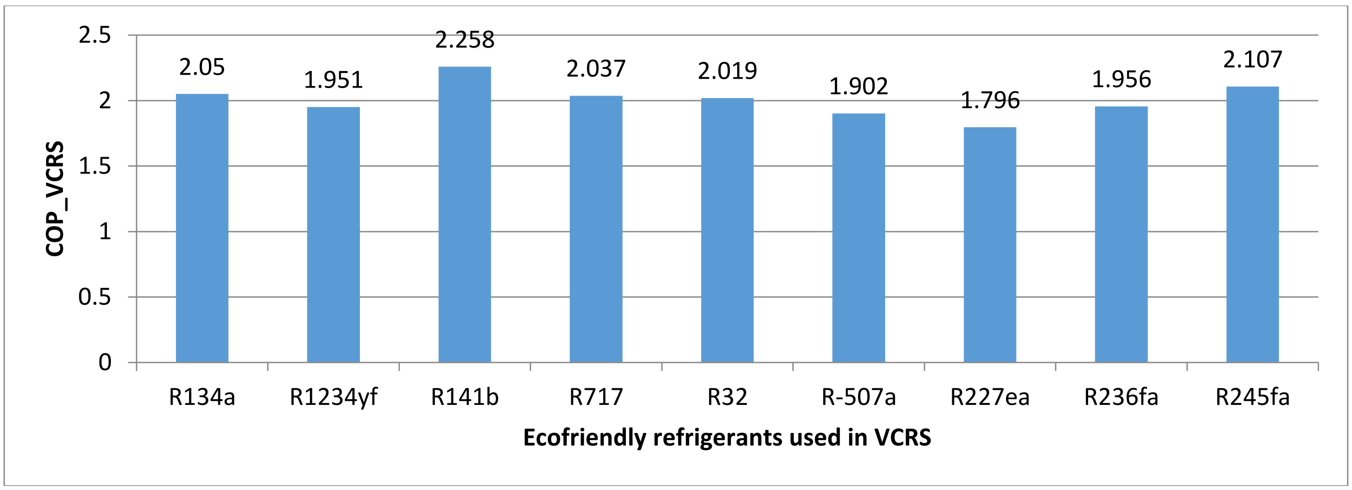

Figure 4: Thermal first law performances (COP_VCRS) of cascade triple effect LiBr vapour absorption refrigeration system coupled with vapour compression refrigeration using ecofriendly refrigerants in the low temperature cycle of VCRS system

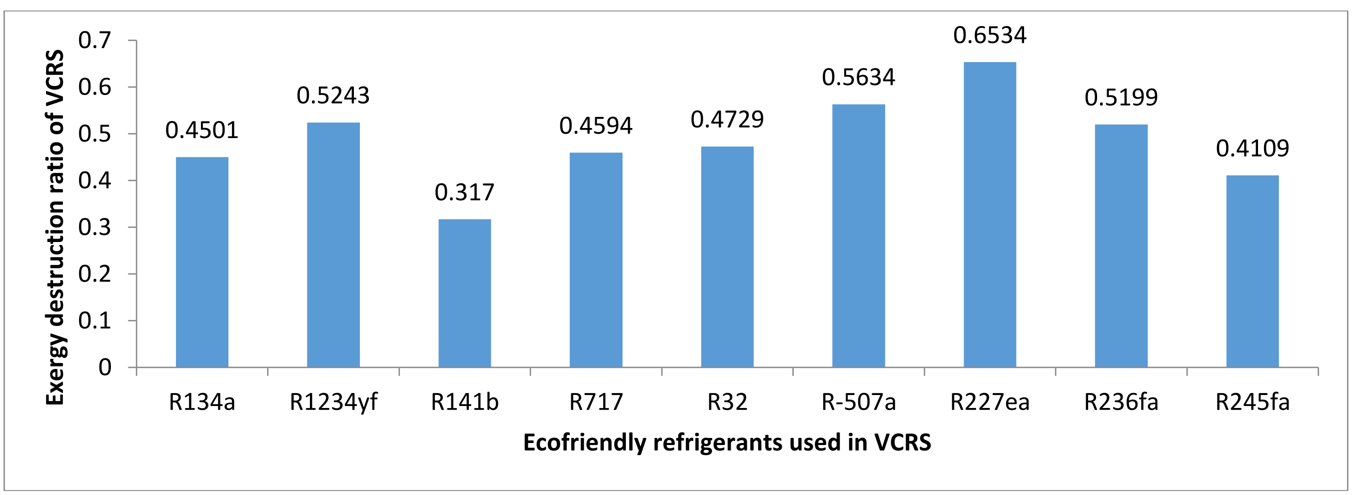

Figure 5: Thermal performances in terms of exergy destruction ratio(EDR_VCRS) of cascade triple effect LiBr vapour absorption refrigeration system coupled with vapour compression refrigeration using ecofriendly refrigerants in the low temperature cycle of VCRS system

