ACTA SCIENTIAE

ISSN: 2178-7727

Recent Advancements In Ejector Technology: A Review

Arvind Kumar[1], Surendra Kumar Yadav[1*], Virendra Kumar[2], Chandra Mohan[3]

[1]Department of Mechanical Engineering, K. R. Mangalam University, Gurugram 122103, India
[2]Department of Mechanical Engineering, Harcourt Butler Technical University, Kanpur 208002, India
[1]Department of Chemistry, K. R. Mangalam University, Gurugram 122103, India

ABSTRACT

A total basic evaluation of the currently existing limit control calculations for two-stage ejectors was acted in this paper. Besides, their benefits and disservices, as well as an examination of their exhibition, were examined. Steam ejectors work by sending thought process steam through a growing spout and depend on the ejector-venturi rule. The spout controls the development of the rationale steam, switching tension over completely to speed and making a vacuum inside the body chamber to attract and entrain gases or fumes. The intention steam and attractions gas are then completely blended and sent through the diffuser or tail, where the speed of the gases is transformed into sufficient strain to arrive at the set release pressure. At the point when the required outright vacuum level is diminished, ejector organizing is expected for more productive activity.

KEYWORDS: Eejector-technology; Performance; Refrigeration; Design and analysis.

INTRODUCTION

An ejector is a fluid dynamic pump without any moving parts. When driven mixers raise the mixing rates in ejectors, a shorter and more compact system is observed. Ejectors can increase thrust, reduce the noise from the jet, and cool jet engines' exhaust. These mixer/ejector systems, however, only work well with low area-to-volume configurations. The use of multistage mixer/ejectors in newer ideas could enhance the effectiveness of ejector systems in a variety of applications. Several ejector pumps are connected in sequence as part of multistage. The potential of systems incorporating ejectors is studied and confirmed in this study. Number of uses of multi-stage ejector system is demonstrated and discussed. In comparison to traditional mixer/ejectors, the novel device produces faster rates of diffusion, better wall cooling, efficient flow mixing [1]. Numerical analysis is used to examine satellite rockets having a large area ratio which will be climbing a higher altitude. This is the reason for which a two staged ejector is used. It helps in achieving the appropriate low vacuum in the test chamber. The goal of the current work is to examine the performance of a two staged ejector as to how different operational and geometric parameters affect it [2]. Authors proposed a few new architectures of two-staged Ejector Organic Flash Cycles using exergo-economic, and exergo-environmental methods. These architectures are ejector-based EOFCs, ejector-built high and low pressure evaporation [3]. The authors proposed a new system that adds a second evaporator following the ejector to improve the quality of the gas going into the divider and an addition of a vapour feedback valve is there as well to reduce the excess gas into the compressor. These changes were made using the stability exploration of the fundamental trans-critical CO_2 ejector expansion refrigeration cycle. The two new parts represent the two distinct cycles of vapour feedback and two-stage evaporation. A theoretical study of the new system is conducted to demonstrate how various parameters affect the system's performance [4]. Authors suggested that the single ejector is replaceable by the two staged ejector because of its greater geometrical ability to use the momentum of the discharge flow to create secondary flow. In this study, the shape and flow parameters of both types of ejectors have been computed using the suggested theory. Performance predictions and flow visualisation have been made using ANSYS-Fluent 14.0, a commercial product for computational fluid dynamics [5]. The refrigerants in a TSE refrigeration cycle using carbon dioxide, nitrous oxide, and ethane are compared. By maximising COP under different conditions for gas cooler and intercooler pressures and evaporator temperature, all of the results were obtained. It has been shown that the operating pressure and Ethane's cycle temperatures are lower than those of other refrigerants, which results in higher longevity and system safety. Based on an exergo-economic

DOI: 10.2030/ASCI.25.4.AS.36

perspective, nitrous oxide is appropriate in some areas [6]. In this research, to significantly boost the production of the freshwater, an adsorption desalination cycle and two staged ejectors is proposed in this study. For this integration, the working pair is silica gel and water. Specific daily freshwater production and the Coefficient of Performance are numerical measures of the hybrid cycle's performance. The cycle and the mathematical models of the ejector are verified [7]. In this research, a cooling system installed in a bus is studied which uses a two staged ejector. Water is used in the system as the working fluid. The condensing temperature in this system is 54°C, while the evaporation temperature is 5° Celsius. According to the findings, replacing the vapour with a cooling system using two-stage ejector is bus's compression scheme is a good substitute. The proposed system is anticipated to have a number of benefits, including lower fuel consumption, lower greenhouse gas emissions, less demand on engine power, and a higher coefficient of performance than the regular ejector cooling system [8]. Authors suggested that the C. R. M. C. two-stage ejector is an alternate geometrical configuration for exploiting the extra momentum of the flow at the exit. Compared to a single-stage ejector, the discharge stream's energy at the conclusion of the mixing stage of a two-stage ejector further permits the entraining of the secondary flow. In the current study, the two-stage ejector shape was computed using the 1-D gas dynamic CRMC model through frictional effects. ANSYS-Fluent 14.0 was used to examine the calculated model numerically for the specified design input parameters, namely the entrainment ratio. The results of the 1-D gas dynamics were validated by numerical data [9]. Vacuum ejectors, which are employed in multi-purpose distillation with vapour compression systems to maintain the vacuum and remove gases those are not condensed, have not received much research attention. To enhance the performance of the desalination system, a vacuum ejector that is two-staged, was studied. A C. F. D simulation was used to choose the most optimal shape out of seven alternative ejector models for comparison [10].

