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

ORIGINAL ARTICLE

Method for enhancing thermal performances of cascaded system using VARS cycle (NH_3H_2O) with VCR cycle using ecofriendly low GWP refrigerants

R.S. Mishra

Department, of Mechanical Engineering, Delhi Technological University Delhi

Article Information

Received: 02 February 2023
Revised: 24 April 2024
Accepted: 19 May 2024
Available online: 09 June 2024

Keywords:

Low GWP refrigerants,
Thermal performance enhancement
Cascaded VAR+VCR systems

Abstract

The expansion of the absorption refrigeration system is the compression–absorption cascade refrigeration system, which can be used to recover surplus heat and balance the demand for refrigeration. There is a wealth of literature comparing the vapour absorption cooling system and a standard vapour compression cooling system using the first and second laws of thermodynamics. A variety of operational parameter functions were examined in relation to the systems' performance. The first law performance of the cascaded VAR+VCR refrigeration system employing compression-absorption systems was found to be between 40% and 50% greater than that of the vapour absorption cycle using eco-friendly refrigerants in the low temperature VCR cycle. Similar improvements in the second law performance under the same operating conditions are achieved with a cascaded compression absorption system that uses R134a and CO2 as refrigerants. The findings indicated that the cascaded VAR+VCR system may achieve an exergy efficiency that is between 125% to 160% greater than that of the vapour absorption system. Every time a system ran on R152A, its COP was higher than when it ran on CO2 and R134a. Investigations have also been conducted into the thermodynamic characteristics of the cascaded VAR+VCR system with respect to temperature overlap and LTC evaporator temperature.

1. Introduction

Waste heat recovery can be effectively achieved by using heat exchangers to transfer heat between cold and hot process streams. Numerous studies have been conducted, including the synthesis of heat exchanger networks and the optimization of heat exchanger design. Due to their better thermal conductivity and ability to provide more carrier fluid properties, nanomaterials were blended with pure fluid for the heat exchanger's optimization design [1]. Numerous studies have been done on the VAR cycle, which is a HT cycle for heat recovery from medium- and LT cycle in terms of producing cooling energy [2]. The VAR cycle is a useful technology, but it is limited in its ability to reach very low evaporation temperatures. Additionally, as evaporation and generation temperatures decrease, so does energy efficiency. In contrast, electrical compression refrigeration (ECR) uses costly electricity but can attain much lower refrigerating temperatures and typically has superior efficiency [3]. Researchers from all across the world are working on creating revolutionary integrated refrigeration systems that are both environmentally friendly and energy efficient. Because it uses less non-renewable energy, the vapour compression-absorption integrated refrigeration system has become more and more common in the past ten years [4]. When compared to an equivalent VCRS (vapour compression refrigeration system),

Corresponding author: R. S. Mishra
Email Address: rsmishra@dtu.ac.in
https://doi.org/10.36037/IJREI.2024.8401.

the integrated system not only significantly lowers electrical energy consumption but also protects the environment by preventing the release of dangerous gases like carbon dioxide, nitrogen oxides, Sulphur oxides, and others that contribute to the greenhouse effect. By recovering waste heat, the Cascaded VAR system maintains the benefits of both VAR cycle and VCR cycle while achieving lower evaporation temperatures with comparatively high efficiency and minimal energy consumption [5]. There have been reports of more and more Cascaded VAR research in the past few years. A number of studies looked into the best working fluid combinations and selections to maximized thermal performances. The electrical energy consumption in the refrigeration cycles was found to be approximately 45% lower than in the classical VCR cycles using R744 and R134a as refrigerants under the same operating conditions. The systems included a conventional VCR system, a vapour compression- VAR single-stage system, and a vapour compression VAR double-stage system operating with CO_2 and R134a in the VCR cycle and H_2O/Li/Br in the absorption cycles [10]. According to the findings, the COP can be 50% greater than that of the absorption refrigeration system. systems utilizing R134a consistently produced higher COP than those using CO_2. of working fluids in order to attain superior performance. Thermodynamic investigation and comparison of the absorption and vapour compression sections' CACRS with different working fluid couplings. The investigation found that the system based on R134a-LiBr/H_2O had the best performance. Prior research on the enhancement of Cascaded VAR with VCR cycle performance primarily examined the energy and exergy analysis [11].

Table-1(a): Environmental properties of ecofriendly refrigerants

S. No.	Ecofriendly refrigerants	GWP	ODP
1	R-32	778	0
2	R-245fa	1087	0
3	R-152a	124	0

For example, exergy-based thermo-economic analyses were conducted, allowing for the identification of optimal operating conditions that prioritized exergetic efficiency and minimal cost. The vapour absorption refrigeration system (VARS) and the VCRS can be connected either in parallel or series. According to in a series design, the VCRS condenser rejects heat to the VARS evaporator [12]. For the cascade refrigeration system, there are a number of configurations that are coupled series-parallel and with an evaporator sub-cooler, respectively. Various configurations were subjected to energy, exergetic, economic, and environmental assessments [13]. The majority of research on integrated refrigeration systems with series and parallel configurations indicates that the integrated system's compressor can save between 50 and 60 percent of the energy used in the system. Because heat and electricity are used simultaneously, the system's running costs are thus lower than those of comparable VCRS. In order to provide context, a baseline scenario uses electrical VCR cycle using HFC-134a to cool process streams. This method generates cooling energy by using electricity instead of process heat. The working fluid in the CACRS absorption subsystem is NH_3/H_2O. The temperature of the heat source generator for a single LiBr/H_2O system cannot be lower than 80 °C or higher than 180 °C in the triple effect case [14].