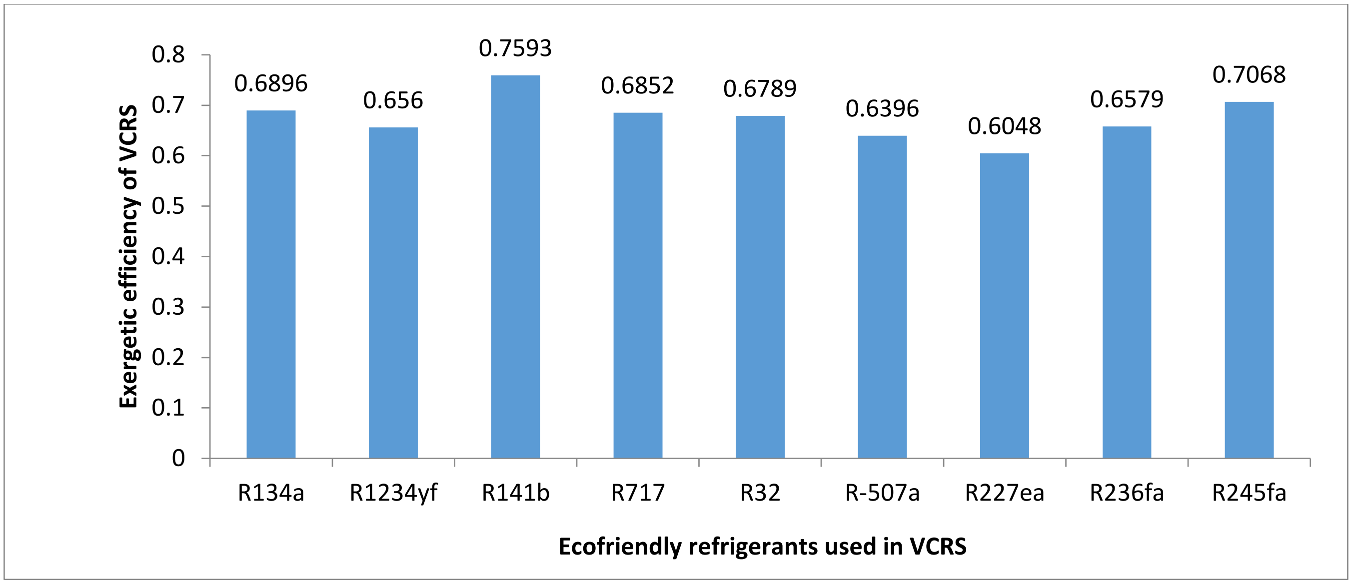

Figure 6: The exergetic efficiency of vapour compression of refrigeration system coupled with vapour compression refrigeration using ecofriendly refrigerants in the low temperature cycle of VCRS system

Table 2: Thermal performances of double effect vapour absorption refrigeration system using vapour compression refrigeration system

Refrigerant	COP_Overall	Overall Exergy Destruction Ratio (EDR)	Overall Exergetic Efficiency	COP_VCRS	VCRS Exergy Destruction Ratio (EDR)	VCRS Exergetic Efficiency
R134a	1.536	1.595	0.3854	1.838	0.6174	0.6183
R1234yf	1.503	1.719	0.3676	1.729	0.7196	0.5815
R141b	1.596	1.389	0.4186	2.054	0.4476	0.6908
R717	1.539	1.582	0.3873	1.850	0.6068	0.6224
R32	1.530	1.615	0.3823	1.819	0.6343	0.6119
R-507a	1.488	1.778	0.3599	1.681	0.7686	0.5654
R227ea	1.452	1.928	0.3416	1.838	0.8916	0.5286
R236fa	1.505	1.709	0.3691	1.572	0.7115	0.5843
R245fa	1.553	1.534	0.3947	1.898	0.5668	0.6383

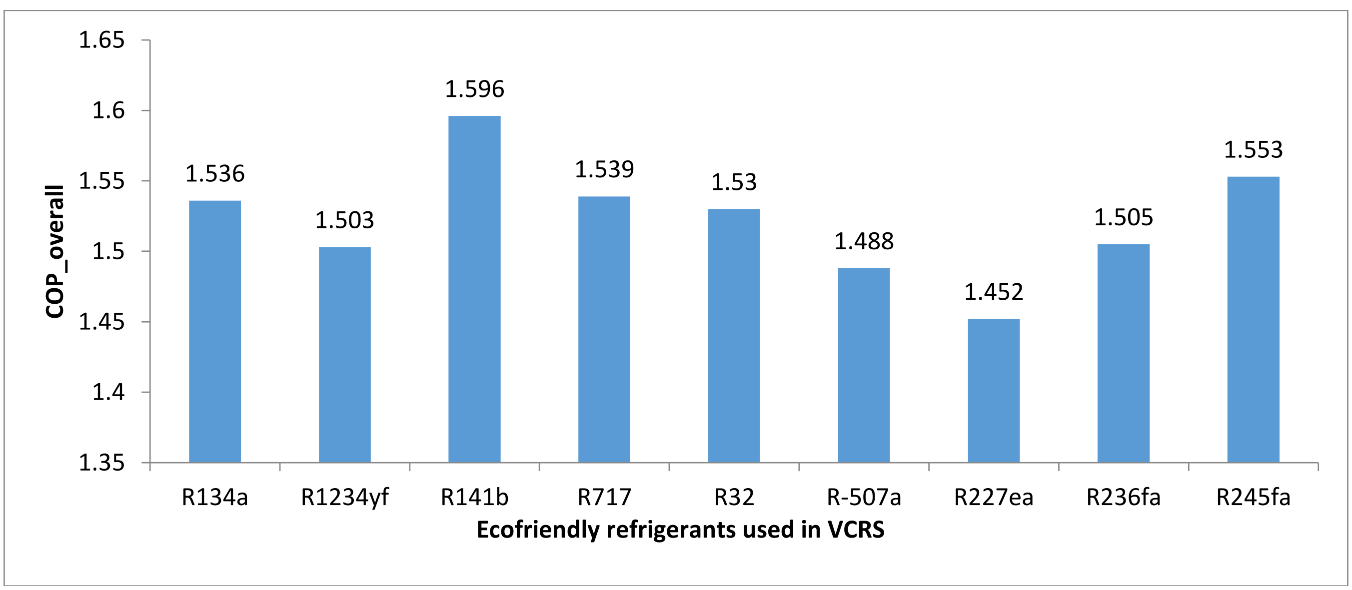

Figure 7: Thermal first law performances (COP_Over all) of cascade double effect LiBr vapour absorption refrigeration system coupled with vapour compression refrigeration using ecofriendly refrigerants in the low temperature cycle of VCRS system