DESIGN METHODOLOGY

As schematically depicted in Fig. 1, the system of ejectors in two stages is nothing but a set of two single ejectors. For easy and flexible handling of this system, an interstage connection section connects the exit of the initial ejector and the second ejector secondary inlet. This study describes a refrigeration system having more than one evaporator with two stages that uses refrigerant R134a. The effects of the refrigerant and various operating conditions is done utilizing CFD simulations, and loads on each stage are examined [11].

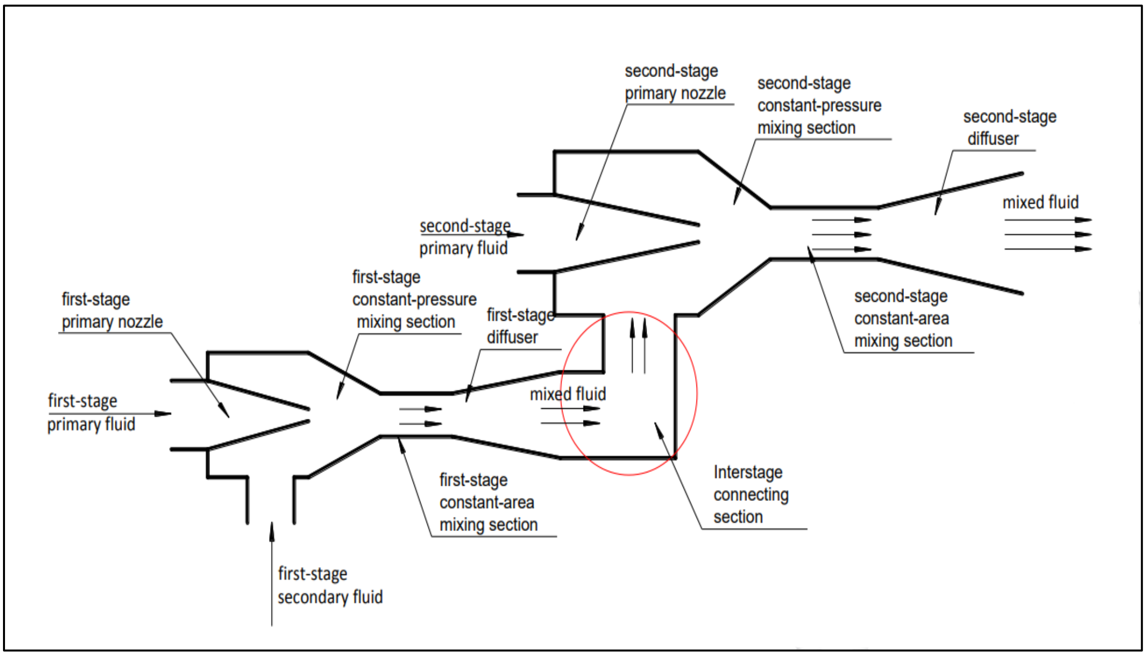

Fig. 1. A diagram showing a two-phase ejector framework [11]

ACTA SCIENTIAE
ISSN: 2178-7727

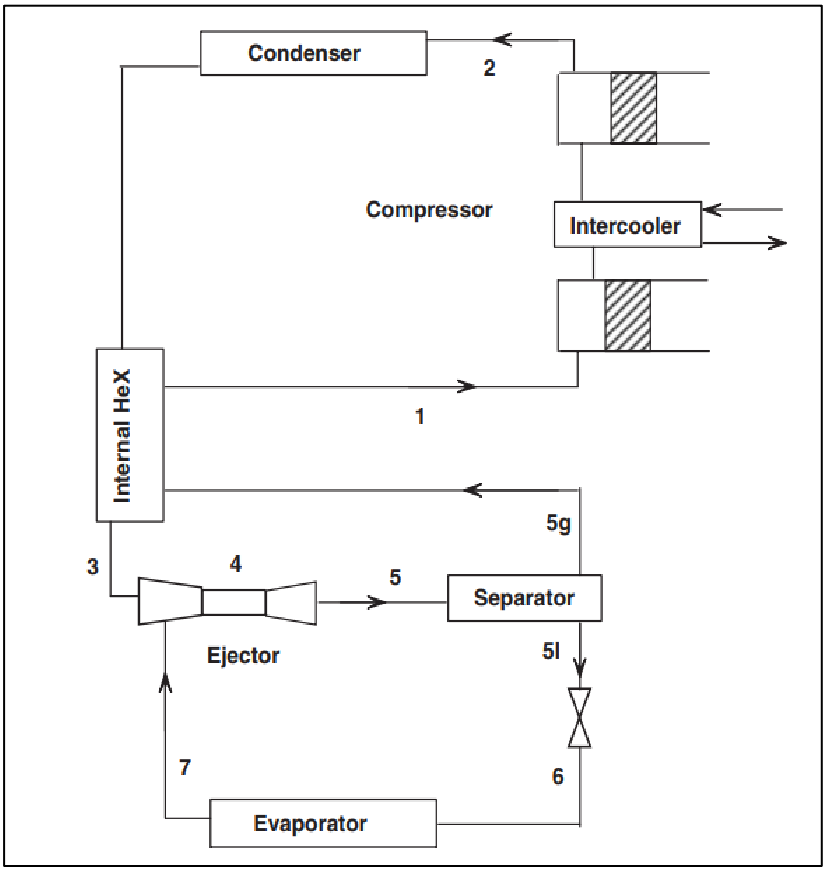

Fig. 2. Diagram showing the ejector-operated refrigeration framework [12]