2. Results and Discussion

Following input values have been taken for finding Thermal performance enhancement of cascaded refrigeration system usingNH_3-H_2O VAR cycle coupled with VCR cycle using low GWP ecofriendly HFO & HFC refrigerants in low temperature cycle.

Table-1(b): Input value

S. No.	Input parameters	Value
1	Higher pressure	13.5 bar
2	Lower pressure	1.5 bar
3	Ambient temperature	25ºC
4	LTC evaporator temperature	-50ºC
5	Temperature overlapping	0,5,10 (ºC)

2.1 Effect of Approach on thermal performances of cascaded refrigeration system usingNH_3-H_2O vapour absorption system coupled with VCR system using ultra-low / low GWP ecofriendly HFO & HFC refrigerants in low temperature cycle

The effect of approach on thermal performances of cascaded refrigeration system usingNH_3-H_2O (VAR) cycle coupled with VCR cycle using ultra-low / low GWP ecofriendly HFO & HFC refrigerants in low temperature cycle have been shown in table-2 to table-3 respectively. It was found that at zero approach (temperature overlapping), the first law efficiency (COP) and second law efficiency (Exergy efficiency) of all cycles is higher and performance enhancement in the first law efficiency (COP) and second law efficiency (Exergy efficiency) is maximum. By increasing temperature overlapping, the first law efficiency (COP) and second law efficiency (Exergy efficiency) of cascaded system is decreasing along with decreasing performance enhancement. The best performance was observed by using R152a and R245fa. Thermal performances of cascaded refrigeration system usingNH_3-H_2O (VAR) cycle coupled with VCR cycle using low GWP ecofriendly R-32A refrigerant in low temperature cycle at evaporator temperature is slightly lower than using HFC-134a and other HFCs in VCR cycle.

2.2 Effect of temperature overlapping on Thermal performances of cascaded refrigeration system usingNH_3-H_2O vapour absorption system coupled with vapour compression refrigeration system using ecofriendly HFC& HCFC refrigerants in low temperature cycle

The effect of temperature overlapping (Approach) on Thermal performances of cascaded refrigeration system usingNH_3-H_2O vapour absorption system coupled with vapour compression refrigeration system using ultra-low / low GWP ecofriendly HCFC & HFC refrigerants in low temperature cycle have been shown in table-2 to table-3 respectively. It was found that at zero approach (temperature overlapping), the first law efficiency (COP) and second law efficiency (Exergy efficiency) of all cycles is higher and performance enhancement in the first law efficiency (COP) and second law efficiency (Exergy efficiency) is maximum. By increasing temperature overlapping, the first law efficiency (COP) and second law efficiency (Exergy efficiency) of cascaded system is decreasing along with decreasing performance enhancement. The best performance was observed by using R152a and R245fa. The Thermal performances of cascaded refrigeration system usingNH_3-H_2O vapour absorption system coupled with vapour compression refrigeration system using low GWP ecofriendly R-125 refrigerant in low temperature cycle at evaporator temperature is slightly lower than using HFC-134a and other HFCs in VCR cycle.

Table-2(a): Thermal performances of cascaded refrigeration system usingNH_3-H_2O (VAR)cycle coupled with VCR cycle using low GWP ecofriendly R-152A refrigerant in low temperature cycle at evaporator temperature =-50ºC

Temperature Overlapping (ºC) using R-32	COP_VAR	COP_VCR	COP_Cascade	% improvement in COP	Exergy Efficiency_VAR	Exergy Efficiency_Cascade	% improvement in Exergy Efficiency
0	0.322	2.906	0.4811	49.3	0.1323	0.3312	150.3
5	0.322	2.571	0.470	45.97	0.1323	0.3234	144.4
10	0.322	2.292	0.4595	42.7	0.1323	0.3161	138.9

Table-2(b): Thermal performances of cascaded refrigeration system usingNH3-H2O (VAR)cycle coupled with VCR cycle using low GWP ecofriendly R-152A refrigerant in low temperature cycle at evaporator temperature =-50ºC

Temperature Overlapping (ºC) using R-152A	COP_VAR	COP_VCR	COP_Cascade	% improvement in COP	Exergy Efficiency_VAR	Exergy Efficiency_Cascade	% improvement in Exergy Efficiency
0	0.322	3.014	0.4811	50.69	0.1323	0.3341	152.4
5	0.322	2.699	0.470	47.35	0.1323	0.3265	146.7
10	0.322	2.414	0.4595	44.16	0.1323	0.3194	141.4