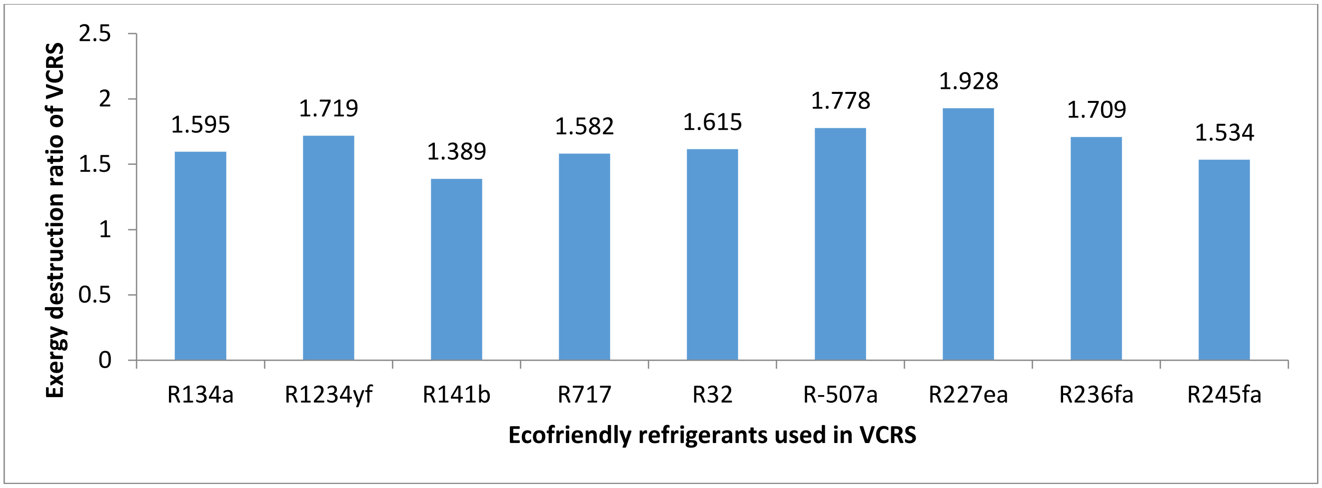

Figure 8: Thermal performances in terms of exergy destruction ratio (EDR_VCRS) of cascade double effect LiBr Vapour absorption refrigeration system coupled with vapour compression refrigeration using ecofriendly refrigerants in the low temperature cycle of VCRS system

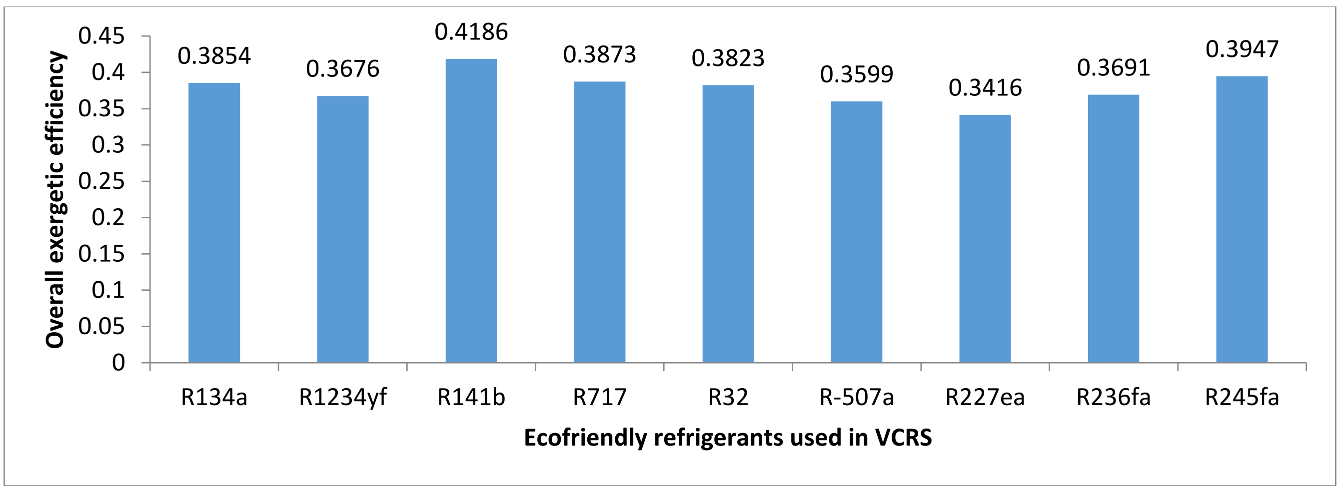

Figure 9: Thermal second law performances (Overall Exergetic Efficiency) of Cascade double effect LiBr Vapour absorption refrigeration system coupled with vapour compression refrigeration using ecofriendly refrigerants in the low temperature cycle of VCRS system