As shown in Fig. 2, a trans-critical CO_2 refrigeration cycle operated by an innovative design of the ejector is proposed in this study. A theoretical analysis of the new cycle's performance characteristics was conducted [12]. Authors studied that when contrasted with the customary ejector refrigeration framework at variable build-up temperatures, is analyzed through changing temperatures of dissipation, build-up, low and high temperature age freely for the variety propensity of framework execution. For the dependability of the framework's activity, R236fa is picked. As dissipation temperatures increase, so do the complete entrainment proportion and COP. This two-stage framework is eventually found to have the option to give more refrigerating impact than the customary single-stage ejector refrigeration framework [13]. Recently, a new trans-critical CO_2 refrigeration framework with two stages of multi-intercooling and ejector expansion was introduced. Studies comparing the COPs of the two cycles under identical operating circumstances revealed that the enhanced cycle might be a more effective. Internal heat exchangers undoubtedly enhanced the pace at which total energy was destroyed, but overall improvement index rose when they were used in the refrigeration cycle [14]. Ejectors are basic mechanical parts that can involve high strain energy from fluid in a pseudo two-stage pressure heat siphon framework associated with a parchment blower, further developing the intensity siphon framework's presentation. The intensity siphon model was made and completely tried utilizing a warm examination model in accordance with the rules of thermodynamics. The impact of the ejector on the intensity siphon framework was exegetically inspected utilizing trial information from the model [15]. This paper depicts another ejector further developed fume pressure refrigeration cycle that involves R32 as a refrigerant. An ejector with two attractions gulfs is utilized in this cycle to recuperate the cycle's losses. The hypothetical model of the fostered cycle is laid out, and the presentation of this cycle utilizing refrigerant R32 is assessed. Also, execution correlations of the planned cycle, the principal fume pressure refrigeration cycle, and the standard ejector extension refrigeration cycle were performed. The newfound cycle might add to the utilization of the refrigerant R32 in cooling frameworks [16]. Although supersonic ejector-diffuser systems are typically employed for cooling through the use of low-grade nuclear power, a few make sense for freezing refrigeration. Mathematical re-enactments using computational liquid elements (CFD) to find the proper plan boundaries

DOI: 10.2030/ASCI.25.4.AS.36

ISSN: 2178-7727

for a scope of working circumstances anticipated the presentation (entrainment proportion) and stream peculiarities of the two-stage ejector [17]. This report depicted a three-evaporator, double ejector refrigeration framework. The creators endeavoured to dissect the impacts of major mathematical elements of each stage on both shows utilizing a two-layered CFD re-enactment technique by joining two separate ejectors in general. To begin with, trial information was utilized to approve the CFD models. Following that, re-enactments were utilized to decide the point-by-point impacts of significant mathematical boundaries, for example, the length of the consistent tension blending segment, the length of the steady region blending segment, and the region proportion of each stage on two-show [18]. A two-stage ejector-diffuser framework has been proposed as a gainful elective game plan for using the released stream's repetitive energy. Execution can be significantly upgraded when contrasted with a conventional single-stage ejector-diffuser framework. Notwithstanding, little examination has been directed on framework enhancement. This is one of the essential purposes behind confining the designing use of the framework. The significant properties of a supersonic two-stage ejector-diffuser framework was investigated top to bottom involving mathematical techniques in this work [19].

PERFORMANCE PARAMETERS

The ongoing examination portrays an original refrigeration cycle with CO_2 as a refrigerant comprising two ejectors. At the concentrated-on cycle, fume pressure happens in two stages, with every fume pressure line having its own ejector. Designing Condition Solver programming is utilized to perform thermodynamic and exergetic investigation on the proposed cycle. A traditional cycle is contrasted with the new cycle. It has been found that, contingent upon the circumstances, the new cycle improves the Coefficient of Execution [20]. As a result of their modest plant expenses, steadfastness, and capacity to utilize water as a working liquid, stream refrigeration cycles seem to introduce an engaging answer for the developing interest in ecological security and the requirement for energy reserve funds. A two-stage ejector with annular essential in the subsequent stage is explored in a group/steam ejector cycle fridge. Heat move irreversibility in heat exchangers and outside contact misfortunes in water streams are considered [21].

