# Development Practices in Ejector Technology for Refrigeration and Air Conditioning Applications

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**Abstract** : *This paper presents a comprehensive literature review on ejector refrigeration systems and working fluids. It deeply analyzes ejector technology and behavior, refrigerant properties and their influence over ejector performance and all of the ejector refrigeration technologies, with a focus on past, present and future trends. Ejector technology was described and description of the refrigerant properties and their influence over ejector performance was highlighted. A review on development practices in ejector technology for refrigeration and air conditioning applications have been presented by various researchers was made available in this paper*.

**Keywords:** ejector, refrigerant, air conditioning, vapor compression etc.

## I. INTRODUCTION

Hasan Sh. Majdi [1] presented in their paper to develop a computer simulation program to evaluate the performance of solar-assited combined ejector absorption (single-effect) cooling system using LiBr/$H_2O$ as a working fluid and operating under steady-state conditions. The ejector possess no moving parts and is simple and reliable, which makes it attractive for combination with single-stage absorption cycle for further improvement to the system's performance. In this research, improvement to the system is achieved by utilizing the potential kinetic energy of the ejector to enhance refrigeration efficiency. The effects of the entrainment ratio of the ejector, operating temperature, on the thermal loads, and system performance have been investigated. The results showed that the evaporator and condenser loads, post-addition of the ejector, is found to be permanently higher than that in the basic cycle, which indicates a significant enhancement of the proposed cycle and the cooling capacity of the system increasing with the increase in evaporator temperature and entrainment ratio. The COP of the modified cycle is improved by up to 60 % compared with that of the basic cycle at the given condition. This process stabilizes the refrigeration system, enhanced its function, and enabled the system to work under higher condenser temperatures.

Giorgio Besagni et al [2] presented in their paper the increasing need for thermal comfort has led to a rapid increase in the use of cooling systems and, consequently, electricity demand for air-conditioning systems in buildings. Heat-driven ejector refrigeration systems appear to be a promising alternative to the traditional compressor-based refrigeration technologies for energy consumption reduction. M. Hassanain et al [3] presented in their paper use of a two-phase flow ejector as an expansion device in vapor compression refrigeration systems was one of the efficient ways to enhance its performance. The present work aims to design a constant-area two phase flow ejector and to evaluate performance characteristics of the ejector expansion refrigeration system working with R134a. In order to achieve these objectives, a simulation program was developed and effects of operating conditions and ejector internal efficiencies on the system performance are investigated using EES software. Comparison between present results and published experimental data revealed that the developed model can predict the system COP with a maximum error of 2.3%. The system COP increased by 87.5% as evaporation temperature changed from −10 °C to 10 °C. Tao Bai at al [4] presented in their paper an ejector enhanced vapor injection $CO_2$ transcritical heat pump cycle with sub-cooler (ESCVI) for heating application in cold regions was proposed.

The thermodynamic analysis using energetic and exegetic methods is carried out to predict the performance characteristics of the ejector enhanced cycle, and then compared with those of the conventional vapor injection heat pump cycle with sub-cooler (SCVI). The simulation results demonstrate that the ejector enhanced cycle exhibits better performance than the conventional vapor injection cycle under the specified operating conditions. The improvements of the maximum system COP and volumetric heating capacity could reach up to 7.7% and 9.5%, respectively. Exergetic analysis indicates that the largest exergy destruction ratio is generated at the compressor followed by the evaporator and gas cooler. Additionally, the exergy efficiency of the ejector is introduced to quantify the effectiveness of the exergy recovery process, which may be a new criterion to evaluate the performance of the ejector enhanced vapor