Table-2(c): Thermal performances of cascaded refrigeration system usingNH3-H2O (VAR)cycle coupled with VCR cycle using low GWP ecofriendly R-245fa refrigerant in low temperature cycle at evaporator temperature =-50ºC

Temperature Overlapping (ºC) using R-245fa	COP_VAR	COP_VCR	COP_Cascade	% improvement in COP	Exergy Efficiency_VAR	Exergy Efficiency_Cascade	% improvement in Exergy Efficiency
0	0.322	3.03	0.4849	50.60	0.1323	0.3341	152.3
5	0.322	2.684	0.4739	47.18	0.1323	0.3265	146.5
10	0.322	2.394	0.4634	43.93	0.1323	0.3194	141.0

Table-2(d): Thermal performances of cascaded refrigeration system usingNH3-H2O (VAR)cycle coupled with VCR cycle using low GWP ecofriendly R-134a refrigerant in low temperature cycle at evaporator temperature =-50ºC

Temperature Overlapping (ºC) using R-134A	COP_VAR	COP_VCR	COP_Cascade	% improvement in COP	Exergy Efficiency_VAR	Exergy Efficiency_Cascade	% improvement in Exergy Efficiency
0	0.322	3.04	0.4852	50.69	0.1323	0.3328	152.4
5	0.322	2.699	0.4744	47.35	0.1323	0.3249	146.7
10	0.322	2.414	0.4642	44.18	0.1323	0.3174	141.4

Table-2(e): Thermal performances of cascaded refrigeration system usingNH3-(VAR) cycle coupled with VCR cycle using low GWP ecofriendly HFO-1234yf refrigerant in low temperature cycle at evaporator temperature =-50ºC

Temperature Overlapping (ºC) using R-1234yf	COP_VAR	COP_VCR	COP_Cascade	% improvement in COP	Exergy Efficiency_VAR	Exergy Efficiency_Cascade	% improvement in Exergy Efficiency
0	0.322	2.909	0.4812	49.46	0.1323	0.3313	150.3
5	0.322	2.552	0.4693	45.75	0.1323	0.3229	144.0
10	0.322	2.250	0.4578	42.18	0.1323	0.3150	138.0

Table-2(f): Thermal performances of cascaded refrigeration system usingNH3-(VAR) cycle coupled with VCR cycle using low GWP ecofriendly HFO-1234ze refrigerant in low temperature cycle at evaporator temperature =-50ºC

Temperature Overlapping (ºC) using R-1234ze	COP_{VAR}	COP_{VCR}	$COP\_{Cascade}$	% improvement in COP	Exergy $Efficiency\_{VAR}$	Exergy $Efficiency\_{Cascade}$	% improvement in Exergy Efficiency
0	0.322	2.96	0.4828	49.95	0.1323	0.3324	151.2
5	0.322	2.606	0.4712	46.35	0.1323	0.3243	145.0
10	0.322	2.307	0.4601	42.89	0.1323	0.3165	139.2

Table-3(a): Thermal performances of cascaded refrigeration system usingNH3-H2O (VAR)cycle coupled with VCR cycle using low GWP ecofriendly HFC-410A refrigerant in low temperature cycle at evaporator temperature =-50ºC

Temperature Overlapping (ºC) using R-410A	COP_{VAR}	COP_{VCR}	$COP\_{Cascade}$	% improvement in COP	Exergy $Efficiency\_{VAR}$	Exergy $Efficiency\_{Cascade}$	% improvement in Exergy Efficiency
0	0.322	2.91	0.4813	49.47	0.1323	0.3313	150.4
5	0.322	2.567	0.4698	45.92	0.1323	0.3233	144.3
10	0.322	2.279	0.4589	42.53	0.1323	0.3158	138.6

Table-3(b): Thermal performances of cascaded refrigeration system usingNH3-H2O (VAR)cycle coupled with VCR cycle using low GWP ecofriendly HFC-141B refrigerant in low temperature cycle at evaporator temperature =-50ºC

Temperature Overlapping (ºC) using R-141b	COP_{VAR}	COP_{VCR}	$COP\_{Cascade}$	% improvement in COP	Exergy $Efficiency\_{VAR}$	Exergy $Efficiency\_{Cascade}$	% improvement in Exergy Efficiency
0	0.322	3.163	0.4888	51.80	0.1323	0.3366	154.3
5	0.322	2.822	0.4785	48.60	0.1323	0.3294	148.9
10	0.322	2.537	0.4688	45.59	0.1323	0.3226	143.8

Table-3(c): Thermal performances of cascaded refrigeration system usingNH3-H2O (VAR)cycle coupled with VCR cycle using low GWP ecofriendly HFC-124 refrigerant in low temperature cycle at evaporator temperature =-50ºC

Temperature Overlapping (ºC) using R-124	COP_{VAR}	COP_{VCR}	$COP\_{Cascade}$	% improvement in COP	Exergy $Efficiency\_{VAR}$	Exergy $Efficiency\_{Cascade}$	% improvement in Exergy Efficiency
0	0.322	3.008	0.4842	50.4	0.1323	0.3334	151.9
5	0.322	2.655	0.4729	46.87	0.1323	0.3255	145.9
10	0.322	2.358	0.4621	43.5	0.1323	0.3179	140..2

