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Performance evaluation of ejector refrigeration systems (ERS) cascaded with vapour compression refrigeration system using low GWP refrigerants

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Abstract

To analyze the performance of ejector refrigeration system a thermodynamic model of the system was developed using Thermodynamic modeling which includes resulting set of governing equations for a particular system component expressed in terms of mass, momentum, energy and exergy balances and related to different ejector refrigeration technology for thermodynamic performance evaluation using alternate refrigerants and optimization was carried out. The thermodynamic energy and exergetic performances of ERS cascaded with VCR system was analyzed with four ecofriendly alternative refrigerants (R1234ze(E), R1234ze(Z), R1224yd(E) and R1243zf) in high temperature ejector refrigeration cycle and also alternative refrigerants (R1233zd(E) , R1225ye(Z) and HFO-1336mzz(Z) in low temperature cycle at 213K of evaporator temperature) for wide range of operating parameters like effect of evaporator of VCRS and condenser temperature of ERS, Boiler/generator temperature and evaporator temperature of ejector refrigeration system with 5oC of super heating and it was found that system R1234ze(E) in high temperature circuit and R1233zd€ in low temperature circuit gives best thermodynamic performances. However, R1225ye(Z) in low temperature cycle gives slightly less (1.5%) performance than R1233zd(E) and 1.4% above than using HFO-1336mzz(Z) in low temperature cycle. However low thermodynamic performances were observed by using R1224yd(E) in high temperature cycle.

Keywords: Energy- Energy-Exergy analysis, Ejector refrigeration system, Thermodynamic performance-evaluation

1. Introduction

As there are growing concerns about the fast melting of the glaciers of the oceans, there is need of alternate environment friendly refrigerants which have very low GWP so that the contribution of the refrigerants decreases. The selection of the working fluid should be such that it prevents the environment from both direct and indirect emissions as discussed before. As per UN report 2018, there are remote areas, in many parts of the world which faces acute problems of poverty, hunger and malnutrition. The reason behind this is the wastage of food due to insufficient supply of electricity in these areas to maintain the food items at the requisite temperatures. In order to meet the goal of providing food for everyone, there should be proper preservation of the food items. The equipment used to preserve the food need to be run by a technology which will provide the necessary cooling to the food which will use less electrical power to run the cooling equipment. Ejector refrigeration technology is the one which can utilize the waste heat to compress the refrigerant instead of the compressor. The electrical energy thus saved can be employed to meet other demands. Also if the ejector is integrated with vapour compression refrigeration system, then the system will use less compressor power to provide the required cooling to the products. Similarly, in outer applications, there exists a potential for energy efficient technology which will provide the sustainable energy solutions.

Literature on performance improvement of conventional VCRS/VARS using two-phase ejector as an expansion device is scantly available and Little research work done on the use of environment friendly refrigerants of low GWP in ejector

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integrated VCR system. Not as much of research work was done on comparison of constant pressure and constant area ejector model in the VCRS cycle with shock analysis. Most of the work is done using exergy-energy analysis of ejector refrigeration system using conventional refrigerants but advanced exergy analysis using natural and environment friendly refrigerants has been scantly reported.

Kornhauser [1990] analyzed the thermodynamic performance of ejector expansion refrigeration cycle using R-12 as refrigerant based on the constant mixing pressure model and found a first law performance in terms of coefficient of performance of up to 21% over the standard cycle under standard operating conditions.

Yapici and Ersoy [2005] have compared the thermal performance of constant pressure and constant area mixing ejector models using the R-123 refrigerant and found that the optimum coefficient of performance and area ratio determined by using the refrigerant the constant area flow model are greater than those of constant pressure model.

Li and Groll [2005] had compared the thermodynamic performances of transcritical CO_2 cycle in by using ejector as expansion device and R744 as refrigerant.

Nehdi E., et.al.[2007] Have theoretical investigated the thermodynamic performance of ejector as expansion device in refrigeration cycle with several synthetic refrigerants and found the 22%(best) thermodynamic performance (COP) improvement using R141b. Also at area ratio of 9.9 using ejector as expansion device, the maximum coefficient of performance (COP) was found. However, R141b and R408a gives the best thermal performance for the given operating conditions.

Bilir and Ersoy [2009] have investigated theoretically the improvement in the thermodynamic performance of the ejector refrigeration cycle using two phase ejector and HFC -134a as a refrigerant and found that maximum first law efficiency in terms of COP occurs for optimum value of secondary pressure drop and also found the improvement in Coefficient of performance (COP) increases with decreasing evaporator temperature or increasing condenser temperature.

Sarkar J. [2010] has carried out the numerically the optimization of the geometric parameters of the ejector refrigeration cycle using natural refrigerant such as R717(ammonia) and hydrocarbons (such as propane (R290) and isobutane(R600a) and concluded that the optimum parameters as well as first law thermodynamic performance (COP) improvement are strongly dependent on the refrigerant properties as well as operating conditions. Also comparing the three ecofriendly refrigerants used in this study and found the R600a (isobutane) gives 21% optimum (maximum) first law efficiency (COP) improvement, whereas propane (R290) gives 17.9% and the ammonia (R-717) gives 11.9%.

Li H, et.al., [2014] had compared the thermal performance characteristics of ejector expansion refrigeration cycle using R 1234yf and r134a as refrigerants and found that the R1234yf has better thermodynamic performances than that of standard refrigeration cycle and is more prominent at higher condensing temperature and lowering evaporating temperature. Also found the maximum improvement using R1234yf in first law thermodynamic performance (COP) at 40ºC condenser temperature and 5ºC evaporator temperature than using R134a.

Chen J., et.al.[2015] have theoretically carried out the conventional and advanced exergy analysis of a ejector refrigeration system and found the severe exergy destruction into endogenous/ exogenous and avoidable/un avoidable parts improves the quality of exergy analysis and concluded the maximum exergy destruction occurs in the ejector (around 53.6%) followed by generator and condenser by using R134a as refrigerant. Also carried out advanced exergy analysis and found that the ejector exergy destruction can be reduced by improving the ejector efficiencies and generator exergy destruction can be reduced by improvement in other components.

Chen J.[2014] theoretically studied the application of different working fluids in ejector refrigeration cycle and used nine refrigerants of wet and isotropic fluids and compared thermodynamic performances and found that the superheating is necessary for some fluids to avoid bubble formation in the ejector. Also concluded that R600a is a good candidate for the ejector refrigeration system due to a relatively high COP and its low environmental impact.

Saleh B. [2016] has numerically investigated the parametric analysis of ejector refrigeration cycle using different refrigerants (e.g. R-134a, R-227ea , R-236fa, R600a, R-236ea, R600,R245fa and R245ca) and found that R245ca gives best thermodynamic performance in the given operating range and ejector behaviour is sensitive to changes in condenser temperature than generator and evaporator pressure.