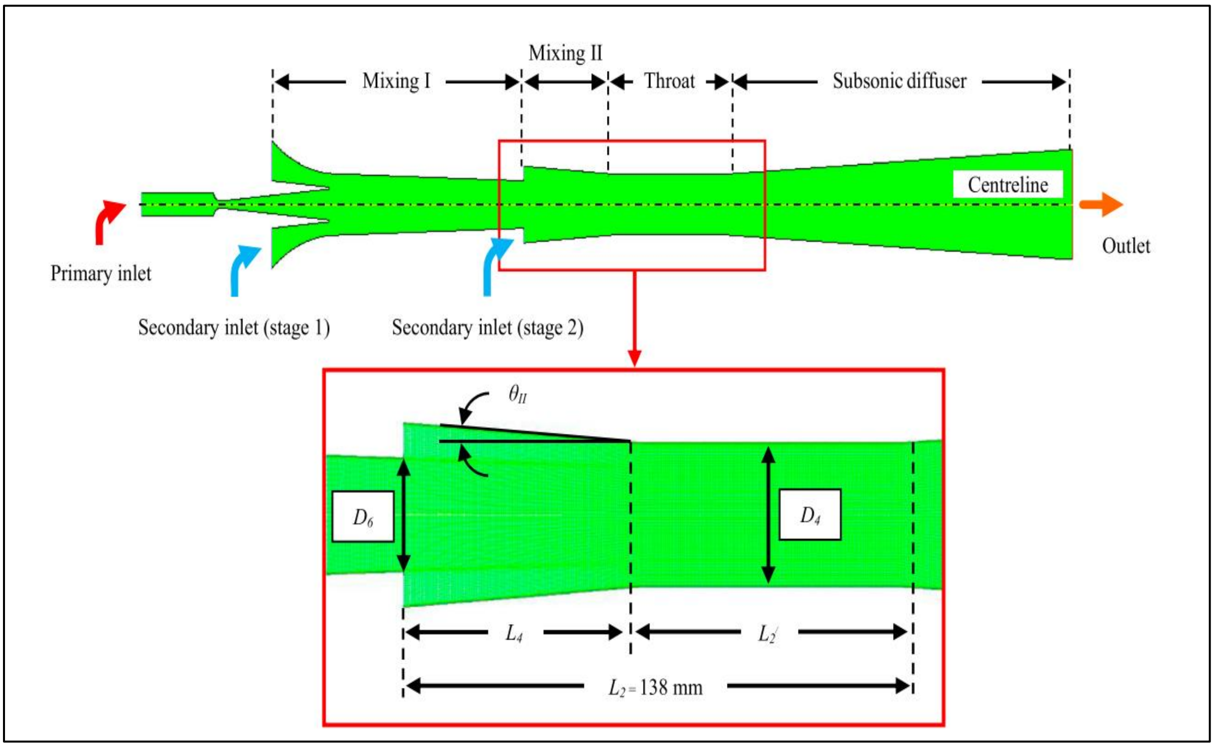

Fig. 3. CFD Model of Two Staged Ejector [21]

As shown in Fig. 3, Computational fluid dynamics was used in this work for a steam ejector utilized in refrigeration frameworks to expand functional adaptability and COP. A two-stage ejector 2-D axisymetric

DOI: 10.2030/ASCI.25.4.AS.36

ISSN: 2178-7727

model was developed and its presentation was contrasted with that of the normally used single-stage ejector [22]. This review suggests a multi-evaporator refrigeration architecture based on ejectors., in which the refrigerant blend leaving the first-stage enters the second-stage essential spout and entrains its optional stream refrigerant, bringing about a profoundly connected ejector with two phases. In this situation, the essential spout throat breadth of the subsequent stage altogether affects and works on the exhibition of the two phases [23].

A changed double evaporator CO2 trans critical refrigeration cycle with a two-stage ejector is projected in this exploration. The two-stage ejector is utilized in MDRC to recuperate development work from cycle choking processes, further develop framework execution, and accomplish double temperature refrigeration simultaneously. In light of vivacious and exergetic assessments, the impacts of a few basic variables on the thermodynamic execution of the overhauled cycle are hypothetically analyzed [24].

COMPARATIVE STUDY

Authors stated that the conventional vapour compression refrigeration systems not only use a lot of electricity, but they also pollute the environment. Among the several techniques to addressing these two issues, a steam-ejector refrigeration system is thought to be the most effective [25]. Another two-stage multi-intercooling trans basic CO2 refrigeration cycle with ejector development gadget is analyzed in this work. The fume pressure line in this cycle has two intercoolers, the first with outside coolant and the second with cycle refrigerant. The new cycle's general exhibition was contrasted with the customary ejector refrigeration cycle and the interior intensity exchange in refrigeration cycle using ejector. It was found that the new cycle has the most noteworthy COP while IHEEC has the least [26]. To appropriately use poor quality intensity in this specific circumstance, a two-stage launch refrigeration framework is depicted under high consolidating or low dissipating temperatures. The exhibition of the two-stage launch refrigeration framework is tried at delivering temperatures going from 130 to 150 degrees Celsius, consolidating temperatures going from 45 to 54 degrees Celsius, and dissipating temperatures going from 630 degrees Celsius [27].