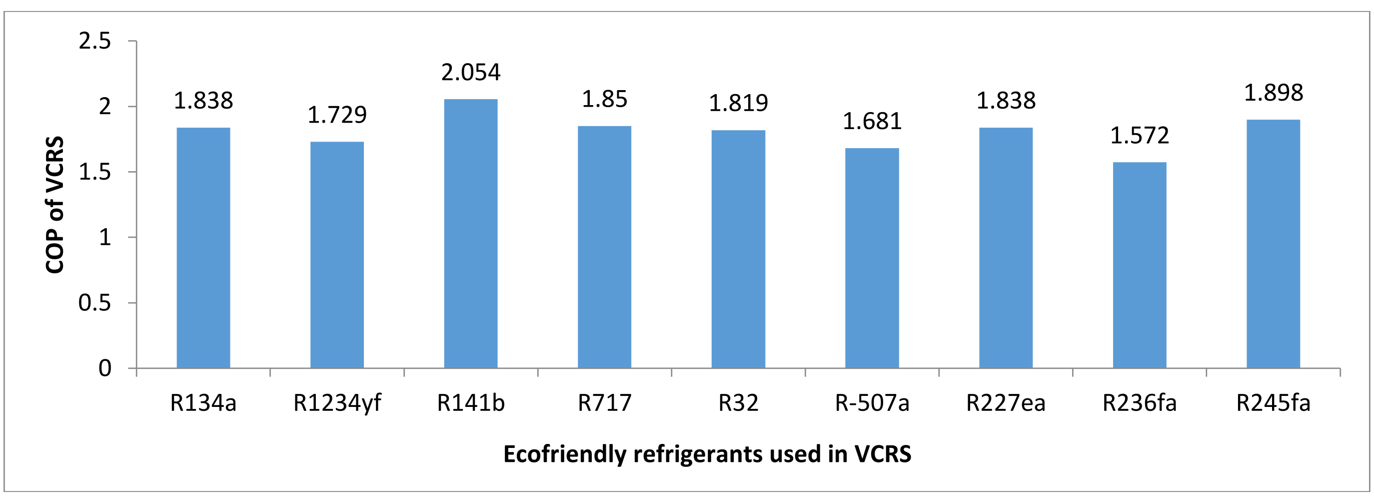

Figure 10: Thermal first law performances (COP_VCRS) of Cascade double effect LiBr Vapour absorption refrigeration system coupled with vapour compression refrigeration using ecofriendly refrigerants in the low temperature cycle of VCRS system

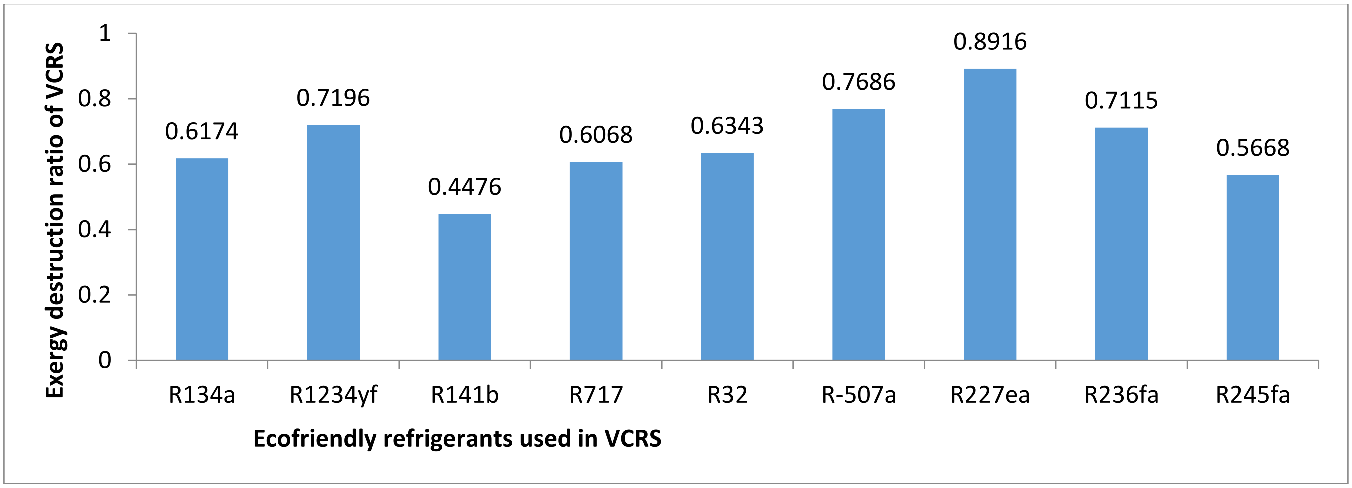

Figure 11: Thermal performances in terms of exergy destruction ratio (EDR_VCRS) of cascade double effect LIBr vapour absorption refrigeration system coupled with vapour compression refrigeration using ecofriendly refrigerants in the low temperature cycle of VCRS system