compression cycle. Hisham El-Dessouky et al [5] presented in their paper steam jet ejectors are an essential part in refrigeration and air conditioning, desalination, petroleum refining, petrochemical and chemical industries. The ejectors form an integral part of distillation columns, condensers and other heat exchange processes. In this study, semi-empirical models are developed for design and rating of steam jet ejectors. The model gives the entrainment ratio as a function of the expansion ratio and the pressures of the entrained vapor, motive steam and compressed vapor. Also, correlations are developed for the motive steam pressure at the nozzle exit as a function of the evaporator and
condenser pressures and the area ratios as a function of the entrainment ratio and the stream pressures. This allows for full design of the ejector, where defining the ejector load and the pressures of the motive steam, evaporator and condenser gives the entrainment ratio, the motive steam pressure at the nozzle outlet and the cross section areas of the diffuser and the nozzle. The developed correlations are based on large database that includes manufacturer design data and experimental data. The model includes correlations for the choked flow with compression ratios above 1.8. In addition, a correlation was provided for the non-choked flow with compression ratios below 1.8. The values of the coefficient of determination ($R2$) are 0.85 and 0.78 for the choked and non-choked flow correlations, respectively. V.O Petrenko, et al [6] presented in their paper the research results of innovative solar and waste heat driven ejector air conditioners and chillers, which was carried out by the Odessa State Academy of Refrigeration, Ukraine, in cooperation with National Taiwan University, Taiwan. On the basis of obtained results, various advanced high-efficiency multipurpose ejector air conditioners and chillers are suggested for application in different areas.
Scott, D.A, Aidoun, Z [7] presented in their paper vapour-jet ejectors have been used in cooling/refrigeration applications since the early 1900s. Recent efforts to reduce energy consumption by harnessing energy from low grade industrial waste heat or renewable energy sources have resulted in a renewed interest in this technology. This paper presents the results of computational fluid dynamics (CFD) simulations of a vapour-jet ejector operating with R245fa as the working fluid. The impact of varying operating conditions on ejector performance is presented. Also considered in this study is the impact of varying three geometrical parameters on ejector performance: the mixing section length and radius, and the primary nozzle exit radius (representative of the velocity of the motive stream). The results of this study show that CFD is a useful tool in the design and optimization of ejectors for refrigeration devices.

Ronan K. McGoverna, et al [8] presented in their paper significant numerical and experimental analyses have been devoted to understanding the variety of flow regimes present in steady flow ejectors. Certain regimes are more conducive to achieving high performance (i.e. high entrainment ratios). In particular, the entrainment ratio is seen to be highest when the entrained fluid reaches a choked condition in the mixing region. In addition, the expansion regime of the motive nozzle (under-, perfectly- or over-expanded) appears to influence performance. In this paper, we propose a method to model an ejector of optimal geometry, designed for a favorable flow regime. Then, rather than focusing upon the maximization of efficiency, we seek operational conditions that maximise ejector efficiency, specifically the reversible entrainment ratio efficiency. Ejector efficiency is found to be highest at low compression ratios and at low driving pressure ratios.
Szabolcs Varga et al **[9]** presented in their paper experimental results for a 5 kW capacity steam ejector with variable primary nozzle geometry are presented and compared to numerical simulations. The variable geometry
was achieved by applying a movable spindle in the primary nozzle. Operating conditions were considered in a range that would be suitable for an air-conditioning application, with thermal energy supplied by vacuum tube solar collectors. The numerical results were obtained using CFD. The experimental entrainment ratio varied in the range of 0.1 to 0.5 depending on operating conditions and spindle tip position. It was found that the primary flow rate can be successfully adjusted by the spindle. CFD and experimental primary flow rates agreed well, with an average relative error of 7.7%. CFD predicted the secondary flow rate and entrainment ratio with good accuracy only in 70% of the cases.
Lin Cai and Miao He [10] presented in their paper supersonic steam ejector was widely used in steam energy systems such as refrigeration, wood drying equipment, paper making machine, and steam turbine. In this paper the Computational Fluids Dynamics (CFD) method was employed to simulate a supersonic steam ejector, SST k-w turbulence model was adopted, and both real gas model and ideal gas model for fluid property were considered and compared. The mixing chamber angle, throat length, and nozzle exit position (NXP) primary pressure and temperature effects on entrainment ratio were investigated. The results show that performance of
the ejector is underestimated using ideal gas model, and the entrainment ratio is 20%–40% lower than that when using real gas model. There is an optimum mixing chamber angel and NXP makes the entrainment ratio achieve its maximum; as throat length is decreased within a range, the entrainment ratio remains unchanged.