Exploratory examination on the trans critical CO_2 ejector extension refrigeration framework with two-stage vanishing under shifted working conditions is introduced in this work. By varying the volumetric stream pace of the second evaporator cooled water, blower speed, development valve opening, and region percentage of the ejector, certain important presentation points were evaluated. These factors included gas cooler strain, mass stream rate, entrainment proportion and tension lift proportion of the ejector, cooling limit, and COP of the framework [28]. The overhauled two-stage cycle's exhibition is assessed utilizing the created numerical model and afterward contrasted with that of the fundamental two-stage cycle with a glimmer tank [29]. The effectiveness of one-and two-stage ejectors are looked at under plan and off-plan settings involving a demonstrated numerical model to give guidance for the best choice of these two ejectors. Under plan conditions, the one-stage ejector performs better at low pressure proportions, however the two-stage ejector performs better at high pressure proportions. Due to diminished blending losses [30].

APPLICATIONS

The ongoing review proposes four imaginative formats three-evaporator two-stage pressure refrigeration frameworks utilizing twofold two-stage ejectors. The impacts of cycle on working temperature and evaporator load dissemination and ejector execution boundaries have been concentrated on utilizing thermodynamic investigation and ejector region proportion improvement. There are additionally execution examinations with essential valve development two-stage pressure, ejector upgraded single-stage pressure, and fundamental valve extension single-stage pressure three-evaporator refrigeration frameworks [31].

DOI: 10.2030/ASCI.25.4.AS.36

ISSN: 2178-7727

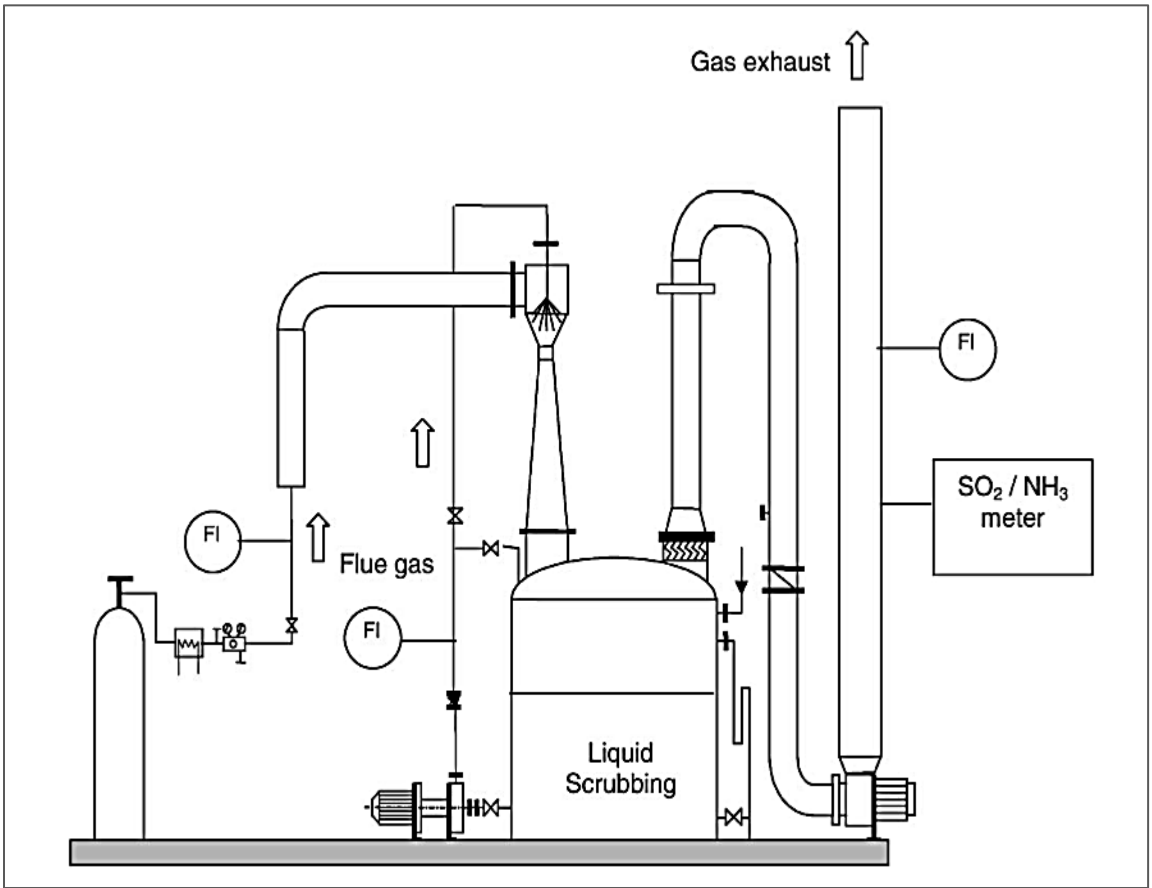

Fig. 4. Schematic diagram of the jet–venturi scrubber pilot plant [31]

In an industrial scale ejector-venturi scrubber, as shown in Fig. 4, the assimilation of SO2 and NH3 from the vent gas into NaOH and H2SO4 arrangements, separately, has been explored. By changing various factors, a factual philosophy is proposed to portray the presentation of the scrubber. A two-stage venturi tube was one of the venturi tube development styles that was assessed. The results showed a critical effect of fluid scouring flowrate on contamination evacuation viability. Both the gas flowrate and the beginning poison fixation had a little effect. In spite of the fact that it expanded energy utilization, the reception of a two-stage venturi tube essentially expanded the retention productivity [32].