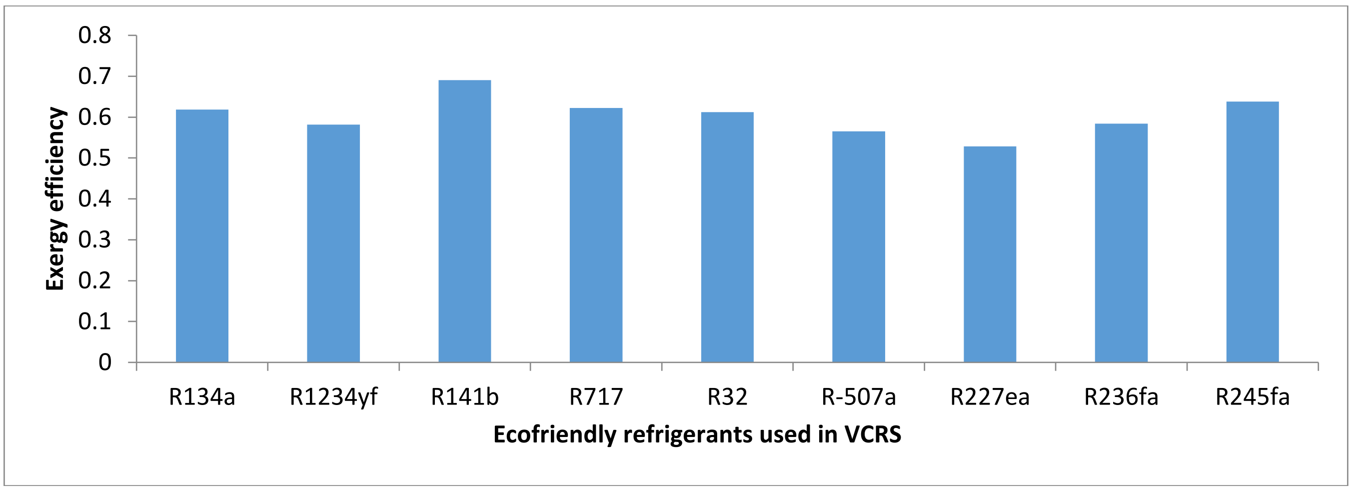

Figure 12: Thermal second law performances (Exergetic Efficiency _VCRS) of Cascade double Effect LiBr vapour absorption refrigeration system coupled with vapour compression refrigeration using ecofriendly refrigerants in the low temperature cycle of VCRS system

Table 3: Thermal performances of single effectvapourabsorption refrigeration system using vapour compression refrigeration system

Refrigerant	COP_Overall	Overall Exergy Destruction Ratio (EDR)	Overall Exergetic Efficiency	COP_VCRS	VCRS Exergy Destruction Ratio (EDR)	VCRS Exergetic Efficiency
R134a	0.9887	1.888	0.3463	1.920	0.60	0.6457
R1234yf	0.9736	2.004	0.3329	1.814	0.6250	0.6157
R141b	1.017	1.688	0.3463	2.132	0.3946	0.7171
R227ea	0.9496	2.023	0.3122	1.859	0.7921	0.5580
R236fa	0.9747	1.996	0.3338	1.821	0.6324	0.6126
R245fa	0.9967	1.828	0.3536	1.978	0.5030	06653
R32	0.9853	1.913	0.3433	1.896	0.5683	0.6376
R717	0.9890	1.885	0.3466	1.922	0.5471	0.6464
R507a	0.9664	2.062	0.3266	1.766	0.6835	0.5940

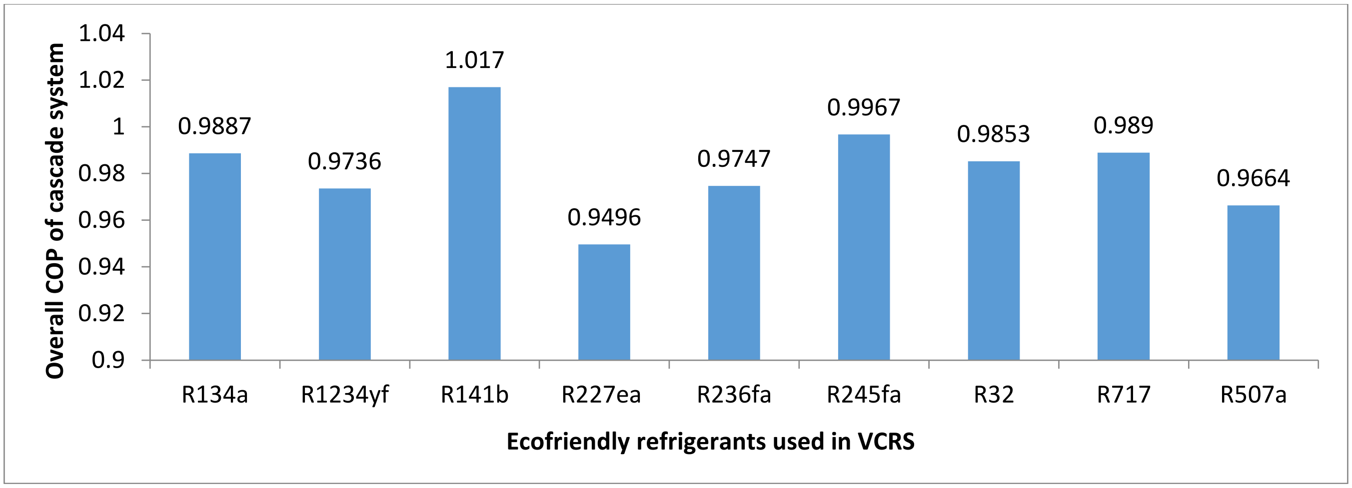

Figure 13: Thermal first law performances (COP_Overall) of cascade single effect LiBr vapour absorption refrigeration system coupled with vapour compression refrigeration using ecofriendly refrigerants in the low temperature cycle of VCRS system