Rohit Khajuria and Jagdev Singh[11] presented in their paper ejector refrigeration was a thermally driven technology which utilizes low grade thermal energy for its operation. This paper experimentally investigates the performance analysis of ejector refrigeration system with R404A as refrigerant. The ejector refrigeration system used exhaust emission of automobile as thermal energy for providing heat to refrigerant in the generator. Effect of different operating parameters on the performance of system has been investigated. The result shows that system using R404A as refrigerant can be used in the ejector refrigeration system for area ratio 7.84. Cooling capacity of the system increases with increase in evaporator temperature and generator temperature.

B. Bogi et al [12] presented in their paper an ejector-based pulse refrigeration system (PRS) that may be powered by solar or waste heat, and which was suitable for terrestrial and micro-gravity environments was previously proposed. This paper addresses the design of the ejector for the PRS which is driven by transient pressure waves from a set of constant volume boilers and which must entrain secondary flow under unsteady conditions. The ejector eliminates the need for a circulation pump, thus reducing system mass and increasing reliability. The design approach uses geometric scaling ratios from existing ejector based cooling systems, together with computational analysis to predict performance. The design and manufacture of two ejector prototypes are described, and CFD results are presented.

Jianlin Yu et al [13] presented in their technical paper a new ejector refrigeration system (NERS) with an additional liquid–vapor jet pump was proposed. The jet pump was used to decrease the backpressure of the ejector, and then the entrainment ratio and the coefficient of performance (COP) of the new systemcould be increased. The theoretical analysis and simulation calculation was carried out for the new system. The comparison betweenNERS and conventional ejector refrigeration system (ERS) was made under the same operating condition. The variation of the newsystem_s COP with generator temperature and backpressure was discussed for two refrigerants: R134a and R152a. The calculation results show the COP of NERS can be improved more effectively and that happens at the cost of more pump work. From the pointof view of exergy, the new system is of higher exergetic efficiency and feasible.

Adam Dudar et al [14] presented in their technical paper deals with theoretical analysis of possible efficiency increase of compression refrigeration cycles by means of application of a twophaseejector. Application of the two phase ejector in subcritical refrigeration system as a booster compressor is discussed in the paper. Results ofexergy analysis of the system operating with various working fluids for variousoperating conditions have been shown. Analysis showed possible exergy efficiency increase of refrigeration compression cycle.

Fang Liu and Eckhard A. Groll [15] presented in their technical paper the theoretical and experimental research of ejector expansion devices used in a transcritical vapor compression system using carbon dioxide (CO2) as the refrigerant and a conventional vapor compression system using R410A as the refrigerant. The expansion losses of an isenthalpic throttling process have been identified as one of the largest irreversibilities of transcritical CO2 refrigeration cycles, which contribute to the low efficiency of such cycles. An ejector expansion device is proposed here to recover the expansion losses and increase the cycle efficiency. The ejector was chosen over other expansion work recovery devices because of its unique advantage such as simple construction and robust operation. Understanding the effects of the geometric parameters and operation conditions on the performance of two-phase flow ejectors is considered the main criteria to reach an optimum design and integrate the ejector into an ejector expansion transcritical refrigeration system. David Scott et al [16] presented in their technical paper supersonic ejectors have been used in cooling/refrigeration applications since the early 1900s. Interest in supersonic ejectors has been rekindled by recent efforts to reduce energy consumption; ejector refrigeration systems can be powered by solar energy or by waste heat generated by another process. This paper presents the results of computational fluid dynamics (CFD) simulations of a supersonic ejector for use in a refrigeration system. The proposed model was applied to a geometry corresponding to an experimental apparatus that operates using R245fa.The impact of varying operating conditions (generator and evaporator pressures) on the ejector entrainment ratio and critical condenser pressures was investigated. Other parameters considered in this study include: the primary nozzle exit position; the length of the mixing chamber; and the diameter of the secondary flow inlet. The results show that CFD is a useful tool in the design of ejectors for refrigeration applications.

S. Croquer at al [17] presented in their technical paper the second part of a numerical analysis of a supersonic ejector in single phase conditions using R134a as the working fluid. In Part 1, a numerical benchmark of some thermodynamic and two-equation turbulence models has been carried out to highlight the numerical model offering the best compromise between accuracy and calculation cost. The validation was achieved by comparing the predicted entrainment ratio with the experimental data of Garcia del Valle et al. In this part, the ejector performance and local flow features are then investigated by a low-Reynolds number k−ω SST model for a wide range of outlet temperatures. Based on these accurate 2D numerical results, a discussion about the validity of the main assumptions usually made by 1D thermodynamic models is then offered. Finally, an exergy analysis is performed at various characteristic sections of the ejector to determine its global efficiency and shed light on the main sources of losses.