Ma Z., et.al.[2017] have developed a correlation for hypothetically area inside an ejector in their numerical investigation using R-134a and r141b as refrigerants and found that there is formation of hypothetical area as primary fluid fan out from the motive nozzle and used two dimensionless variable s for the correlation. The ratio of hypothetical throat area to the mixing area was correlated with two dimensionless variables i.e. one is the ratio of primary and secondary flow pressure ratio and another is nozzle throat area to the mixing area.

Lucas C. and Koehler J. [2012] have investigated experimentally the improvement in first law efficiency (COP) of the vapour compression refrigeration cycle using carbon dioxide (CO2) as refrigerant (R744) and found that with increase in high side pressure, the entrainment ratio and ejector efficiency increases. Also at the high side pressure at which the ejector efficiency is maximal decreases with decreasing evaporator pressure temperature.

Chaiwongsa and Wongwises [2004] have investigated the effect of throat diameter of the nozzle on the performance of the refrigeration cycle using two phase ejector as expansion device and R134a is used as a refrigerant in their experimental study.

Disawas and Wongwises [2004] have experimentally investigated the use of two phase ejector as an expansion device using the refrigerants (e.g. R134a and R12) using three different motive nozzles of diameters of 0.8mm, 0.9mm and 1.0mm and found that the motive nozzle with 0.8mm throat diameter gives highest value of cooling capacity and first law efficiency (COP). Also found the motive mass flow rate is highly dependent on the heat sink temperature as compared to higher temperature.

The above investigators have not evaluated the performance of cascaded ERS with VCRS using ultralow GWP refrigerants. The effect of HFO refrigerants in high temperature cycle and low temperature cycle of cascaded ERS system is investigated.

2. Results and Discussion

Following Numerical values have been chosen for numerical computation shown in table-1.

Input data in High Temperature Cycle	Ejector geometric input data	Input data in Low Temperature Cycle
Boiler temperature ejector refrigeration (T_{boiler}) =353(K) Evaporator temperature of ejector refrigeration (T_eva) =263(K) Condenser temperature of ejector refrigeration (T_cond) =303(K) Ambient temperature (To) =300(K) Refrigerant used in ejector refrigeration system = R1234ze(Z), R1234ze(E), R1243zf and R1224yd(Z)	(Length / Diameter} ratio of constant area mixing chamber(L/D) of ejector =10 Diameter of primary nozzle throat (D_throat)metre =(0.5/1000) Diameter of mixing chamber (D_m) metre =(1.4/1000) Exit diameter of primary nozzle (D_p) metre =(0.8/1000) Diffuser angle(theta) =3° Diffuser Length (L_d) metre =(112/1000) Area Ratio =7.84	Cooling Load of ejector refrigeration system (Qeva) =4.75 "kW" Evaporator temperature of low temperature cycle (T_eva) =223(K) Condenser temperature of low temperature refrigeration cycle (T_cond_LTC) =T_Eva+Approach Ambient temperature (To) =300(K) Refrigerant used in low temperature refrigeration system =R1225ye(Z), R1233zd(E) and HFO-1336mzz(Z) Compressor efficiency=80%

Table-2 shows the effect of high temperature cycle ecofriendly HFO refrigerants on the exergetic performances of cascaded ejector refrigeration system cascaded with vapour compression cycles HFO-1336mzz(Z) in the low temperature cycle and it was found that by using R1233zd(E) in high temperature cycle , the minimum exergy destruction ratio along with the optimum (highest value of 2%) second law exergetic efficiency which is can be achieved and percentage improvement in exergetic efficiency is to be found as 150.098% . Table-3 shows the effect of high temperature cycle ecofriendly HFO refrigerants on the exergetic performances of cascaded ejector refrigeration system cascaded with vapour compression cycles *R-1225ye(Z)* in the low temperature cycle and it was found that by using R1233zd(E) in high temperature cycle ,the minimum exergy destruction ratio along with the optimum (highest value of 25%) second law exergetic efficiency which is can be achieved and percentage improvement in exergetic efficiency is to be found as 134.8% .From table-(2)and table (3), The highest second law exergetic efficiency is to be found by using HFO-1336mzz(Z) and percentage improvement is 150.1% as compared by using R1225ye(Z).

Table-4 shows the effect of low temperature cycle ecofriendly HFO refrigerants on the exergetic performances of cascaded ejector refrigeration system cascaded with vapour compression cycles R-1234ze(Z) in the high temperature cycle and it was found that by using R1233zd(E), the minimum exergy destruction ratio along with the optimum (highest value of 24.98%) second law exergetic efficiency which is can be achieved and percentage improvement in exergetic efficiency is to be found as 133.05%. Table-5 shows the effect of low temperature cycle ecofriendly HFO refrigerants on the exergetic performances of cascaded ejector refrigeration system cascaded with vapour compression cycles R-1234ze(E) in the high temperature cycle and it was found that by using R1233zd(E), the minimum exergy destruction ratio along with the optimum (highest value of 24.98%) second law exergetic efficiency which is can be achieved and percentage improvement in exergetic efficiency is to be found as 144.9% . Table-6 shows the effect of low temperature cycle ecofriendly HFO refrigerants on the exergetic performances of cascaded ejector refrigeration system cascaded with vapour compression cycles R-1243zf in the high temperature cycle and it was found that by using R1233zd(E), the minimum exergy destruction ratio along with the optimum (highest value of 24.98%) second law exergetic efficiency which is can be achieved and percentage improvement in exergetic efficiency is to be found as 134.1%. Table-7(a) shows variation of boiler temperature of the effect of high temperature cycle on the first and second law (exergetic)performances of ejector refrigeration system cascaded with vapour compression cycles using R1234ze(E) in the high temperature cycle and HFO-1336mzz(Z) in low temperature cycle and it was found that by increasing boiler temperature, the first law thermodynamic performance (COP) and second law thermodynamic (exergetic) performance is decreases , while exergy destruction of ejector refrigeration system is increases . Similarly, overall cascaded first law thermodynamic performance (COP_Cascade) and cascade second law thermodynamic (exergetic) performance is decreases and cascaded exergy destruction ratio is increases and improvement in exergetic performances are also increases with increasing boiler temperature. Table-7(b) shows variation of boiler temperature of the effect of high temperature cycle on the first and second law (exergetic)performances of ejector refrigeration system cascaded with vapour compression cycles using R1234ze(Z) in the high temperature cycle and HFO-1336mzz(Z) in low temperature cycle and it was found that by increasing boiler temperature, the first law thermodynamic performance (COP) and second law thermodynamic (exergetic) performance is decreases , while exergy destruction of ejector refrigeration system and entrainment ratio is increases. Similarly, overall cascaded first law thermodynamic performance (COP_Cascade) and cascade second law thermodynamic (exergetic) performance is decreases while cascaded exergy destruction ratio is increases and improvement in exergetic performances are also increases with increasing boiler temperature

Table-7(c) shows variation of boiler temperature of the effect of high temperature cycle on the first and second law (exergetic)performances of ejector refrigeration system cascaded with vapour compression cycles using R1224yd(Z) in the high temperature cycle and HFO-1336mzz(Z) in low temperature cycle and it was found that by increasing boiler temperature, the first law thermodynamic performance (COP) and second law thermodynamic (exergetic) performance is , while exergy destruction of ejector refrigeration system and entrainment ratio is increases . Similarly, overall cascaded first law thermodynamic performance (COP_Cascade) and cascade second law thermodynamic (exergetic) performance aand cascaded exergy destruction ratio is increases and improvement in exergetic performances are also increases.