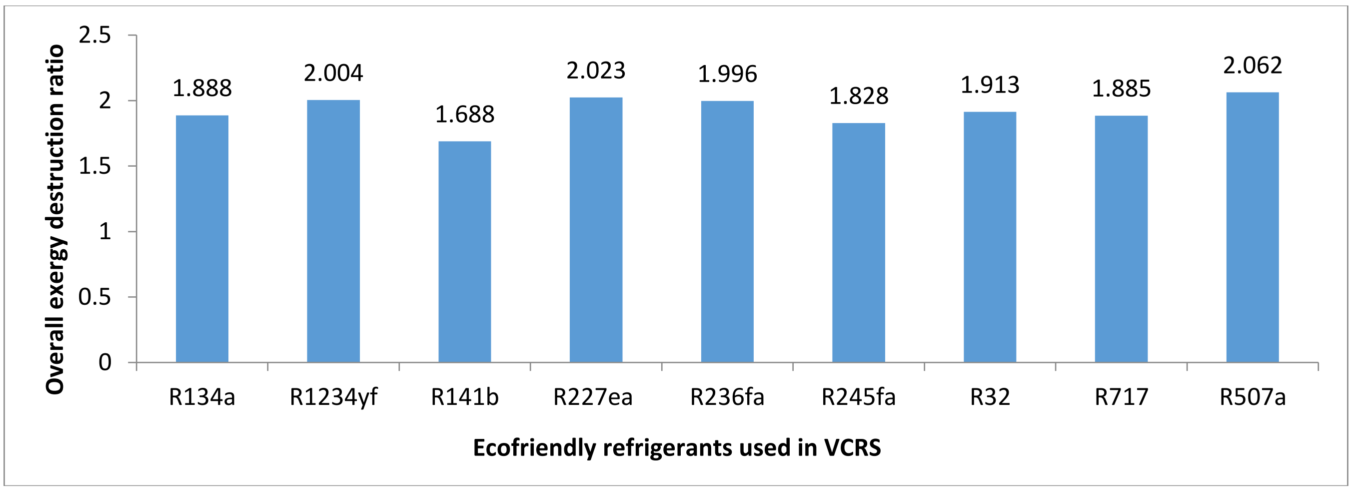

Figure 14: Thermal performances in terms of exergy destruction Ratio (EDR_VCRS) of cascade single effect LiBr vapour absorption refrigeration system coupled with vapour compression cycle

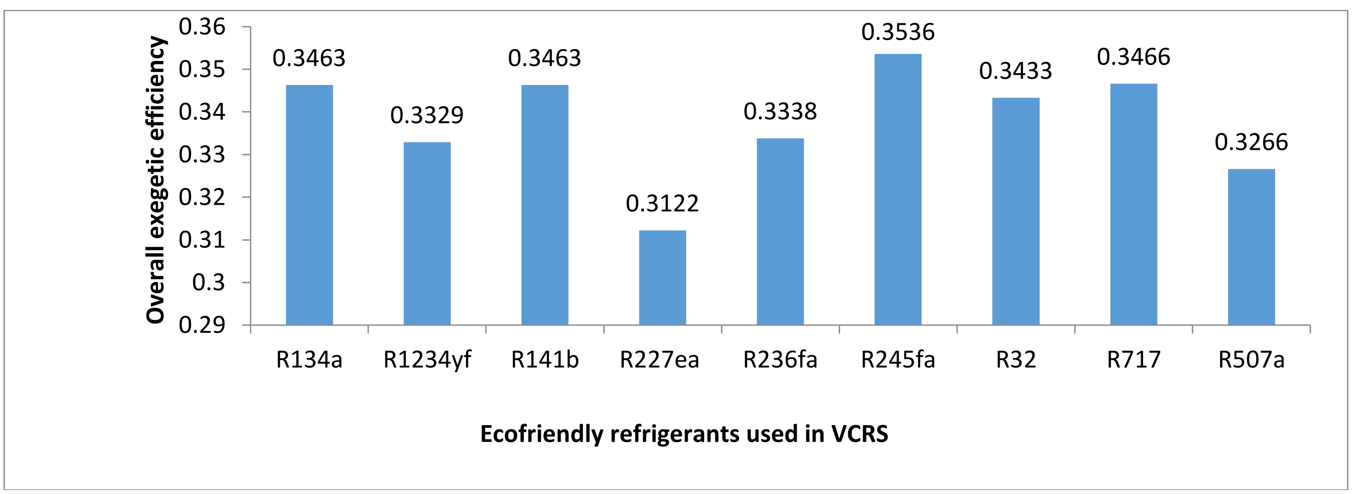

Figure 15: Thermal second law performances (Exergetic Efficiency_Overall) of cascade single effect LiBr vapour absorption refrigeration system coupled with vapour compression refrigeration using ecofriendly refrigerants in the low temperature cycle of VCRS system

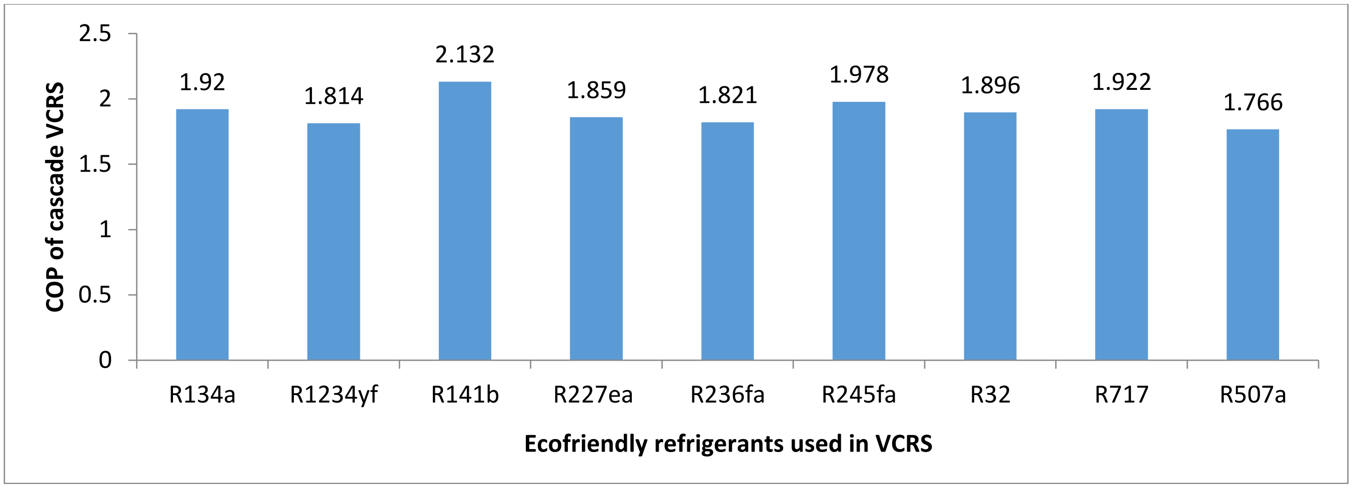

Figure 16: Thermal second law performances (Exergetic Efficiency _Overall) of cascade single effect LiBr vapour absorption refrigeration system coupled with vapour compression refrigeration using ecofriendly refrigerants in the low temperature cycle of VCRS system