M. Dennis[18] presented in their technical paper solar heat driven cooling systems are an attractive concept. The need for cooling is associated with high ambient temperatures. Ejector based cooling systems have been inexistence for some time but have not gained widespread use due to their low performance and difficulty of control. Furthermore, although ejectors are well suited tosteady state operation, they do not couple well to varying solar conditions. However,ejectors offer a robust and reliable design which demonstrates flexibility to a range ofrefrigerants and most importantly, a low electrical power requirement.Variable geometry ejectors help to overcome the present objections of ejectors by taking advantage of cooler ambient conditions and allowing continued operation atelevated ambient temperatures.

Stefan Elbel Predrag Hrnjak [19] presented in their technical paper ever since the renaissance of transcritical R744 systems in the late 1980s, ejectors have been considered to improve energy efficiencies. However, the invention of the ejector dates back far longer. This review paper gives an overview of historical and recent developments regarding air-conditioning and refrigeration systems that use ejectors. More than 150 ejector papers available in the open literature have been studied and important findings and trends were summarized. Included are the early beginnings starting with the invention of the ejector and major fields of use are outlined. Research on refrigeration cycles that utilize low-grade energy to produce a refrigeration effect is summarized. Another major field, expansion work recovery by two-phase ejector, is described next. This application appears very promising when used in transcritical R744 cycles. Less commonly encountered setups, such as systems in which ejectors are used to raise the compressor discharge pressure instead of the suction pressure are also introduced.

Cüneyt Ezgi and Ibrahim Girgin[20] presented in their technical paper naval surface ships should use thermally driven heating and cooling technologies tocontinue the Navy's leadership role in protecting the marine environment. Steam ejector refrigeration(SER) or steam ejector heat pump (SEHP) systems are thermally driven heating and cooling technologies and seem to be a promising technology to reduce emissions for heating and cooling onboard naval surface ships. In this study, design and thermodynamic analysis of a seawater cooledSER and SEHP as an HVAC system for a naval surface ship application are presented and comparedwith those of a current typical naval ship system case, an $H_2O$-LiBr absorption heat pump and avapour-compression heat pump. The off-design study estimated the coefficient of performances(COPs) were 0.29–0.11 for the cooling mode and 1.29–1.11 for the heating mode, depending on thepressure of the exhaust gas boiler at off-design co nditions. In the system operating at the exhaust gasboiler pressure of 0.2 MPa, the optimum area ratio obtained was 23.30.

Michael Colarossi[21] presented in their technical paper condensing ejectors utilize the beneficial thermodynamics of condensation to produce an exiting static pressure that can be in excess of either entering static pressure.The phase change process is driven by both turbulent mixing and interphase heat transfer.Semi-empirical models can be used in conjunction with computational fluid dynamics(CFD) to gain some understanding of how condensing ejectors should be designed andoperated.The current work describes the construction of a multidimensional simulationcapability built around an Eulerian pseudo-fluid approach. The transport equations formass and momentum treat the two phases as a continuous mixture. The fluid is treated asbeing in a non-thermodynamic equilibrium state, and a modified form of the homogenous relaxation model (HRM) is employed. This model was originally intended for representing flash-boiling, but with suitable modification, the same ideas could be used for condensing flow. The computational fluid dynamics code is constructed using theopen-source OpenFOAM library. Fluid properties are evaluated using the REFPROPdatabase from NIST, which includes many common fluids and refrigerants.The working fluids used are water and carbon dioxide. For ejector flow, simulations using carbon dioxide are more stable than with water. Using carbon dioxide as the working fluid, the results of the validation simulations show a pressure rise that iscomparable to experimental data. It is also observed that the flow is near thermodynamicequilibrium in the diffuser for these cases, suggesting that turbulence effects present thegreatest challenge in modeling these ejectors