Table-7(d) shows variation of condenser temperature of the effect of high temperature cycle on the first and second law (exergetic)performances of ejector refrigeration system cascaded with vapour compression cycles using R1243zf in the high temperature cycle and HFO-1336mzz(Z) in low temperature cycle and it was found that by by increasing condenser temperature, the first law thermodynamic performance (COP) and second law thermodynamic (exergetic) performance is , while exergy destruction of ejector refrigeration system and entrainment ratio is increases. Similarly, overall cascaded first law thermodynamic performance (COP_Cascade) and cascade second law thermodynamic (exergetic) performance is decreases and cascaded exergy destruction ratio is increases and improvement in exergetic performances are also increases.

Table-8(a) shows variation of condenser temperature of the effect of high temperature cycle on the first and second law (exergetic)performances of ejector refrigeration system cascaded with vapour compression cycles using R1234ze(E) in the high temperature cycle and HFO-1336mzz(Z) in low temperature cycle and it was found that by increasing condenser temperature, the first law thermodynamic performance (COP) and second law thermodynamic (exergetic) performance is decreases , while exergy destruction of ejector refrigeration system and entrainment ratio is increases. Similarly, overall cascaded first law thermodynamic performance (COP_Cascade) and cascaded exergy destruction ratio is decreases and cascade second law thermodynamic (exergetic) performance is increases. Also improvement in exergetic performances are also increases.

Table-8(b) shows variation of condenser temperature of the effect of high temperature cycle on the first and second law (exergetic)performances of ejector refrigeration system cascaded with vapour compression cycles using R1234ze(Z) in the high temperature cycle and HFO-1336mzz(Z) in low temperature cycle and it was found that by by increasing condenser temperature, the first law thermodynamic performance (COP) and second law thermodynamic (exergetic) performance is decreases , while exergy destruction of ejector refrigeration system and entrainment ratio is increases. Similarly, overall cascaded first law thermodynamic performance (COP_Cascade) and cascaded exergy destruction ratio is decreases and cascade second law thermodynamic (exergetic) performance increases. Also improvement in exergetic performances are also increases with increasing condenser temperature.

Table-8(c) shows variation of condenser temperature of the effect of high temperature cycle on the first and second law (exergetic)performances of ejector refrigeration system cascaded with vapour compression cycles using R1224yd(Z) in the high temperature cycle and HFO-1336mzz(Z) in low temperature cycle and it was found that by increasing condenser temperature, the first law thermodynamic performance (COP) and second law thermodynamic (exergetic) performance is decreases , while exergy destruction of ejector refrigeration system and entrainment ratio is increases. Similarly, overall cascaded first law thermodynamic performance (COP_Cascade) and cascaded exergy destruction ratio is decreases and cascade second law thermodynamic (exergetic) performance is increases. Also improvement in exergetic performances are also increases.

Table-8(d) shows variation of condenser temperature of the effect of high temperature cycle on the first and second law (exergetic)performances of ejector refrigeration system cascaded with vapour compression cycles using R124zf in the high temperature cycle and HFO-1336mzz(Z) in low temperature cycle and it was found that by increasing condenser temperature, the first law thermodynamic performance (COP) and second law thermodynamic (exergetic) performance is , while exergy destruction of ejector refrigeration system and entrainment ratio is increases. Similarly, overall cascaded first law thermodynamic performance (COP_Cascade) and cascaded exergy destruction ratio is decreases and cascade second law thermodynamic (exergetic) performance is increases. Also improvement in exergetic performances are also increases.

Table-9(a) shows variation of evaporator temperature of the effect of high temperature cycle on the first and second law (exergetic)performances of ejector refrigeration system cascaded with vapour compression cycles using R1234ze(E) in the high temperature cycle and HFO-1336mzz(Z) in low temperature cycle and it was found that by increasing evaporator temperature, the first law thermodynamic performance (COP) is increases and second law thermodynamic (exergetic) performance is decreases , while exergy destruction of ejector refrigeration system increases and entrainment ratio is decreases and compression ratio of ejector refrigeration system is increases. Similarly, overall cascaded first law thermodynamic performance (COP_Cascade) is decreases and cascade second law thermodynamic (exergetic) performance decreases while improvement in exergetic performances are also increases with increasing high temperature cycle evaporator temperature.

Table-9(b) shows variation of evaporator temperature of the effect of high temperature cycle on the first and second law (exergetic)performances of ejector refrigeration system cascaded with vapour compression cycles using R1234ze(Z) in the high temperature cycle and HFO-1336mzz(Z) in low temperature cycle and it was found that by increasing evaporator temperature, the first law thermodynamic performance (COP) is increases and second law thermodynamic (exergetic) performance is decreases , while exergy destruction of ejector refrigeration system increases and entrainment ratio is decreases and compression ratio of ejector refrigeration system is increases. Similarly, overall cascaded first law thermodynamic performance (COP_Cascade) is decreases and cascade second law thermodynamic (exergetic) performance decreases while improvement in exergetic performances are also increases with increasing high temperature cycle evaporator temperature.

Table-9(c) shows variation of evaporator temperature of the effect of high temperature cycle on the first and second law (exergetic)performances of ejector refrigeration system cascaded with vapour compression cycles using R1224yd(z) in the high temperature cycle and HFO-1336mzz(Z) in low temperature cycle and it was found that by increasing evaporator temperature, the first law thermodynamic performance (COP) is increases and second law thermodynamic (exergetic) performance is decreases, while exergy destruction of ejector refrigeration system increases and entrainment ratio is decreases and compression ratio of ejector refrigeration system is increases. Similarly, overall cascaded first law thermodynamic performance (COP_Cascade) is decreases and cascade second law thermodynamic (exergetic) performance decreases while improvement in exergetic performances are also increases with increasing high temperature cycle evaporator temperature.