Table-3(d): Thermal performances of cascaded refrigeration system usingNH3-(VAR) cycle coupled with VCR cycle using low GWP ecofriendly HFC-227ea refrigerant in low temperature cycle at evaporator temperature =-50ºC

Temperature Overlapping (ºC) using R-227ea	COP_{VAR}	COP_{VCR}	$COP\_{Cascade}$	% improvement in COP	Exergy $Efficiency\_{VAR}$	Exergy $Efficiency\_{Cascade}$	% improvement in Exergy Efficiency
0	0.322	2.771	0.4768	48.09	0.1323	0.3282	148.0
5	0.322	2.41	0.4641	44.2	0.1323	0.3193	141.3
10	0.322	2.104	0.4516	40.26	0.1323	0.3107	134.8

Table-3(e): Thermal performances of cascaded refrigeration system usingNH3-(VAR) cycle coupled with VCR cycle using low GWP ecofriendly HCFC-123 refrigerant in low temperature cycle at evaporator temperature =-50ºC

Temperature Overlapping (ºC) using R-123	COP_{VAR}	COP_{VCR}	$COP\_{Cascade}$	% improvement in COP	Exergy $Efficiency\_{VAR}$	Exergy $Efficiency\_{Cascade}$	% improvement in Exergy Efficiency
0	0.322	3.083	0.4864	51.08	0.1323	0.3350	153.1
5	0.322	2.739	0.4758	47.76	0.1323	0.3275	147.4
10	0.322	2.452	0.4656	44.62	0.1323	0.3204	142.1

Table-3(f): Thermal performances of cascaded refrigeration system usingNH3-(VAR) cycle coupled with VCR cycle using low GWP ecofriendly HFC-407C refrigerant in low temperature cycle at evaporator temperature =-50ºC

Temperature Overlapping (ºC) using R-407c	COP_VAR	COP_VCR	COP_Cascade	% improvement in COP	Exergy Efficiency_VAR	Exergy Efficiency_Cascade	% improvement in Exergy Efficiency
0	0.322	2.517	0.468	45.36	0.1323	0.3221	143.4
5	0.322	2.249	0.4577	42.16	0.1323	0.3149	138.0
10	0.322	2.019	0.4478	39.9	0.1323	0.3081	132.8

Table-3(g): Thermal performances of cascaded refrigeration system usingNH3-H2O (VAR)cycle coupled with VCR cycle using low GWP ecofriendly HFC-507A refrigerant in low temperature cycle at evaporator temperature =-50ºC

Temperature Overlapping (ºC) using R-507A	COP_VAR	COP_VCR	COP_Cascade	% improvement in COP	Exergy Efficiency_VAR	Exergy Efficiency_Cascade	% improvement in Exergy Efficiency
0	0.322	2.84	0.4790	48.78	0.1323	0.3292	149.2
5	0.322	2.485	0.4669	45.0	0.1323	0.3213	142.8
10	0.322	2.185	0.4551	41.33	0.1323	0.3131	136.6

Table-3(h): Thermal performances of cascaded refrigeration system usingNH3-H2O (VAR)cycle coupled with VCR cycle using low GWP ecofriendly HFC-143A refrigerant in low temperature cycle at evaporator temperature =-50ºC

Temperature Overlapping (ºC) using R-143a	COP_VAR	COP_VCR	COP_Cascade	% improvement in COP	Exergy Efficiency_VAR	Exergy Efficiency_Cascade	% improvement in Exergy Efficiency
0	0.322	3.609	0.5003	55.39	0.1323	0.3447	160.5
5	0.322	3.162	0.4887	51.79	0.1323	0.3366	154.3
10	0.322	2.789	0.4774	48.27	0.1323	0.3286	148.3

Table-3(i): Thermal performances of cascaded refrigeration system usingNH3-H2O (VAR)cycle coupled with VCR cycle using low GWP ecofriendly HFC-125 refrigerant in low temperature cycle at evaporator temperature =-50ºC

Temperature Overlapping (ºC) using R-125	COP_VAR	COP_VCR	COP_Cascade	% improvement in COP	Exergy Efficiency_VAR	Exergy Efficiency_Cascade	% improvement in Exergy Efficiency
0	0.322	2.768	0.4767	48.06	0.1323	0.3281	148.0
5	0.322	2.406	0.4639	44.08	0.1323	0.3192	141.2
10	0.322	2.10	0.4514	40.2	0.1323	0.3106	134.7

Table-3(j): Thermal performances of cascaded refrigeration system usingNH3-(VAR) cycle coupled with VCR cycle using low GWP ecofriendly HFC-404A refrigerant in low temperature cycle at evaporator temperature =-50ºC

Temperature Overlapping (ºC) using R-404a	COP_VAR	COP_VCR	COP_Cascade	% improvement in COP	Exergy Efficiency_VAR	Exergy Efficiency_Cascade	% improvement in Exergy Efficiency
0	0.322	2.80	0.4778	48.38	0.1323	0.3289	148.50
5	0.322	2.455	0.4657	44.65	0.1323	0.3205	142.2
10	0.322	2.162	0.4541	41.03	0.1323	0.3124	136.1