Jianyong Chen[22] presented in their technical paper refrigeration systems, air-conditioning units and heat pumps have been recognized as indispensable machines in human life, and are used for e.g.food storage, provision of thermal comfort. These machines are dominatedby the vapor compression refrigeration system and consume a largepercentage of world-wide electricity output. Moreover, $CO_2$ emissions related to the heating and cooling processes contribute significantly to thetotal amount of $CO_2$ emission from energy use. The ejector refrigeration system (ERS) has been considered as a quite interesting system that can be driven by sustainable and renewable thermal energy, like solar energy, and low-grade waste heat, consequently, reducing the electricity use. The system has some other remarkable merits, such as being simple and reliable, having low initial and running cost with long lifetime, and providing the possibility of using environmentally-friendly refrigerants, which make it very attractive. The ERS has received extensive attention theoretically and experimentally.This thesis describes in-depth investigations of vapor ejectors in the ERSto discover more details. An ejector model is proposed to determine thesystem performance and obtain the required area ratio of the ejector byintroducing three ejector efficiencies. Based on this ejector model, thecharacteristics of the vapor ejector and the ERS are investigated fromdifferent perspectives.The working fluid significantly influences the ejector behavior andsystem performance as well as the ejector design. No perfect working fluid that satisfies all the criteria of the ERS can be found. The performance ofnine refrigerants has been parametrically compared in the ERS. Based onthe slope of the vapor saturation curve in a *T-s* diagram, the working fluids can be divided into three categories: wet, dry and isentropic. A wet fluid hasa negative slope of the vapor saturation curve in the *T-s* diagram. Anisentropic expansion process from a saturated vapor state will make thestate after the expansion to fall inside the liquid-vapor area of the *T-s*diagram which will result in droplet formation.

Generally, an isentropicexpansion for a dry fluid will not occur inside the liquid-vapor area, andconsequently no droplets will form. An isentropic fluid has a vertical slopeof the vapor saturation curve in the *T-s* diagram and an isentropic expansionprocess will hence follow the vapor saturation curve in the *T-s* diagram,ideally without any droplet formation. However, when the saturationcondition is close to the critical point, it is possible that the isentropicexpansion process of a dry fluid and an isentropic fluid occurs inside theliquid-vapor area of the *T-s* diagram, resulting in formation of droplets. In order to avoid droplet formation during the expansion, a minimum requiredsuperheat of the primary flow has been introduced before the nozzle inlet.Results show that the dry fluids have generally better performance than thewet fluids and the isentropic fluid. Hence the thesis mostly focuses on thefeatures of vapor ejectors and the ERS using dry fluids.Exergy analysis has been proven to be very useful to identify the location,magnitude, and sources of exergy destruction and exergy loss, and to determine the possibilities of system performance improvement. Thismethod is applied to the ejector and the ERS. The ejector parameters areclosely interacting. The operating condition and the ejector area ratio have a great impact on the ejector overall efficiency and system COP. The ejector efficiencies are sensitive to the operating conditions, and they significantlyinfluence the system performance. A so-called advanced exergy analysis isadopted to quantify the interactions among the ERS components and toevaluate the realistic potential of improvement. The results indicate that, at the studied operating condition, the ejector should have the highest priorityto be improved, followed by the condenser, and then the generator. Thermoeconomics, which combines the thermodynamic analysis and economic principles, is applied to reveal new terms of interest of the ERS.The economic costs of the brine side fluids (fluids that supply heat to thegenerator and evaporator and remove heat from the condenser) play very essential roles in the thermoeconomic optimization of the ERS. Dependingon different economic conditions, the system improvement from athermodynamic point of view could be quite different from thethermoeconomic optimization. The ERS is economically sound when usingfree heat sources and heat sink.An ejector test bench has been built to test the entrainment ratio ofdifferent ejectors. Although the experiments do not achieve the desiredresults, they could still be discussed. The insignificant effect of the superheatof the secondary flow found in the theoretical study is validated. Theassumption of neglecting the velocities at the ejector inlets and outlet areconfirmed. The quantification of the ejector efficiencies shows that theylargely depend on the operating conditions and the ejector dimensions. Sonia Rani, Gulshan Sachdeva[23] presented in their technical paper performance of refrigerant R134a was discussed throughout an ejector for low temperature heat source for refrigeration and air–conditioning applications.The proposed system performance has been compared withCarnot cycle working at same operating conditions with influence of condenser, generator, and evaporator temperatureon performance of Vapour Jet Refrigeration (VJR) system.Furthermore, the effect of ejector efficiency also discussed at constant operating conditions. The design conditions wereevaporator temperature (5-15˚C), condenser temperature(30-45˚C) and generator temperature (75-80˚C). Forcalculation purpose mathematical equations are developed andsimulation results are obtained with EES (Engineering EquationSolver). The present results depicts that the performance of theejector highly depend on operating conditions on the performance of ejector system.