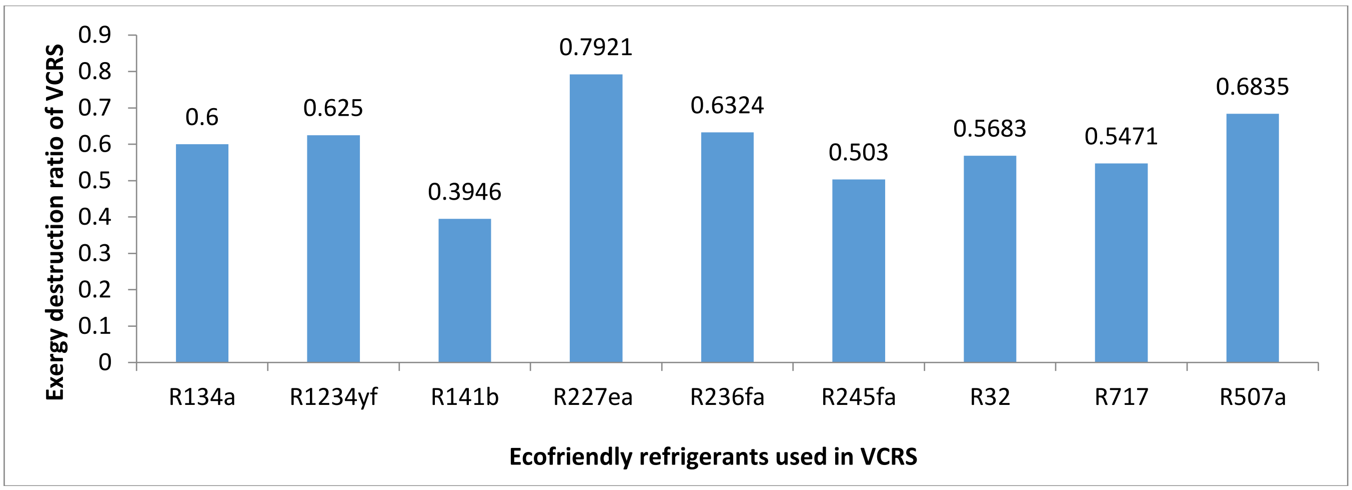

Figure 17: Thermal performances in terms of exergy destruction ratio (EDR_VCRS) of cascade single effect LiBr vapour absorption refrigeration system coupled with vapour compression refrigeration using ecofriendly refrigerants in the low temperature cycle of VCRS system

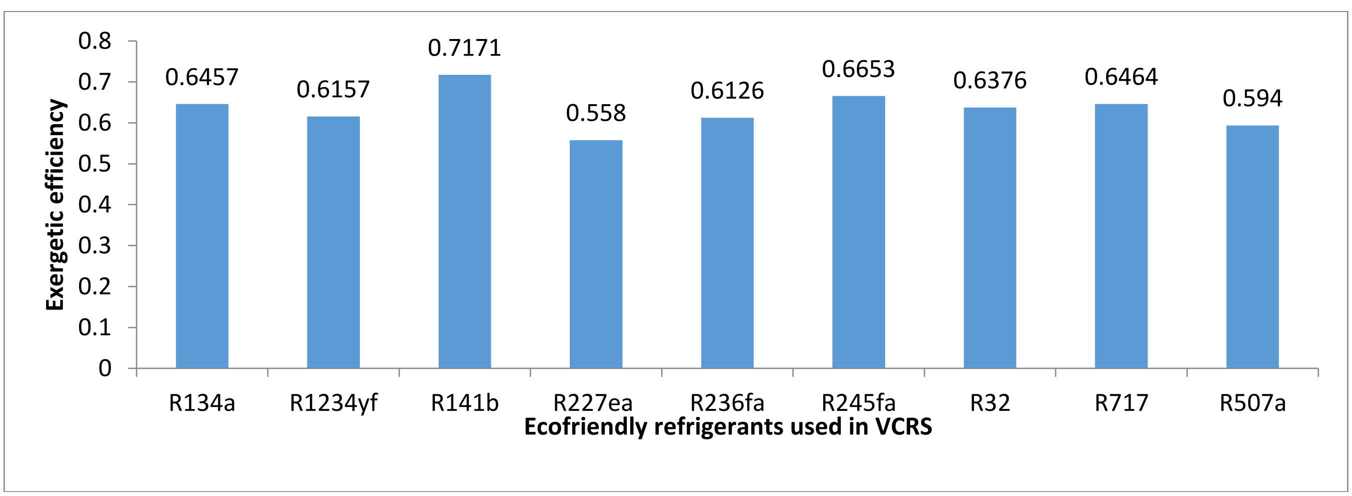

Figure 18: Thermal second law performances(Exergetic Efficiency _VCRS) of cascade single effect LiBr vapour absorption refrigeration system coupled with vapour compression refrigeration using ecofriendly refrigerants in the low temperature cycle of VCRS system

The performance parameters have been compared with three cascade vapour absorption-compression refrigeration system and it was observed that 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 reduction is 56.61% using triple effect VARS cascaded with VCRS and 25.92% reduction using double effect VARS cascaded with VCRS as shown in Table-4(a)-Table 4(c) respectively.