2.3 *Effect of low temperature cycle evaporator temperature on ideal Thermal performances of cascaded refrigeration system usingNH_3-H_2O (VAR) cycle coupled with VCR cycle using ultra-low/ low GWP ecofriendly HFO & HFC refrigerants in low temperature cycle*

The effect of LTC Evaporator Temperature (ºC) on Thermal performances of cascaded refrigeration system usingNH_3-H_2O (VAR)cycle coupled with VCR cycle using ultra-low / low GWP ecofriendly HFO & HFC refrigerants in low temperature cycle have been shown in tables-4 respectively. It was found that by increasing LTC Evaporator Temperature (ºC) of cascaded cycle, the first law efficiency (COP) is increasing while and second law efficiency (Exergy efficiency) is decreasing. Similarly, % improvement in cascaded system COP and cascaded exergy efficiency is decreasing. The best performance was observed by using R152a and R245fa. The Thermal performances of cascaded refrigeration system usingNH_3-H_2O (VAR)cycle coupled with VCR cycle using low GWP ecofriendly R-32A refrigerant in low temperature cycle at evaporator temperature is slightly lower than using HFC-134a and other HFCs in VCR cycle. By increasing LTC evaporator temperature, the first law efficiency (COP) of cascaded system is increasing along with increasing performance enhance and second law efficiency (exergy efficiency) of cascaded system is decreasing along with decreasing performance enhancement.

Table-4(a): Ideal Thermal performances of cascaded refrigeration system usingNH3-H2O (VAR)cycle coupled with VCR cycle using low GWP ecofriendly HFO-1234yf refrigerant in low temperature cycle at evaporator temperature =-50^{o}C

LTC Evaporator Temperature (^{o}C) using R-1234yf	COP_$_{Cascade}$	COP_$_{VAR}$	% improvement in COP	Exergy Eff_$_{Cascade}$	Exergy Eff._$_{VAR}$	% improvement in Exergy Efficiency	COP_$_{VCR}$	Exergy Eff._$_{VCR}$
-50	0.4895	0.322	52.03	0.3371	0.1323	154.7	3.19	0.108
-45	0.5023	0.322	56.02	0.3361	0.1323	154.0	3.689	0.1058
-40	0.5155	0.322	60.10	0.3346	0.1323	152.8	4.305	0.1022
-35	0.5290	0.322	64.29	0.3325	0.1323	151.3	5.082	0.09794
-30	0.5428	0.322	68.58	0.330	0.1323	149.4	6.092	0.09314

Table-4(b): Thermal performances of cascaded refrigeration system usingNH3-H2O (VAR) cycle coupled with VCR cycle using low GWP ecofriendly HFC- R-152a refrigerant in low temperature cycle at evaporator temperature =-50^{o}C

LTC Evaporator Temperature (^{o}C) using R-152a	COP_$_{Cascade}$	COP_$_{VAR}$	% improvement in COP	Exergy Eff_$_{Cascade}$	Exergy Eff._$_{VAR}$	% improvement in Exergy Efficiency	COP_$_{VCR}$	Exergy Eff._$_{VAR}$
-50	0.4945	0.322	53.58	0.3406	0.1323	157.4	3.374	0.1116
-45	0.5067	0.322	57.38	0.3390	0.1323	156.2	3.881	0.1080
-40	0.5193	0.322	61.27	0.3369	0.1323	154.6	4.505	0.1039
-35	0.5321	0.322	65.26	0.3344	0.1323	152.7	5.290	0.09925
-30	0.5453	0.322	69.36	0.3314	0.1323	150.4	6.307	0.09410

Table-4(c): Thermal performances of cascaded refrigeration system usingNH3-H2O (VAR) cycle coupled with VCR cycle using low GWP ecofriendly HFC- R-245fa refrigerant in low temperature cycle at evaporator temperature =-50^{o}C

LTC Evaporator Temperature (^{o}C) using R-245fa	COP_$_{Cascade}$	COP_$_{VAR}$	% improvement in COP	Exergy Eff_$_{Cascade}$	Exergy Eff._$_{VAR}$	% improvement in Exergy Efficiency	COP_$_{VCR}$	Exergy Eff._$_{VAR}$
-50	0.4940	0.322	53.43	0.3403	0.1323	157.1	3.355	0.1113
-45	0.5064	0.322	57.28	0.3388	0.1323	156.0	3.867	0.1078
-40	0.5191	0.322	61.23	0.3368	0.1323	154.5	4.497	0.1038
-35	0.5321	0.322	65.27	0.3344	0.1323	152.7	5.292	0.09927
-30	0.5455	0.322	69.41	0.3314	0.1323	150.3	6.321	0.09416

Table-4(d): Thermal performances of cascaded refrigeration system usingNH3-(VAR) cycle coupled with VCR cycle using low GWP ecofriendly HFC- R-134a refrigerant in low temperature cycle at evaporator temperature =-50^{o}C