Anjani Kumar et al [24] presented in their technical paper experimental model presents a method of reduce energy consumption and enhance the refrigerating effect. With the help of two phases condensing ejector it was found that ejector work as sub compressor in refrigeration flow cycle.

That helps to reduce compressor load effectively and hence improve refrigerating effect. The new cycle includes a second step compression by an ejector device, the compressor compresses the vapour to approximately 4/5 of the final pressure and additional compression (i.e. 1/5 of final pressure) was provided in an ejector, the thermodynamic model has developed for R134 and R22 refrigerant showing a possible efficiency improvement as compared to the traditional vapour compression cycle. The investigation of a new cycle for vapour compression refrigeration with using a novel device for non-mechanical compression of refrigerants is called a condensing ejector has carried out within this project. This novel device was a hybrid of simple vapour compression refrigeration system [SVCRS] and ejector refrigeration system [ERS] was more attractive than traditional refrigeration system because of higher coefficient of performance [COP].

Szabolcs Varga et al [25] presented in their technical paper ejector refrigeration was one of the most promising technologies because of its relative simplicity and low initial cost. In this work, a theoretical study has been carried out to assess system and refrigeration efficiencies of a solar-assisted ejector cycle using water as the operating fluid. The model was based on a 1D ejector approach, including both the refrigeration and solar collector cycles. Ejector performance was evaluated for different operating conditions. The results indicated that in order to achieve an acceptable coefficient of performance, generator temperatures should not fall below 908C. Evaporator temperatures below 108C and condenser temperatures over 358C resulted in a significant drop in system efficiency, and therefore these conditions can be identified as minimal (reference) design values. The required solar collector area to provide 5 kW of cooling power was calculated for different operating conditions. Ejector dimensions were also calculated using the constant pressure mixing ejector theory.

D Konar[26] presented in their technical paper the uses of ejector for efficient refrigeration are manifold – it has been used, among other applications, in the VCRS to reduce the compression ratio, in the combined ejectorabsorption cycle to enhance the refrigeration capacity and in the ejector absorber cycle to obtainlower evaporator pressures, higher absorber pressures and pre-absorption of the refrigerant in theejector. Hence, modeling of flow which may be two phase two fluid as in ejector absorber cycle ortwo phase single fluid as in VCRS in an ejector assumes utmost importance. However, much workhas not been done in this field. The primary objective of the present work is to discuss about therole of ejectors in various refrigeration systems and to model the two phase two fluid flow in thenozzle and the diffuser of an ejector under suitable assumptions. The equations of conservation ofmass, momentum and energy have been solved to find the different flow properties like pressure,temperature and velocity of the two phases as function of the length in the diffuser. Different casespertaining to different flows have been taken care of by appreciating what type of phenomena canactually occur at the interface of the two phases. Higher pressure rise was obtained for a givendiffuser length with higher diffuser angles, smaller droplet diameter, higher inlet velocity of thegaseous phase and higher drag coefficients. Among other results, it was also seen that the twophases reached thermal equilibrium faster with higher diffuser angle, smaller droplet diameter and higher heat transfer coefficient.

Fang Liu, Eckhard A. Groll [27] presented in their technical paper the analysis of a two phase flow ejector for the transcritical $CO_2$ cycle. A detailed simulation model of a two phase flow ejector was developed. A controllable ejector expansion device was designed, constructed, and installed in a transcritical $CO_2$ experimental air conditioning system. System-level experimental results were obtained at different operation conditions and various ejector geometries. The ejector expansion model was then utilized to determine the efficiencies of the motive nozzle, suction nozzle, and mixing section using the system-level measured data. It was found that motive nozzle efficiency decreases as ejector throat area decreases and that the suction nozzle efficiency is affected by the outdoor temperature and ejector throat area. In addition, the distance from the motive nozzle exit to the mixing section constant area entry not only affects the suction nozzle efficiency, but also affects the mixing section efficiency.