In spite of the specialized hardships related with high tension, particularly in warm environments, prompting trans-basic activity and a resulting COP decrease, the regular refrigerant R744 has all the earmarks of being the drawn-out answer for be forced in the food retail industry, where low and medium refrigeration temperatures are generally required. To bypass such difficulties, numerous ways have been presented in the writing, with the utilization of equal blowers or their combination with ejector extension gadgets being especially famous. The ongoing work portrays the streamlining strategies for the working states of a two-stage CO2 refrigeration unit with and without an ejector. The bends showing ideal blends of gas cooler and glimmer tank pressures, alluded to as functional control regulations, are shown, alongside the COP got [33].
Due to its exceptional highlights, for example, no moving parts and primary straightforwardness when contrasted with other liquid apparatuses, the supersonic ejector framework has been broadly utilized in numerous modern applications. The ordinary ejector framework, then again, has been reprimanded for failure because of energy misfortune during the blending stage and, all the more significantly, energy squander during the release activity. The stream peculiarities inside single-stage and two-staged ejector frameworks were fundamentally anticipated in this study using a mathematical procedure in view of Reynolds found the middle value of Navier-Stirs up conditions and a hypothetical assessment in light of a 1-D numerical model. With accessible trial information, both mathematical and hypothetical outcomes were approved [34]. A novel two-staged pressure trans critical CO2 double evaporator refrigeration cycle with an ejector is proposed in this

ISSN: 2178-7727

examination. The interesting framework's ejector and blaze tank are used to bring down the glimmered fume going through the low-temperature evaporator and hence the information force of the low-temperature blower, as opposed to normally lessening the blower input power by raising the blower pull pressure [35].

The exhibition of a two-staged ejector trans basic refrigeration cycle with ethane and CO_2 as refrigerants is investigated in this examination. A supercritical ORC is likewise utilized for gas-cooler waste intensity recuperation [36]. Due to the high measure of fossil utilization, improving the energy proficiency of the freezing refrigeration framework on board fishing vessels for frozen gathered fishery products is basic. Area Ratio is utilized as the plan boundary in each stage to acquire the best entrainment proportion inside the common scope of halfway tension. Besides, the water-cooled condenser is utilized to bring down the tension distinction between the condenser and evaporator, taking into consideration a bigger entrainment proportion [37].

This research presents a new two-staged configuration of an ejector trans critical CO_2 refrigeration cycle. The new cycle's performance characteristics were theoretically analysed using the first and second laws of thermodynamics [38]. A gas-terminated air-to-water ejector heat nozzle is introduced and thermodynamically read up for family boiling water age. The use of multiple liquids increases the COP of the EHP, and a LiBr-H2O retention subsystem and a second-stage ejector efficiently manage the high backpressure in the primary ejector. For examination and execution assessment, a thermodynamic model is built [39]. The main synthetic laser in light of electronic changes is the compound oxygen-iodine laser. In its generally expected setup, it is basically a low strain, high stream rate framework that requires enormous limit vacuum siphons to work. Since the result force of Loop frameworks is an immediate capability of the info fuel rate, power scaling is an unmistakable choice that can be utilized in an assortment of common and guard applications [40]. The detailed summary of literature is shown in table 1.

Table 1 Summary of literature review.

Ref.	**Year**	**Working fluid**	**Single Stage Ejector**	**Two Stage Ejector**	**Inference**
Askalany et al. [7]	2020	Silica gel/water	The highest COP of the cycle is improved by 192%.	-	A brand-new hybridization between two ejectors and the adsorption desalination cycle is suggested.
Kumar A et al. [5]	2021	air	-	Entrainment capacity improved by 57% in comparison with single stage ejector.	A comparison of the numerical performance of variable area SSE and TSE ejectors
Yadav S.K. et al. [9]	2020	air	-	Two stage ejectors	Comparative study of two stage ejector
Yari M.et al. [12]	2008	CO2	-	The new cycle's entrainment ratio is, on average, 35% greater than the traditional cycle's.	The ejector-expansion transcritical CO2 (TRCC) refrigeration cycle is described in a new configuration.

DOI: 10.2030/ASCI.25.4.AS.36

ISSN: 2178-7727

Manjili F. et al. [20]	2019	CO2	When compared to the standard cycle, NERC increases the COP by 20% to 80%.	-	Performance of a new two-stage, dual-ejector transcritical CO2 refrigeration cycle
Carrillo J. et al. [33]	2020	CO2	COP improvements of up to 13%.	-	Thermodynamic analysis of both with and without an ejector the ideal operating conditions for a two-stage CO2 refrigeration device.
Liu Y et al. [35]	2020	CO2	-	The new system's COP and energy efficiency are 19.6% and 15.9% greater, respectively, than those of the traditional system.	A novel two-stage compression transcritical CO2 dual-evaporator refrigeration cycle with an ejector is suggested in this paper.
Ding Z et al. [17]	2016	R134a	-	The two-stage ejector's ideal entrainment ratios are 0.0736, 0.0761, and 0.0813 for saturated temperatures of -22, -20, and -18 degrees Celsius, respectively.	CFD techniques were used to examine the two-stage ejector's flow characteristics.
Wang P et al. [39]	2020	HFE7500 and water	-	An entrainment ratio of 0.12 is required to get the maximum COP of 2.	Thermodynamic analysis is proposed for a gas-fired air-to-water ejector heat pump.