LTC Evaporator Temperature (^{o}C) using R-134a	COP_$_{Cascade}$	COP_$_{VAR}$	% improvement in COP	Exergy Eff_$_{Cascade}$	Exergy Eff._$_{VAR}$	% improvement in Exergy Efficiency	COP_$_{VCR}$	Exergy Eff._$_{VAR}$
-50	0.4922	0.322	52.88	0.3390	0.1323	156.2	3.289	0.1104
-45	0.5047	0.322	56.75	0.3377	0.1323	155.2	3.792	0.1070
-40	0.5175	0.322	60.73	0.3358	0.1323	153.8	4.411	0.1031
-35	0.5306	0.322	64.81	0.3335	0.1323	152.0	5.191	0.09864
-30	0.5441	0.322	68.99	0.3307	0.1323	149.9	6.203	0.09364

Table-4(e): Thermal performances of cascaded refrigeration system usingNH3-H2O (VAR)cycle coupled with VCR cycle using low GWP ecofriendly HFC- R-32 refrigerant in low temperature cycle at evaporator temperature =-50^{o}C

LTC Evaporator Temperature (^{o}C) using R-32	COP_$_{Cascade}$	COP_$_{VAR}$	% improvement in COP	Exergy Eff_$_{Cascade}$	Exergy Eff._$_{VAR}$	% improvement in Exergy Efficiency	COP_$_{VCR}$	Exergy Eff._$_{VAR}$
-50	0.4902	0.322	52.24	0.3376	0.1323	155.1	3.355	0.1092
-45	0.5028	0.322	56.16	0.3364	0.1323	154.2	3.867	0.1060
-40	0.5158	0.322	60.19	0.3347	0.1323	152.9	4.497	0.1023
-35	0.5291	0.322	64.31	0.3326	0.1323	151.3	5.292	0.09797
-30	0.5427	0.322	68.55	0.3299	0.1323	149.3	6.321	0.09310

Table-4(f): Thermal performances of cascaded refrigeration system usingNH3-H2O (VAR)cycle coupled with VCR cycle using low GWP ecofriendly R-717 refrigerant in low temperature cycle at evaporator temperature =-50°C

LTC Evaporator Temperature (°C) using R-717	$COP\_{Cascade}$	COP_{VAR}	% improvement in COP	Exergy $Eff\_{Cascade}$	Exergy $Eff.\_{VAR}$	% improvement in Exergy Efficiency	COP_{VCR}	Exergy $Eff.\_{VAR}$
-50	0.490	0.322	52.17	0.3374	0.1323	155.0	3.206	0.1091
-45	0.5029	0.322	56.20	0.3365	0.1323	154.3	3.715	0.1061
-40	0.5162	0.322	60.32	0.3350	0.1323	153.1	4.341	0.1025
-35	0.5297	0.322	64.52	0.3330	0.1323	151.6	5.130	0.09825
-30	0.5435	0.322	68.80	0.3304	0.1323	149.7	6.152	0.09340

2.4 Effect of low temperature cycle evaporator temperature on ideal thermal performances of cascaded refrigeration system usingNH_3-H_2O VAR cycle coupled with VCR cycle using ultra low/ low GWP ecofriendly HFO & HFC refrigerants in low temperature cycle

The effect of LTC Evaporator temperature (°C) on actual Thermal performances of cascaded refrigeration system usingNH_3-H_2O (VAR) cycle coupled with VCR cycle using ultra-low / low GWP ecofriendly HFO & HFC refrigerants in low temperature cycle have been shown in tables-5 respectively. It was found that by increasing LTC Evaporator Temperature (°C) of cascaded cycle, the first law efficiency (COP) is increasing while and second law efficiency (Exergy efficiency) is decreasing. Similarly the percentage improvement in cascaded system COP and cascaded exergy efficiency is decreasing. The best performance were observed by using R152a and R245fa. The thermal performances of cascaded refrigeration system usingNH_3-H_2O vapour absorption system coupled with vapour compression refrigeration system using low GWP ecofriendly R-32A refrigerant in low temperature cycle at evaporator temperature is slightly lower than using HFC-134a and other HFCs in VCR cycle. By increasing LTC evaporator temperature, the first law efficiency (COP) of cascaded system is increasing along with increasing performance enhance and second law efficiency (exergy efficiency) of cascaded system is decreasing along with decreasing performance enhancement.