Mark J. Bergander et al [28] presented in their technical paper describes a novel approach to the Rankine vapor compression cycle for cooling and refrigeration. The specific innovation is the application of a two-phase device known as a “condensing ejector” (CE) for a second stepof compression. The innovation has the potential of increasing the efficiency of the standard single-stage vaporcompression cycle through a reduction of mechanical compression at the expense of harnessing kinetic energy ofgas in the ejector device. In addition it will reduce the greenhouse gas emission by providing the same amount ofcooling with less electric energy consumption. This is the continuation of the developmental work performed under the funding from the NSF and US Dept. of Energy.

B.Elhub, et al[29] presented in their technical paper focuses and presents literature studies on recent development in ejector cooling system also the enhancement of the performance. Some of researches have conducted and categorized in working fluid selections, simulation and mathematical modelling of the ejector, geometrical and operation conditions optimization. However, most of the experimental studies which have been done in last two decades are still insufficient if compared with simulation modelling; more experiments studies and big scale work are required in order to come out with good understanding in real application.

T.Aravind et al [30] presented in their technical paper focuses on the numerical simulation of the working of a steam ejector in order improve the performance. Computational Fluid Dynamics (CFD) was employed for the numerical simulation. In this work theeffect of operating conditions on the performance of the steam ejector operating in conjunction with anejector refrigeration cycle was considered along with the effect of geometry parameter. The model and meshing isdone with GAMBIT and FLUENT solver is used for the analysis. The simulations are performed with differentoperating conditions and geometries. The entrainment ratio is found to increase with the decrease of boiler saturationtemperature for the same condition of superheat, evaporator temperature and condenser pressure. The entrainment ratiois also found to increase with increase of evaporator temperature keeping the boiler temperature and condenserpressure constant. The entrainment ratio does not vary much with the condenser pressure until the critical condenserpressure. It is also found that the entrainment ratio increases with decrease of throat diameter of the primary nozzle.The increase of entrainment ratio can be found out from the moving downwards of the effective position. But, a largermass of secondary fluid causes the momentum of the mixed stream to decrease. The decrease of momentum can bedetermined from the moving upstream of the shocking position. The movement of shocking position upstream can cause the ejector to operate at a lower critical condenser pressure.

Sajad Alimohammadi et al [31] presented in their technical paper to develop the technical knowledge, especially the optimum geometries, for the design and manufacturing of a supersonic gas-gas ejector for a waste heat driven vehicle cooling system.Although several studies have been performed to investigate the effects of geometrical configurations ofgas-gas ejectors, a progressive design methodology of an ejector compressor for application to a vehiclecooling system has not yet been described. First, an analytical model for calculation of the ejector optimumgeometry for a wide range of operating conditions is developed, using R134a as the working fluid with arated cooling capacity of 2.5 kW. To assess the effect of various dimensional quantities, an optimization technique has been proposed for calculation of the most efficient geometry of the target ejector for manufacturing. Using a vehicle cooling system as a test case, the final optimized dimensions are reported and discussed. An experimental validation confirms the CFD results and the ejector performance with a normalized deviation of 5% between observed and simulated results, demonstrating that the methodology is a valid ejector design tool for a wide range of applications.

## CONCLUSIONS

Literature concerned with ejectors used in air-conditioning and refrigeration describes numerical simulations of vapor jet ejectors. A number of established ejector flow theories point out the importance of flow choking and shock wave phenomena. Two phase ejectors which can be used instead of an expansion valve to recover expansion work. In the particular case of R744, some numerical work on two-phase ejectors has been published in the open literature, but the availability of experimental R744 ejector data appears to be extremely limited. While many of the flow theories and design guidelines developed for single-phase ejectors should be transferable to two-phase ejectors, a number of significant differences exist. Metastability effects caused by delayed flashing of the primary nozzle flow as well as supersonic two-phase flow are believed to add more complexity to the task of designing efficient two-phase ejectors.

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