SUMMARY AND FUTURE SCOPE

It was found that arranging the ejector works on push increase at all essential fly stagnation pressures, however is best at low tensions and with huge ejector region proportions for any gas mix. Steam ejectors are generally utilized all the while, food, steel, and petrochemical areas. Filtration, refining, retention, blending, vacuum pressing, freeze drying, getting dried out, and degassing are common obligations. Ejectors are fit for taking care of both condensable and non-condensable gas loads, as well as minor amounts of particles or fluids. Just at irrationally high breadths can organizing give a sensible benefit in push expansion over a solitary stage ejector with a similar in general measurement.The one-layered stream suppositions couldn't think about conduit length. Practically speaking, on the off chance that the level of blending fluctuates, a two-stage ejector with a given width might limit the complete length expected for a specific degree of execution. This is on the grounds that these parts are generally significant in deciding ejector effectiveness. Be that as it may, further thorough examination on the properties of a two-stage ejector as a development gadget is as yet essential.

ISSN: 2178-7727

REFERENCES

[1] W.Presz, and M.Werle (2002) Multi-stage mixer/ejector systems, In 38th AIAA/ASME/SAE/ASEE Joint Propulsion Conference & Exhibit, 4064.

[2] R.M.Kumaran, T.Sundararajan, D.R.Manohar, and D.Dason (2012) Modeling of two-stage ejector for high-altitude testing of satellite thrusters, AIAA journal, 50(6), 1398-1408.

[3] L.M.Hadelu, and F.A.Boyaghchi (2020) Exergoeconomic and exergoenvironmental analyses and optimization of different ejector based two stage expander-organic flash cycles fuelled by solar energy, Energy Conversion and Management, 216, 112943.

[4] Y.He, J.Deng, and Z.Zhang (2014) Thermodynamic study on a new transcritical CO2 ejector expansion refrigeration system with two-stage evaporation and vapor feedback, Hvac&R Research, 20(6), 655-664.

[5] A.Kumar, V.Kumar, P.M.V.Subbarao, S.K.Yadav, and G.Singhal (2022) Numerical assessment on the performance of variable area single-and two-stage ejectors: A comparative study, Proceedings of the Institution of Mechanical Engineers, Part E: Journal of Process Mechanical Engineering, 236(1), 114-125.

[6] A.Nemati, H.Nami, and M.Yari (2017) A comparison of refrigerants in a two-stage ejector-expansion transcritical refrigeration cycle based on exergoeconomic and environmental analysis, international journal of refrigeration, 84, 139-150.

[7] A.Askalany, E.S.Ali, and R.H.Mohammed (2020) A novel cycle for adsorption desalination system with two stages-ejector for higher water production and efficiency, Desalination, 496, 114753.

[8] T.Jaruwongwittaya, and G.Chen (2012) Application of two stage ejector cooling system in a bus, Energy Procedia, 14, 187-197.

[9] S.K.Yadav, K.M.Pandey, V.Kumar, and R.Gupta (2021) Computational analysis of a supersonic two-stage ejector, Materials Today: Proceedings, 38, 2700-2705.

[10] H.Xue, L.Wang, L.Jia, C.Xie, and Q.Lv (2020) Design and investigation of a two-stage vacuum ejector for MED-TVC system, Applied Thermal Engineering, 167, 114713.

[11] N.Wen, L.Wang, J.Yan, X.Li, Z.Liu, S.Li, and G.Zou (2019) Effects of operating conditions and cooling loads on two-stage ejector performances, Applied Thermal Engineering, 150, 770-780.

[12] M.Yari, and M.Sirousazar (2008) Cycle improvements to ejector-expansion transcritical CO2 two-stage refrigeration cycle, International Journal of Energy Research, 32(7), 677-687.

[13] G.Chen, R.Zhang, D.Zhu, S.Chen, L.Fang, and X.Hao (2017) Experimental study on two-stage ejector refrigeration system driven by two heat sources, International Journal of Refrigeration, 74, 295-303.

[14] M.Goodarzi, A.Gheibi, and M.Motamedian (2015) Comparative analysis of an improved two-stage multi-inter-cooling ejector-expansion trans-critical CO2 refrigeration cycle, Applied Thermal Engineering, 81, 58-65.

[15] X.Shuxue, and M.Guoyuan (2011) Exergy analysis for quasi two-stage compression heat pump system coupled with ejector, Experimental thermal and fluid science, 35(4), 700-705.

[16] J.Yu, X.Song, and M.Ma (2013) Theoretical study on a novel R32 refrigeration cycle with a two-stage suction ejector, international journal of refrigeration, 36(1), 166-172.

[17] Z.Ding, L.Wang, H.Zhao, H.Zhang, and C.Wang (2016) Numerical study and design of a two-stage ejector for subzero refrigeration, Applied Thermal Engineering, 108, 436-448.