Table-5(a): Actual Thermal performances of cascaded refrigeration system usingNH3-H2O (VAR)cycle coupled with VCR cycle using low GWP ecofriendly HFO-1234yf refrigerant in low temperature cycle at evaporator temperature =-50°C

LTC Evaporator Temperature (°C) using R-1234yf	$COP\_{Cascade}$	COP_{VAR}	% improvement in COP	Exergy $Eff\_{Cascade}$	Exergy $Eff.\_{VAR}$	% improvement in Exergy Efficiency	COP_{VCR}	Exergy $Eff.\_{VAR}$
-50	0.4693	0.322	45.75	0.3229	0.1323	144.0	2.552	0.09792
-45	0.4825	0.322	49.86	0.3230	0.1323	144.1	2.951	0.09593
-40	0.4963	0.322	54.15	0.3227	0.1323	143.9	3.444	0.09340
-35	0.5108	0.322	58.61	0.3219	0.1323	143.3	4.066	0.09033
-30	0.5256	0.322	63.26	0.3207	0.1323	142.4	4.873	0.08668

Table-5(b): Actual Thermal performances of cascaded refrigeration system usingNH3-H2O (VAR)cycle coupled with VCR cycle using low GWP ecofriendly HFC- R-152a refrigerant in low temperature cycle at evaporator temperature =-50°C

LTC Evaporator Temperature (°C) using R-152a	$COP\_{Cascade}$	COP_{VAR}	% improvement in COP	Exergy $Eff\_{Cascade}$	Exergy $Eff.\_{VAR}$	% improvement in Exergy Efficiency	COP_{VCR}	Exergy $Eff.\_{VAR}$
-50	0.4744	0.322	47.35	0.3265	0.1323	146.7	2.699	0.1007
-45	0.4871	0.322	51.28	0.3260	0.1323	146.4	3.105	0.09819
-40	0.5003	0.322	55.38	0.3252	0.1323	145.7	3.604	0.09521
-35	0.5141	0.322	59.66	0.3239	0.1323	144.8	4.232	0.09172
-30	0.5284	0.322	64.11	0.3222	0.1323	143.5	5.046	0.08772

Table-5(c): Actual Thermal performances of cascaded refrigeration system usingNH3-H2O (VAR)cycle coupled with VCR cycle using low GWP ecofriendly HFC- R-245fa refrigerant in low temperature cycle at evaporator temperature =-50°C

LTC Evaporator Temperature (°C) using R-245fa	$COP\_{Cascade}$	COP_{VAR}	% improvement in COP	Exergy $Eff\_{Cascade}$	Exergy $Eff.\_{VAR}$	% improvement in Exergy Efficiency	COP_{VCR}	Exergy $Eff.\_{VAR}$
-50	0.4739	0.322	47.18	0.3262	0.1323	146.5	2.684	0.1004
-45	0.4868	0.322	51.18	0.3258	0.1323	146.2	3.093	0.09802
-40	0.5002	0.322	55.34	0.3251	0.1323	145.6	3.598	0.09514
-35	0.5141	0.322	59.67	0.3239	0.1323	144.8	4.233	0.09174
-30	0.5286	0.322	64.17	0.3223	0.1323	143.6	5.057	0.08779

Table-5(d): Thermal performances of cascaded refrigeration system usingNH3-H2O (VAR)cycle coupled with VCR cycle using low GWP ecofriendly HFC- R-134a refrigerant in low temperature cycle at evaporator temperature =-50ºC

LTC Evaporator Temperature (ºC) using R-134a	$COP_{\_Cascade}$	$COP_{\_VAR}$	% improvement in COP	Exergy $Eff_{\_Cascade}$	Exergy $Eff._{\_VAR}$	% improvement in Exergy Efficiency	$COP_{\_VCR}$	Exergy $Eff._{\_VAR}$
-50	0.4721	0.322	46.62	0.3249	0.1323	145.5	2.631	0.09943
-45	0.4850	0.322	50.63	0.3247	0.1323	145.3	3.033	0.09715
-40	0.4934	0.322	54.81	0.3240	0.1323	144.8	3.528	0.09437
-35	0.5321	0.322	59.16	0.3230	0.1323	144.10	4.153	0.09107
-30	0.5455	0.322	63.7	0.3215	0.1323	142.9	4.962	0.08722

Table-5(e): Actual Thermal performances of cascaded refrigeration system usingNH3-(VAR) cycle coupled with VCR cycle using low GWP ecofriendly HFC- R-32 refrigerant in low temperature cycle at evaporator temperature =-50ºC

LTC Evaporator Temperature (ºC) using R-32	$COP_{\_Cascade}$	$COP_{\_VAR}$	% improvement in COP	Exergy $Eff_{\_Cascade}$	Exergy $Eff._{\_VAR}$	% improvement in Exergy Efficiency	$COP_{\_VCR}$	Exergy $Eff._{\_VAR}$
-50	0.470	0.322	45.97	0.3234	0.1323	144.3	2.571	0.09829
-45	0.4830	0.322	50.01	0.3234	0.1323	144.3	2.967	0.09616
-40	0.4966	0.322	54.23	0.3229	0.1323	144.0	3.499	0.09352
-35	0.5108	0.322	58.63	0.3220	0.1323	143.3	4.070	0.09036
-30	0.5255	0.322	63.22	0.3207	0.1323	142.3	4.867	0.08664

Table-5(f): Actual Thermal performances of cascaded refrigeration system usingNH3-H2O (VAR)cycle coupled with VCR cycle using low GWP ecofriendly R-717 refrigerant in low temperature cycle at evaporator temperature =-50ºC