Table-9(d) shows variation of evaporator temperature of the effect of high temperature cycle on the first and second law (exergetic)performances of ejector refrigeration system cascaded with vapour compression cycles using R1243zf in the high temperature cycle and HFO-1336mzz(Z) in low temperature cycle and it was found that by increasing condenser temperature, the first law thermodynamic performance (COP) is increases and second law thermodynamic (exergetic) performance is decreases , while exergy destruction of ejector refrigeration system increases and entrainment ratio is decreases while compression ratio is increases. Similarly, overall cascaded first law thermodynamic performance (COP_Cascade) is decreases and cascade second law thermodynamic (exergetic) performance decreases while improvement in exergetic performances are also increases with increasing high temperature cycle evaporator temperature.

Table- 2 (a): Variation of evaporator temperature with thermodynamic performances of VCRS cascaded ejector vapour compression refrigeration system using HFO-1336mzz(Z) in low temperature cycle and following ecofriendly refrigerants in high temperature cycle

Refrigerants in HTC	COP_ ERS	EDR_ ERS	Exergetic Efficiency	Entrainment Ratio	Compression Ratio	COP_ VCRS	Cascade COP	Cascade EDR	Cascade Exergetic Efficiency
R1234ze(Z)	0.7531	8.439	0.1059	4.796	0.7828	2.907	0.4704	3.102	0.2438
R1234ze(E)	0.7296	8.743	0.1026	3.895	0.8684	2.907	0.4580	3.030	0.2482
R1243zf)	0.7586	8.37	0.1067	3.607	0.8792	2.907	0.4733	3.054	0.2467
R1233zd(E)	0.7222	8.843	0.1016	5.146	0.7806	2.907	0.4541	3.08	0.2541
R1225ye(Z)	0.7241	8.876	0.1019	3.921	0.8692	2.907	0.4551	2.99	0.2506
R1224yd(Z)	0.7025	9.118	0.09883	4.997	0.7991	2.907	0.4436	3.03	0.2480
R1234yf	0.7338	8.687	0.1032	3.537	0.9062	2.907	0.4602	2.99	0.2506

Table 2(b): Variation of evaporator temperature with thermodynamic performances of VCRS cascaded ejector vapour compression refrigeration system using R-1225ye(Z) in low temperature cycle and following ecofriendly refrigerants in high temperature cycle

Refrigerants in HTC	COP_ ERS	EDR_ ERS	Exergetic Efficiency	Entrainment Ratio	Compression Ratio	COP_ VCRS	Cascade COP	Cascade EDR	Cascade Exergetic Efficiency
R1234ze(Z)	0.7531	8.439	0.1059	4.796	0.7828	2.901	0.4694	3.093	0.2443
R1234ze(E)	0.7296	8.743	0.1059	3.895	0.8684	2.901	0.4571	3.021	0.2487
R1243zf)	0.7586	8.37	0.1067	3.607	0.8792	2.901	0.4723	3.045	0.2472
R1233zd(E)	0.7222	8.843	0.1016	6.067	0.7725	2.901	0.4532	3.071	0.2457
R1224yd(Z)	0.7025	9.118	0.09883	4.997	0.7991	2.901	0.4427	3.024	0.2485
HFO-1336mzz(Z)	0.6579	9.804	0.09256	6.067	0.7725	2.901	0.4186	3.039	0.2476
R1234yf	0.7338	8.687	10.32	3.537	0.9062	2.901	0.4593	2.981	0.2512

Table 3: Variation of evaporator temperature with thermodynamic performances of VCRS cascaded ejector vapour compression refrigeration system using R1234ze(Z) ecofriendly refrigerant in ejector refrigeration system (ERS) and following ecofriendly refrigerants in VCRS

Refrigerants in LTC	COP_ ERS	EDR_ ERS	Exergetic Efficiency	Entrainment Ratio (shy)	Compression Ratio (mu_1)	COP_ VCRS	Cascade COP	Cascade EDR	Cascade Exergetic Efficiency
HFO1336mzz(Z)	0.7531	8.439	0.1059	4.796	0.7828	2.907	0.4898	3.102	0.2438
R1233zd(E)	0.7531	8.439	0.1059	4.796	0.7828	2.976	0.4739	3.052	0.2468
R1225ye(Z)	0.7531	8.439	0.1059	4.796	0.7828	2.901	0.4694	3.093	0.2443
R1234yf	0.7531	8.439	0.1059	4.796	0.7828	2.828	0.4649	3.136	0.2418

Table 4: Variation of evaporator temperature with thermodynamic performances of VCRS cascaded ejector vapour compression refrigeration system using R1234ze(E)ecofriendly refrigerant in ejector refrigeration system (ERS) and following ecofriendly refrigerants in VCRS

Refrigerants in LTC	COP_ ERS	EDR_ ERS	Exergetic Efficiency	Entrainment Ratio	Compression Ratio	COP_ VCRS	Cascade COP	Cascade EDR	Cascade Exergetic Efficiency
HFO1336mzz(Z)	0.7296	8.783	0.1026	3.896	0.8684	2.907	0.4574	3.03	0.2482
R1233zd(E)	0.7296	8.783	0.1026	3.896	0.8684	2.976	0.4614	2.98	0.2513
R1225ye(Z)	0.7296	8.783	0.1026	3.896	0.8684	2.901	0.4571	3.021	0.2484
R1234yf	0.7296	8.783	0.1026	3.896	0.8684	2.828	0.4527	3.063	0.2461

Table 5: Variation of evaporator temperature with thermodynamic performances of VCRS cascaded ejector vapour compression refrigeration system using R1243zf ecofriendly refrigerant in ejector refrigeration system (ERS) and following ecofriendly refrigerants in VCRS

Refrigerants in LTC	COP_ ERS	EDR_ ERS	Exergetic Efficiency	Entrainment Ratio	Compression Ratio	COP_ VCRS	Cascade COP	Cascade EDR	Cascade Exergetic Efficiency
HFO1336mzz(Z)	0.7586	8.370	0.1067	3.607	0.8792	2.907	0.4784	3.054	0.2467
R1233zd(E)	0.7586	8.370	0.1067	3.607	0.8792	2.976	0.4825	3.004	0.2498
R1225ye(Z)	0.7586	8.370	0.1067	3.607	0.8792	2.901	0.4780	3.045	0.2472
R1234yf	0.7586	8.370	0.1067	3.607	0.8792	2.828	0.4735	3.087	0.2447

Table 6: Variation of evaporator temperature with thermodynamic performances of VCRS cascaded ejector vapour compression refrigeration system using R1224yd(Z) ecofriendly refrigerant in ejector refrigeration system (ERS) and following ecofriendly refrigerants in VCRS

Refrigerants in LTC	COP_ ERS	EDR_ ERS	Exergetic Efficiency	Entrainment Ratio (shy)	Compression Ratio (mu_1)	COP_ VCRS	Cascade COP	Cascade EDR	Cascade Exergetic Efficiency
HFO1336mzz(Z)	0.7025	9.118	0.09883	4.977	0.7991	2.907	0.4430	3.033	0.2480
R1233zd(E)	0.7025	9.118	0.09883	4.977	0.7991	2.976	0.4469	2.983	0.2511
R1225ye(Z)	0.7025	9.118	0.09883	4.977	0.7991	2.901	0.4427	3.024	0.2485
R1234yf	0.7025	9.118	0.09883	4.977	0.7991	2.828	0.4385	3.066	0.2459

Table 7(a): Effect of boiler temperature on the variation of thermal performance parameters of ejector refrigeration system (ERS) using R-1234ze(E) ecofriendly refrigerant in high temperature circuit cascaded vapour compression vapour compression refrigeration system refrigeration system (VCRS) using R-1336mzz(Z) ecofriendly refrigerant in low temperature circuit.