[18] J.Yan, N.Wen, L.Wang, X.Li, Z.Liu, and S.Li (2018) Optimization on ejector key geometries of a two-stage ejector-based multi-evaporator refrigeration system, Energy Conversion and Management, 175, 142-150.

[19] F.Kong, and H.D.Kim (2016) Optimization study of a two-stage ejector–diffuser system, International Journal of Heat and Mass Transfer, 101, 1151-1162.

[20] F.E.Manjili, and M.Cheraghi (2019) Performance of a new two-stage transcritical CO2 refrigeration cycle with two ejectors, Applied Thermal Engineering, 156, 402-409.

[21] G.Grazzini, and A.Rocchetti (2002) Numerical optimisation of a two-stage ejector refrigeration plant, international journal of refrigeration, 25(5), 621-633.

DOI: 10.2030/ASCI.25.4.AS.36

ISSN: 2178-7727

[22] N.Suvarnakuta, K.Pianthong, T.Sriveerakul, and W.Seehanam (2020) Performance analysis of a two-stage ejector in an ejector refrigeration system using computational fluid dynamics, Engineering Applications of Computational Fluid Mechanics, 14(1), 669-682.
[23] J.Yan, Q.Cai, and H.Wen (2021) Optimization on key geometries of a highly coupled two-stage ejector, Applied Thermal Engineering, 197, 117362.
[24] T.Bai, G.Yan, and J.Yu (2015) Thermodynamics analysis of a modified dual-evaporator CO2 transcritical refrigeration cycle with two-stage ejector, Energy, 84, 325-335.
[25] Y.M.Chen, and C.Y.Sun (1997) Experimental study of the performance characteristics of a steam-ejector refrigeration system, Experimental Thermal and Fluid Science, 15(4), 384-394.
[26] F.E.Manjili, and M.A.Yavari (2012) Performance of a new two-stage multi-intercooling transcritical CO2 ejector refrigeration cycle, Applied Thermal Engineering, 40, 202-209.
[27] Y.He, Z.Chen, L.Tang, and G.Chen (2015) Investigation on a two-stage ejection refrigeration system, Applied Thermal Engineering, 86, 49-59.
[28] L.Zheng, and J.Deng (2017) Experimental investigation on a transcritical CO2 ejector expansion refrigeration system with two-stage evaporation, Applied Thermal Engineering, 125, 919-927.
[29] M.Xing, J.Yu, and X.Liu (2014) Thermodynamic analysis on a two-stage transcritical CO2 heat pump cycle with double ejectors, Energy Conversion and Management, 88, 677-683.
[30] H.Chen, J.Zhu, and W.Lu (2018) Optimized selection of one-and two-stage ejectors under design and off-design conditions, Energy conversion and management, 173, 743-752.
[31] J.Sarkar (2017) Performance analyses of novel two-phase ejector enhanced multi-evaporator refrigeration systems, Applied Thermal Engineering, 110, 1635-1642.
[32] X.Gamisans, M.Sarrà, and F.J.Lafuente (2002) Gas pollutants removal in a single-and two-stage ejector–venturi scrubber, Journal of hazardous materials, 90(3), 251-266.
[33] J.A.Expósito-Carrillo, F.J.Sánchez-de La Flor, B.Perís-Pérez, and J.M.Salmerón-Lissén (2021) Thermodynamic analysis of the optimal operating conditions for a two-stage CO2 refrigeration unit in warm climates with and without ejector, Applied Thermal Engineering, 185, 116284.
[34] F.Kong, and H.D.Kim (2015) Analytical and computational studies on the performance of a two-stage ejector–diffuser system, International Journal of Heat and Mass Transfer, 85, 71-87.
[35] Y.Liu, J.Liu, and J.Yu (2020) Theoretical analysis on a novel two-stage compression transcritical CO2 dual-evaporator refrigeration cycle with an ejector, International Journal of Refrigeration, 119, 268-275.
[36] A.Nemati, R.Mohseni, and M.Yari (2018) A comprehensive comparison between CO2 and Ethane as a refrigerant in a two-stage ejector-expansion transcritical refrigeration cycle integrated with an organic Rankine cycle (ORC), The Journal of Supercritical Fluids, 133, 494-502.
[37] X.Wang, L.Wang, Y.Song, J.Deng, and Y.Zhan (2021) Optimal design of two-stage ejector for subzero refrigeration system on fishing vessel, Applied Thermal Engineering, 187, 116565.
[38] M.Yari (2009) Performance analysis and optimization of a new two-stage ejector-expansion transcritical CO2 refrigeration cycle, International Journal of Thermal Sciences, 48(10), 1997-2005.
[39] P.Wang, H.Ma, J.Spitzenberger, A.Abu-Heiba, and K.Nawaz (2021) Thermal performance of an absorption-assisted two-stage ejector air-to-water heat pump, Energy Conversion and Management, 230, 113761.
[40] G.Singhal, R.Rajesh, R.K.Tyagi, A.L.Dawar, P.M.V.Subbarao, and M.Endo (2006) Two-stage ejector-based pressure recovery system for small scale SCOIL, Experimental thermal and fluid science, 30(5), 415-426.