LTC Evaporator Temperature (ºC) using R-717	$COP_{\_Cascade}$	$COP_{\_VAR}$	% improvement in COP	Exergy $Eff_{\_Cascade}$	Exergy $Eff._{\_VAR}$	% improvement in Exergy Efficiency	$COP_{\_VCR}$	Exergy $Eff._{\_VAR}$
-50	0.4696	0.322	45.89	0.3233	0.1323	144.3	2.565	0.09816
-45	0.4831	0.322	50.06	0.3234	0.1323	144.4	2.972	0.09623
-40	0.4971	0.322	54.37	0.3232	0.1323	144.2	3.473	0.09373
-35	0.5115	0.322	58.85	0.3224	0.1323	143.6	4.104	0.09065
-30	0.5264	0.322	63.50	0.3211	0.1323	142.7	4.921	0.08697

3. Conclusions

The following conclusions were made

- The first law performance of the cascaded employing compression-absorption systems using low GWP eco-friendly refrigerants in the low temperature VCR cycle was found between 40% and 50% greater than that of the vapour absorption cycle.
- The improvements in the second law performance under the same operating conditions are achieved with a cascaded compression VAR system uses R134a than uses R744 as refrigerant.
- The findings indicated that the cascaded VAR+VCR system may achieve an exergy efficiency that is between 125% to 160% greater than that of the vapour absorption system.
- (iv)Every time a system ran on R152A, its COP was higher than when it run on CO_2 and R134a.
- Investigations have also been conducted into the thermal characteristics of the cascaded VAR+VCR system with respect to temperature overlap and LTC evaporator temperature and found that increasing overlapping, system´s performance is decreased. while increasing LTC temperature, energy performance (COP) is increased while exergy performance is decreased.

References

[1] Alkanhal, T.A.[2015],Thermal management of MHD nanofluid within the porous medium enclosed in a wavy shaped cavity with square obstacle in the presence of radiation heat source. Int. J. Heat Mass Transf. 2019, 139, 87–94.

[2] Sheikholeslami,[2019]Heat transfer of nanoparticles employing innovative turbulator considering entropy generation. Int. J. Heat Mass Transf. 2019, 136, 1233–1240.

[3] Yee, T.F.;Grossmann,I.E.[1990], Simultaneous optimization models for heat integration—II. Heat exchanger network synthesis. Comput. Chem. Eng. , 14, 1165.

[4] Yan, X.[2013], A novel absorption refrigeration cycle for heat sources with large temperature change. Appl. Therm. Eng., 52, 179–186.

[5] Saleh, A.; Mosa, M. .[2014], Optimization study of a single-effect water-lithium bromide absorption refrigeration system powered by flat-plate collector in hot regions. Energy Convers. Manag., 87, 29–36.

[6] Cimsit, C.; Ozturk, I.T. .[2012],Analysis of compression-absorption cascade refrigeration cycles. Appl. Therm. Eng. 2012, 40, 311–317.

[7] Colorado, D.; Rivera, W. .[2015], Performance comparison between a conventional vapor compression and compression-absorption single-stage and double-stage systems used for refrigeration. Appl. Therm. Eng., 87, 273–285.

[8] Cimsit, C.; Ozturk, I.T.; Hosoz, M.[2014] Second law based thermodynamic analysis of compression-absorption cascade refrigeration cycles. J. Therm. Sci. Technol., 34, 9–18.

[9] D. Colorado, W.Rivera ,[2015],Performance comparison between a conventional vapor compression and compression-absorption single-stage and double-stage systems used for refrigeration, Applied Thermal Engineering, Volume 87, 5 August 2015, Pages 273-285, https://doi.org/10.1016/j.applthermaleng.2015.05.029

[10] Zhili Sun , et.al.,[2020] Theoretical study on a novel CO_2 Two-stage compression refrigeration system with parallel compression and solar absorption partial cascade refrigeration system, Energy Conversion and Management, Volume 204, 112278, https://doi.org/10.1016/j.enconman.2019.112278.
[11] Cimsit, C.; Ozturk, I.T., [2015]Thermoeconomic optimization of LiBr/H_2O-R134a compression-absorption cascade refrigeration cycle. Appl. Therm. Eng. , 76, 105–115.
[12] Jain, V.[2015]; Energy, exergy, economic and environmental (4E) analyses based comparative performance study and optimization of vapor compression-absorption integrated refrigeration system. Energy , 91, 816–832.
[13] Xu, Y.;et.al., [2016],Performance study on a low-temperature absorption-compression cascade refrigeration system driven by low-grade heat. Energy Convers. Manag. , 119, 379–388.
[14] Aminyavari, M.; et.al.[2014] Exergetic, economic and environmental (3E) analyses, and multi-objective optimization of a CO_2/NH_3 cascade refrigeration system. Appl. Therm. Eng., Vol-65, page-42–50.

***Cite this article as*:** R.S. Mishra, Method for enhancing thermal performances of cascaded system using VARS cycle (NH3H2O) with VCR cycle using ecofriendly low GWP refrigerants, International Journal of Research in Engineering and Innovation Vol-8, Issue-4 (2024), 135-143. *https://doi.org/10.36037/IJREI.2024.8401*.