T_boiler (K)	ERS COP	ERS EDR	ERS Exergetic Effi	VCRS COP	Entrainment Ratio (shy)	Compression Ratio	Cascaded COP	Cascaded EDR	Cascaded Exergetic Efficiency	% Improvement
333	0.7577	8.381	0.1066	2.199	3.895	0.9337	0.4211	3.014	0.2491	133.7
338	0.7484	8.498	0.1053	2.199	3.895	0.9152	0.4169	3.018	0.2489	136.4
343	0.7404	8.60	0.1042	2.199	3.895	0.8984	0.4133	3.021	0.2487	138.8
348	0.7330	8.697	0.1031	2.199	3.895	0.8799	0.4099	3.024	0.2485	141.0
353	0.7296	8.743	0.1026	2.199	3.895	0.8684	0.4084	3.026	0.2484	142.0
358	0.7271	8.776	0.1023	2.199	3.895	0.8548	0.4072	3.027	0.2483	142.7
363	0.7267	8.781	0.1022	2.199	3.895	0.8421	0.4071	3.029	0.2482	142.8
368	0.7289	8.752	0.1025	2.199	3.895	0.830	0.4080	3.029	0.2482	142.9

Table 7(b) Effect of boiler temperature on the variation of thermal performance parameters of ejector refrigeration system (ERS) using R-1234ze(Z) ecofriendly refrigerant in high temperature circuit cascaded vapour compression vapour compression refrigeration system refrigeration system (VCRS) using R-1336mzz(Z) ecofriendly refrigerant in low temperature circuit.

Boiler temp (K)	ERS COP	ERS EDR	ERS Exergetic Eff	VCRS COP	Entrainment Ratio	Compression Ratio	Cascade COP	Cascade EDR	Cascade Exergetic Effi	% improvement in Exergetic Efficiency
333	0.7924	7.97	0.1115	2.199	4.790	0.8463	0.4366	3.072	0.2456	120.3
338	0.7818	8.092	0.110	2.199	4.790	0.8280	0.4319	3.076	0.2453	123.0
343	0.7621	8.211	0.1086	2.199	4.790	0.8114	0.4274	3.081	0.2451	125.7
348	0.7445	8.327	0.1072	2.199	4.790	0.7964	0.4231	3.085	0.2448	128.3
353	0.7531	8.547	0.1047	2.199	4.790	0.7703	0.4151	3.090	0.2445	133.4
358	0.7531	8.439	0.1059	2.199	4.790	0.7828	0.4190	3.087	0.2447	131.0
363	0.7365	8.651	0.1036	2.199	4.790	0.7589	0.4115	3.094	0.2442	135.7
368	0.7291	8.749	0.1026	2.199	4.790	0.7485	0.4082	3.098	0.2440	137.0

Table 7(c) Effect of boiler temperature on the variation of thermal performance parameters of ejector refrigeration system (ERS) using R-1224yd(Z) ecofriendly refrigerant in high temperature circuit cascaded vapour compression vapour compression refrigeration system refrigeration system (VCRS) using R-1336mzz(Z) ecofriendly refrigerant in low temperature circuit.

Boiler Temp (K)	ERS COP	ERS EDR	ERS Exergetic Effi	VCRS COP	Entrain ment Ratio	Compression Ratio	Cascade COP	Cascade EDR	Cascade Exergetic Efficiency	% improve-ment in Exergetic Efficiency
333	0.7495	8.484	0.1054	2.199	4.997	0.8569	0.4174	3.014	0.2491	136.3
338	0.7368	8.647	0.1037	2.199	4.997	0.8401	0.4117	3.018	0.2489	140.1
343	0.7248	8.807	0.1020	2.199	4.997	0.8250	0.4062	3.020	0.2487	143.9
348	0.7134	8.964	0.1004	2.199	4.997	0.8401	0.4009	3.024	0.2485	147.6
353	0.7025	9.118	0.0988	2.199	4.997	0.7991	0.3959	3.026	0.2483	151.2
358	0.6922	9.268	0.0974	2.199	4.997	0.7878	0.3912	3.032	0.2480	154.7
363	0.6825	9.415	0.0960	2.199	4.997	0.7776	0.3867	3.035	0.2478	158.1
368	0.6734	9.556	0.0947	2.199	4.997	0.7682	0.3824	3.039	0.2476	161.4

Table 7(d) Effect of boiler temperature on the variation of thermal performance parameters of ejector refrigeration system (ERS) using R-1243zf ecofriendly refrigerant in high temperature circuit cascaded vapour compression vapour compression refrigeration system refrigeration system (VCRS) using R-1336mzz(Z) ecofriendly refrigerant in low temperature circuit.

Boiler Temp (K)	ERS COP	ERS EDR	ERS Exergetic Effi	VCRS COP	Entrainment Ratio	Comp-ression Ratio	Cascade COP	Cascade EDR	Cascade Exergetic Efficiency	% improve-ment in Exergetic Efficiency
333	0.7813	8.098	0.1099	2.199	3.607	0.9460	0.4316	3.035	0.2478	125.5
338	0.7733	8.192	0.1088	2.199	3.607	0.9270	0.4281	3.038	0.2476	127.6
343	0.7667	8.081	0.1079	2.199	3.607	0.9097	0.4251	3.041	0.2475	129.4
348	0.7616	8.328	0.1071	2.199	3.607	0.8938	0.4228	3.043	0.2473	130.8
353	0.7586	8.370	0.1067	2.199	3.607	0.8792	0.4215	3.046	0.2472	131.6
358	0.7582	8.375	0.1067	2.199	3.607	0.8654	0.4213	3.047	0.2471	131.7
363	0.7616	8.333	0.1071	2.199	3.607	0.8523	0.4228	3.048	0.2471	130.6
368	0.7717	8.211	0.1086	2.199	3.607	0.8393	0.4273	3.047	0.2471	127.6

Table 8(a) : Effect of condenser temperature on the variation of thermal performance parameters of ejector refrigeration system (ERS) using R-1234ze(E) ecofriendly refrigerant in high temperature circuit cascaded vapour compression vapour compression refrigeration system refrigeration system (VCRS) using R-1336mzz(Z) ecofriendly refrigerant in low temperature circuit.