Table 4(a): Performance parameters obtained from computed Results obtained from developed model for vapour absorption LiBr-H_2O refrigeration systems (only)

Performance Parameters	Single Effect VARS	Double Effect VARS	% Incre-ment	Tripple Effect VARS	% Increment
First Law Efficiency of VARS (COP_{VARS})	0.7496	1.338	78.495	1.644	121.99
Exergetic_ Efficiency of _ VARS	0.1927	0.2364	22.68	0.3458	79.45
Irreversibility Ratio/EDR (EDR_{VARS})	4.36	3.230	25.92 Reduction	1.892,	56.61 Reduction

Table 4(b): Overall cascade system performance parameters obtained from computed results from developed model using vapour compression refrigeration system (only) using R134a for10°C of temperature overlapping (approach).

Performance Parameters	Single Effect VARS	Double Effect VARS	% Incre-ment	Tripple Effect VARS	% Incre-ment
First Law Efficiency of VARS (COP_{VARS})	0.9887	1.536	55.36	1.782	80.30
Exergetic_ Efficiency of _ VARS	0.3463	0.3854	11.29	0.4218	21.80
Irreversibility Ratio/EDR (EDR_{VARS})	1.888	1.595	15.52 Reduction	1.371	37.10

Table 4(c): Overall cascade system performance parameters obtained from computed results obtained from developed model using cascaded condenser of vapour compression system using R134a coupled with LiBr absorption Refrigeration Systems

Performance Parameters	Single Effect VARS	Double Effect VARS	% Increment	Tripple Effect VARS	% Increment
First Law Efficiency of VARS (COP_{VARS})	1.921	1.838	4.32 Reduction	2.05	6.72
Exergetic_ Efficiency of _ VARS	0.6457	0.6183	4.24 Reduction	0.6896	6.80
Irreversibility Ratio/EDR based on exergy output (EDR_{VARS})	0.60	0.6174	2.90	0.4501	24.98 Reduction

Similarly performance parameters have been compared with three cascade vapour absorption-compression refrigeration system and it was observed that 22.87% first law efficiency enhancement using triple effect VARS cascaded with VCRS and 46.28% enhancement in second law efficiency using triple effect VARS cascaded with VCRS as compared with double effect vapour absorption refrigeration cascaded with vapour compression refrigeration system. Similarly exergy reduction is 41.42% using triple effect VARS cascaded with VCRS as compared to double effect VARS cascaded with VCRS as shown in Table-5(a)-Table 5(c) respectively.

Table 5(a): Performance parameters obtained from computed Results obtained from developed model for Vapour Absorption LiBr-H_2O refrigeration systems (only)

Performance Parameters	Double Effect VARS	Tripple Effect VARS	% Incre-ment
First Law Efficiency of VARS (COP_{VARS})	1.338	1.644	22.87
Exergetic_ Efficiency of _ VARS	0.2364	0.3458	46.28
Irreversibility Ratio/EDR (EDR_{VARS})	3.230	1.892,	41.42%Reduction

Table 5(b): Performance parameters obtained from computed results obtained from developed model using vapour compression refrigeration system (only) using R134a for 10°C of temperature overlapping (approach).

Performance Parameters	Double Effect VARS	Tripple Effect VARS	% Incre-ment
First Law Efficiency of VARS (COP_{VARS})	1.536	1.782	16.01
Exergetic_ Efficiency of _ VARS	0.3854	0.4218	9.44
Irreversibility Ratio/EDR (EDR_{VARS})	1.595	1.371	-14.04

Table 5(c): Overall Cascade system performance parameters obtained from computed results obtained from developed model using cascaded condenser of vapour compression system using R134a coupled with LiBr absorption refrigeration systems

Performance Parameters	Double Effect VARS	Tripple Effect VARS	% Increment
First Law Efficiency of VARS (COP_{VARS})	1.838	2.05	11.534
Exergetic_ Efficiency of _ VARS	0.6183	0.6896	11.532
Irreversibility Ratio/EDR based on exergy output (EDR_{VARS})	0.6174	0.4501	-27.10

4. Conclusion

The following conclusions were drawn.

(i) The 122% increment of first law efficiency (i.e. over all COP) of the triple effect vapour absorption refrigeration cascade system and 78.495% increment of first law efficiency (i.e. over all COP) of the double effect vapour absorption refrigeration system cascade system as compared to single effect vapour absorption compression refrigeration system.

(ii) The 80.30% increment of first law efficiency (i.e. over all COP) of the triple effect vapour absorption refrigeration system and 55.36% increment of first law efficiency (i.e. over all COP) of the double effect vapour absorption refrigeration system cascade system as compared to single effect vapour absorption -compression refrigeration system.

(iii) The 6.72% increment of first law efficiency (i.e. over all COP) of the triple effect vapour absorption refrigeration system and 4.32% reduction in first law efficiency (i.e. over all COP) of the double effect vapour absorption refrigeration system cascade system as compared to single effect vapour absorption -compression refrigeration system.

(iv) The 22.87% increment of first law efficiency (i.e. over all COP) of the triple effect vapour absorption refrigeration system and 46% increment of exergetic efficiency and 41.42% reduction in EDR as compared to double effect vapour absorption -compression refrigeration system.

(v) The 16.01% increment of first law efficiency (i.e. over all COP) of the triple effect vapour absorption refrigeration system as compared to double effect vapour absorption -compression refrigeration system with reduction in system exergy destruction ratio as compared to vapour compression system.

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