T_Cond [K]	ERS COP	ERS EDR	ERS Exergetic Efficiency	VCRS COP	Entrainment Ratio (shy)	Compre-ssion Ratio	Cascaded COP	Cascaded EDR	Cascaded Exergetic Efficiency	% Improvement
303	0.7296	8.743	1.026	2.199	3.895	0.8684	0.4084	3.026	0.2484	142.0
304	0.7275	8.771	1.023	2.199	4.009	0.8684	0.4074	3.025	0.2485	142.8
305	0.7254	8.799	1.020	2.199	4.126	0.8684	0.4064	3.024	0.2485	143.5
306	0.7232	8.828	1.017	2.199	4.246	0.8684	0.4055	3.023	0.2486	144.3
307	0.7210	8.858	1.014	2.199	4.368	0.8684	0.4045	3.022	0.2486	145.1
308	0.7188	8.889	1.011	2.199	4.493	0.8684	0.4034	3.021	0.2487	145.9
309	0.7165	8.921	1.008	2.199	4.620	0.8684	0.4024	3.020	0.2487	146.8
310	0.7142	8.952	1.005	2.199	4.75	0.8684	0.4013	3.019	0.2488	147.6
311	0.7118	8.985	1.001	2.199	4.883	0.8684	0.4002	3.019	0.2488	148.5
312	0.7094	9.019	0.0998	2.199	5.019	0.8684	0.3991	3.018	0.2489	149.4
313	0.7070	9.054	0.0995	2.199	5.157	0.8684	0.3980	3.017	0.2490	150.3

Table 8(b) Effect of condenser temperature on the variation of thermal performance parameters of ejector refrigeration system (ERS) using R-1234ze(Z) ecofriendly refrigerant in high temperature circuit cascaded vapour compression vapour compression refrigeration system refrigeration system (VCRS) using R-1336mzz(Z) ecofriendly refrigerant in low temperature circuit.

Condenser Temp (K)	ERS COP	ERS EDR	ERS Exergetic Effi	VCRS COP	Entrainment Ratio	Compression Ratio	Cascade COP	Cascade EDR	Cascade Exergetic Effi	% improvement in Exergetic Efficiency
303	0.7240	6.435	0.1345	2.789	7.77	0.7233	0.4474	3.102	0.2434	81.26
304	0.7224	6.451	0.1342	2.789	8.032	0.7233	0.4466	3.102	0.2438	81.66
305	0.7209	6.467	0.1339	2.789	8.302	0.7233	0.4458	3.101	0.2438	82.08
306	0.7193	6.483	0.1336	2.789	8.578	0.7233	0.4450	3.10	0.2439	82.50
307	0.7177	6.50	0.1333	2.789	8.861	0.7233	0.4441	3.10	0.2439	82.93
308	0.7161	6.517	0.1330	2.789	9.151	0.7233	0.4433	3.099	0.2439	83.37
309	0.7145	6.534	0.1327	2.789	9.449	0.7233	0.4425	3.099	0.2440	83.82
310	0.7128	6.552	0.1324	2.789	9.754	0.7233	0.4416	3.098	0.2440	84.27
311	0.7111	6.570	0.1321	2.789	10.07	0.7233	0.4407	3.098	0.2440	84.74
312	0.7094	6.588	0.1318	2.789	10.39	0.7233	0.4398	3.097	0.2441	85.21
313	0.7077	6.607	0.1315	2.789	10.72	0.7233	0.4389	3.096	0.2441	85.69

Table 8(c) Effect of condenser temperature on the variation of thermal performance parameters of ejector refrigeration system (ERS) using R-1234ze(Z) ecofriendly refrigerant in high temperature circuit cascaded vapour compression vapour compression refrigeration system refrigeration system (VCRS) using R-1336mzz(Z) ecofriendly refrigerant in low temperature circuit.

Condenser Temp (K)	ERS COP	ERS EDR	ERS Exergetic Effi	VCRS COP	Entrainment Ratio	Compression Ratio	Cascade COP	Cascade EDR	Cascade Exergetic Efficiency	% improve-ment in Exergetic Efficiency
303	0.7242	6.433	0.1345	2.789	5.339	0.8157	0.4475	3.059	0.2464	83.12
304	0.7221	6.455	0.1341	2.789	5.487	0.8157	0.4464	3.058	0.2464	83.70
305	0.7199	6.477	0.1337	2.789	5.639	0.8157	0.4453	3.057	0.2465	84.29
306	0.7177	6.50	0.1333	2.789	5.793	0.8157	0.4442	3.056	0.2465	84.90
307	0.7155	6.524	0.1329	2.789	5.951	0.8157	0.4430	3.055	0.2466	85.52
308	0.7132	6.548	0.1325	2.789	6.112	0.8157	0.4418	3.054	0.2466	86.16
309	0.7108	6.573	0.1321	2.789	6.276	0.8157	0.4406	3.053	0.2467	86.82
310	0.7085	6.598	0.1316	2.789	6.443	0.8157	0.4393	3.053	0.2468	87.49
311	0.7060	6.624	0.1312	2.789	6.614	0.8157	0.4380	3.052	0.2468	88.18
312	0.7035	6.651	0.1307	2.789	6.787	0.8157	0.4367	3.051	0.2469	88.89
313	0.7010	6.679	0.1302	2.789	6.965	0.8157	0.4354	3.050	0.2469	89.92

Table 8(d) Effect of condenser temperature on the variation of thermal performance parameters of ejector refrigeration system (ERS) using R-1234ze(Z) ecofriendly refrigerant in high temperature circuit cascaded vapour compression vapour compression refrigeration system refrigeration system (VCRS) using R-1336mzz(Z) ecofriendly refrigerant in low temperature circuit.

Condenser Temp (K)	ERS COP	ERS EDR	ERS Exergetic Effi	VCRS COP	Entrainment Ratio	Compression Ratio	Cascade COP	Cascade EDR	Cascade Exergetic Efficiency	% improve-ment in Exergetic Efficiency
303	0.6693	7.042	0.1242	2.789	8.227	0.7406	0.4187	3.040	0.2475	99.88
304	0.6674	7.066	0.1240	2.789	8.510	0.7406	0.4176	3.039	0.2476	99.70
305	0.6653	7.091	0.1236	2.789	8.801	0.7406	0.4166	3.039	0.2476	100.3
306	0.6633	7.115	0.1232	2.789	9.10	0.7406	0.4155	3.038	0.2476	101.0
307	0.6612	7.141	0.1228	2.789	9.406	0.7406	0.4144	3.037	0.2477	101.6
308	0.6591	7.167	0.1224	2.789	9.721	0.7406	0.4133	3.037	0.2477	102.3
309	0.6570	7.193	0.1221	2.789	10.04	0.7406	0.4121	3.036	0.2478	103.0
310	0.6548	7.220	0.1217	2.789	10.37	0.7406	0.4110	3.036	0.2478	103.7
311	0.6527	7.248	0.1212	2.789	10.71	0.7406	0.4098	3.035	0.2478	104.4
312	0.6504	7.276	0.1208	2.789	11.06	0.7406	0.4086	3.034	0.2479	105.1
313	0.6482	7.305	0.1204	2.789	11.42	0.7406	0.4074	3.034	0.2479	105.9

Table 9(a) : Effect of evaporator temperature on the variation of thermal performance parameters of ejector refrigeration system (ERS) using R-1234ze(E) ecofriendly refrigerant in high temperature circuit cascaded vapour compression vapour compression refrigeration system refrigeration system (VCRS) using R-1336mzz(Z) ecofriendly refrigerant in low temperature circuit.

T_eva [K]	ERS COP	ERS EDR	ERS Exergetic Effi	VCRS COP	Entrainment Ratio (shy)	Compression Ratio	Cascaded COP	Cascaded EDR	Cascaded Exergetic Efficiency	% improvement
253	0.6917	6.782	0.1285	2.789	5.918	0.806	0.4305	3.088	0.2477	92.77
258	0.7107	7.644	0.1157	2.468	4.778	0.8363	0.4196	3.028	0.2482	114.6
263	0.7296	8.743	0.1026	2.199	3.895	0.8684	0.4084	3.026	0.2484	142.0
268	0.7484	10.19	0.08936	1.968	3.204	0.8972	0.3963	3.029	0.2482	177.7
273	0.7671	12.18	0.07587	1.768	2.657	0.9311	0.3837	3.04	0.2475	226.3
278	0.7893	15.83	0.05941	1.56	2.145	0.9739	0.3676	3.064	0.2461	314.2
283	0.8038	19.71	0.04829	1.437	1.870	1.004	0.3564	3.088	0.2446	406.6

Table 9(b) Effect of evaporator temperature on the variation of thermal performance parameters of ejector refrigeration system (ERS) using R-1234ze(Z) ecofriendly refrigerant in high temperature circuit cascaded vapour compression vapour compression refrigeration system refrigeration system (VCRS) using R-1336mzz(Z) ecofriendly refrigerant in low temperature circuit.

Evap Temp (K)	ERS COP	ERS EDR	ERS Exergetic Efficiency	VCRS COP	Entrainment Ratio	Compression Ratio	Cascade COP	Cascade EDR	Cascade Exergetic Efficiency	% improvement in Exergetic Efficiency
253	0.7240	6.438	0.1345	2.789	7.770	0.7233	0.4474	3.102	0.2438	81.23
258	0.7385	7.318	0.1202	2.468	6.072	0.7524	0.4333	3.091	0.2444	103.3
263	0.7831	8.439	0.1059	2.199	4.796	0.7828	0.4190	3.087	0.2447	131.0
268	0.7676	9.91	0.09166	1.968	3.826	0.8146	0.4044	3.090	0.2445	166.7
273	0.7821	11.93	0.07736	1.768	3.084	0.8487	0.3895	3.010	0.2439	215.3
278	0.7961	14.86	0.06304	1.593	2.507	0.8844	0.3744	3.117	0.2429	285.3
283	0.8111	19.52	0.04873	1.437	2.055	0.9219	0.3588	3.144	0.2413	395.2

Table 9(c) Effect of evaporator temperature on the variation of thermal performance parameters of ejector refrigeration system (ERS) using R-1224yd(Z) ecofriendly refrigerant in high temperature circuit cascaded vapour compression vapour compression refrigeration system refrigeration system (VCRS) using R-1336mzz(Z) ecofriendly refrigerant in low temperature circuit.

Evap Temp (K)	ERS COP	ERS EDR	ERS Exergetic Eff	VCRS COP	Entrainment Ratio	Compression Ratio	Cascade COP	Cascade EDR	Cascade Exergetic Efficiency	% improvement in Exergetic Effi
253	0.6693	7.042	0.1243	2.789	8.227	0.7406	0.4187	3.04	0.2475	99.06
258	0.6859	7.956	0.1117	2.468	6.375	0.7693	0.4075	3.031	0.2481	122.2
263	0.7025	9.118	0.0988	2.199	4.997	0.7991	0.3959	3.028	0.2483	151.2
268	0.7193	10.64	0.0859	1.968	3.96	0.830	0.3839	3.032	0.2480	188.8
273	0.7361	12.74	0.0728	1.768	3.171	0.8623	0.3714	3.044	0.2473	239.7
278	0.7530	15.78	0.05960	1.593	2.563	0.8962	0.3585	3.063	0.2461	313.0
283	0.7699	20.62	0.04625	1.437	2.090	0.9321	0.3450	3.092	0.2444	428.4

Table 9(d) Effect of evaporator temperature on the variation of thermal performance parameters of ejector refrigeration system (ERS) using R-1243zf ecofriendly refrigerant in high temperature circuit cascaded vapour compression vapour compression refrigeration system refrigeration system (VCRS) using R-1336mzz(Z) ecofriendly refrigerant in low temperature circuit.

Evap Temp (K)	ERS COP	ERS EDR	ERS Exergetic Effi	VCRS COP	Entrainment Ratio	Compression Ratio	Cascade COP	Cascade EDR	Cascade Exergetic Efficiency	% improvement in Exergetic Efficiency
253	0.7242	6.433	0.1345	2.789	5.339	0.8157	0.4475	3.092	0.2464	83.12
258	0.7414	7.285	0.1207	2.468	4.370	0.8464	0.4347	3.049	0.2470	104.6
263	0.7586	8.370	0.1067	2.199	3.607	0.8792	0.4215	3.046	0.2472	131.6
268	0.7757	9.797	0.9262	1.968	3.002	0.9126	0.4078	3.048	0.2470	166.7
273	0.7927	11.76	0.0784	1.768	2.517	0.9480	0.3936	3.059	0.2464	214.3
278	0.8095	14.61	0.06406	1.593	2.126	0.9848	0.3790	3.077	0.2453	282.9
283	0.8262	19.15	0.04963	1.437	1.807	1.024	0.3638	3.105	0.2436	390.8

Table-10(a) : shows the variation of low temperature cycle evaporator temperature on first and second law performance of ejector refrigeration system using R1234ze(E) in HTC cascaded with vapour compression refrigeration system using R1233zd(E) in LTC and found that as increasing LTC evaporator temperature, the first law performance in terms of COP is increasing while cascaded second law(exergetic) performance is decreasing . Similarly exergy destruction ratio of cascaded system is increases and improvement in second law (exergetic) performances is also decreasing.

Table- 10(a): Variation LTC evaporator temperature with thermodynamic performance of ejector refrigeration system using R1234ze(E) in HTC cascaded with vapour compression refrigeration system using R1233zd(E) in LTC

Low Temperature Evaporator $T_{\_EVA}$(K)	Cascaded second law Efficiency	% improvement	Cascaded COP	Cascaded EDR
215	0.2528	146.3	0.4134	2.956
218	0.2522	145.7	0.4371	2.965
223	0.2513	144.8	0.4574	2.980
228	0.250	143.5	0.4861	3.001
233	0.2482	141.3	0.5114	3.029
238	0.2460	139.6	0.5371	3.066
243	0.2431	136.8	0.5633	3.114

Table-10(b) shows the variation of low temperature cycle evaporator temperature on first and second law performance of ejector refrigeration system using R1234ze(E) in HTC cascaded with vapour compression refrigeration system using HFO1336mzz(Z)in LTC and found that as increasing LTC evaporator temperature, the first law performance in terms of COP is increasing while cascaded second law(exergetic) performance is decreasing. Similarly exergy destruction ratio of cascaded system is increases and improvement in second law (exergetic) performances is also decreasing

Table 10(b): Variation with condenser temperature of ejector fitted vapour compression refrigeration system using R1336mzz(z)

Low Temp Evap T_EVA(K)	Cascaded second law Effi	% improvement	Cascaded EDR	Cascaded COP
215	0.2485	142.0	0.4084	3.025
218	0.2484	142.1	0.4326	3.026
223	0.2482	141.8	0.4574	3.030
228	0.2474	141.1	0.4827	3.042
233	0.2462	139.9	0.5085	3.062
238	0.2444	138.1	0.5348	3.092
243	0.2419	135.7	0.5615	3.134

Table-10(c): shows the variation of low temperature cycle evaporator temperature on first and second law performance of ejector refrigeration system using R1234ze(E) in HTC cascaded with vapour compression refrigeration system using R1225ye(Z)in LTC and found that as increasing LTC evaporator temperature, the first law performance in terms of COP is increasing while cascaded second law (exergetic) performance is decreasing. Similarly, exergy destruction ratio of cascaded system is increases and improvement in second law (exergetic) performances is also decreasing.

Table 10(c): Variation LTC evaporator temperature with thermodynamic performance of ejector refrigeration system using R1234ze(E) in HTC cascaded with vapour compression refrigeration system using R1225ye(Z)in LTC

Low Temp Evap T_EVA [K]	Cascaded second law Effi	% improve-ment	Cascaded EDR	Cascaded COP
213	0.2495	141.3	3.091	0.4087
218	0.2493	142.9	3.091	0.4326
223	0.2487	142.3	3.091	0.4571
228	0.2478	141.4	3.091	0.4822
233	0.2464	140.0	3.091	0.5078
238	0.2444	138.1	3.091	0.5344
243	0.2414	135.6	3.135	0.5606

Table-11, shows the comparison between three ecofriendly ultra-low GWP refrigerants used in low temperature cycle, it is observed that the best thermodynamics was observed that, by using R1233zd(E) in low temperature cycle and lowest was observed by using HFO-1336mzz(Z). and by using R1225ye(Z), the exergetic performances is slightly higher than using HFO 1336mzz(Z) and slightly less than using R1233zd(E). Although the second law(exergetic) performances is nearly same with the variation of 1.7%.

Table 10(d) : Variation LTC evaporator temperature with the improvement in thermodynamic(exergetic) performance of ejector refrigeration system using R1234ze(E) in HTC cascaded with vapour compression refrigeration system using HFO1336mzz(Z)in LTC

Low Temp Evap T_EVA(K)	% improvement R-1233zd(E)	% improvement R1225ye(Z)	% improvement HFO-1336mzz(Z)
215	146.3	143.1	142.0
218	145.7	142.9	142.1
223	144.8	142.3	141.8
228	143.5	141.4	141.1
233	141.3	140.0	139.9
238	139.6	138.1	138.1
243	136.8	135.6	135.7

3. Conclusions

Following conclusions were drawn.

- The optimum second law exergetic efficiency is to be found by using HFO-1336mzz(Z) and percentage improvement is 150.1% as compared by using R1225ye(Z)which has 134.8% improvement
- The 11.3% improvement can be achieved by using HFO-1336mzz(Z) in low temperature cycle as compared to R1225ye(Z) used in low temperature cycle.
- The optimum second law exergetic efficiency is to be found by using HFO-1336mzz(Z) and percentage improvement is 155.37% (using R1224yd(Z)as compared by using R-1234ze(Z) which has 133.05% improvement
- The 16.75% improvement can be achieved by using HFO-1224yd(Z) in high temperature cycle as compared to R1234ze(Z) used in high temperature cycle.
- By increasing LTC evaporator temperature, the first law performance in terms of COP is increasing while cascaded second law(exergetic) performance is decreasing.
- By increasing LTC evaporator temperature, exergy destruction ratio of cascaded system is increases and improvement in second law (exergetic) performances is also decreasing.
- By increasing boiler temperature, the first law thermodynamic performance (COP) and second law thermodynamic (exergetic) performance is , while exergy destruction of ejector refrigeration system and entrainment ratio is increases .
- By increasing boiler temperature, overall cascaded first law thermodynamic performance (COP_Cascade) and cascade second law thermodynamic (exergetic) performance aand cascaded exergy destruction ratio is increases and improvement in exergetic performances are also increases.
- By increasing condenser temperature, the first law thermodynamic performance (COP) and second law thermodynamic (exergetic) performance is decreases , while exergy destruction of ejector refrigeration system and entrainment ratio is increases .
- By increasing condenser temperature, the overall cascaded first law thermodynamic performance (COP_Cascade) and cascaded exergy destruction ratio is decreases and cascade

- second law thermodynamic (exergetic) performance is increases. Also improvement in exergetic performances are also increases.
- By increasing HTC evaporator temperature, the first law thermodynamic performance (COP) is increases and second law thermodynamic (exergetic) performance is decreases, while exergy destruction of ejector refrigeration system increases and entrainment ratio is decreases and compression ratio of ejector refrigeration system is increases.
- By increasing HTC evaporator temperature, the overall cascaded first law thermodynamic performance (COP_Cascade) is decreases and cascade second law thermodynamic (exergetic) performance decreases while improvement in exergetic performances are also increases with increasing high temperature cycle evaporator temperature.
- The best thermodynamic first law performance(COP) and second law (exergetic) performances obtained by using R1234ze(E) in high temperature circuit and R1233zd(E) in the low temperature cycle of VCRS.

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