Ejector refrigeration: perspectives and comparative analysis

To cite this article: Giorgio Besagni et al 2021 J. Phys.: Conf. Ser. 2116 012090

View the article online for updates and enhancements.

You may also like

- A thermodynamic investigation and optimization of an ejector refrigeration system using R1233zd(E) as a working fluid
  A Mwesigye, A Kiamari and S B Dworkin

- X-Ray Plasma Ejection Associated with an Impulsive Flare on 1992 October 5: Physical Conditions of X-Ray Plasma Ejection
  Masamitsu Ohyama and Kazunari Shibata

- Performance analysis of solar assisted vapour jet refrigeration system with regenerator (CRMC method)
  Prakash P Sathiya and A Kalaisselvane
Ejector refrigeration: perspectives and comparative analysis

Giorgio Besagni¹, Lorenzo Croci¹, Paolo Bellasio¹,² and Luigi Pietro Maria Colombo²

¹ Ricerca sul Sistema Energetico - RSE S.p.A., Power System Development Department, via Rubattino 54, 20134 Milano (Italy)
² Politecnico di Milano, Department of Energy, via Lambruschini 4a, 20156, Milano (Italy)

giorgio.besagni@polimi.it

Abstract. Within the broader discussion regarding the decarbonisation of the household sector, ejector refrigeration is attracting a growing attention. This communication contributes to the present day discussion concerning the performances and the perspectives in ejector refrigeration systems. Based on a very large dataset, gathered from the previous literature (encompassing a wide range of system design, operating conditions and refrigerants), this paper proposes a comprehensive comparative analysis. First, the current trends in ejector refrigeration systems, refrigerants and performances are presented. Second, the relationships between ejector performances, refrigerants and boundary conditions (in terms of non-dimensional temperatures, to ensure generality of the proposed analysis) are presented. In conclusion, this paper is intended to provide guidelines for perspective researchers and practitioners interested in selecting suitable ejector-based systems.

1. Introduction
In the broader framework of reducing the energy consumption of the household-scale, ejector refrigeration systems (ERSs) seem a promising alternative to the traditional compressor-based technologies owing to their reliability, limited maintenance needs and low initial and operational costs [1]. In addition, ejector-based systems have no limitation concerning refrigerants, which is beneficial taking into account the cutting-edge discussion regarding refrigerant selection [2, 3]. Nevertheless, ejector refrigeration has not been able to penetrate the market due to its low performance coefficient and severe degradation in performance when not operating under on-design conditions [4]. In particular, this paper contributes to the present day discussion regarding the performances and the perspective in ejector refrigeration. Based on a very large dataset (viz., based on 99 papers collected from the literature, 1293 data points extracted from such papers) the current trends in ejector refrigeration systems, refrigerants and performances are presented. For the sake of brevity and clarity, the reader might refer to ref. [1] for details regarding ejector system nomenclature and details regarding refrigerant properties.

2. Literature survey: performances and perspectives
Figure 1 displays the coefficient of performance (COP) for SERS is in the range of 0.2 – 0.6, which is lower compared with other system configuration. This result was expected owing to the system configuration (i.e., the absence of a compressor) and the well-known issues in off-design system performances. In general, for the different configurations it is possible to observe rising performance over time, especially for TEERS and CERS systems; this is, of course, caused by the intense research activities on the topic. Conversely, SERS-WP systems have COP in the range of 0.2 – 0.3: this range is lower compared with the other systems and remained constant over time. In addition, it is noted that, since the second half of 1990s, ejector refrigeration systems started to be coupled with solar systems. Figure 2 displays that the best performances can be obtained using natural, HFO or HFC refrigerants. In the case of natural refrigerants, COP ranges between...
0.2 and 4.0, and higher values are reached with carbon dioxide (viz., TEERS system design). Starting from 1990s, CFC and HCFC were progressively phased out in order to be replaced with more environmental friendly fluids such as HFO and refrigerant mixtures. It is also observed that mixtures have COP in the range of 0.1 – 1.3, which is lower compared with HFO. In the forthcoming years, it is expected a raising interest in natural refrigerants (i.e., R718, R744), R290-based systems and forth generation refrigerants [5].

**Figure 1.** Relationships between COP, system layout [1] and time variable.

**Figure 2.** Relationships between COP, refrigerant employed and time variable.

Figure 3, Figure 4 and Figure 5 picture the relationships between ejector system performances, refrigerants and boundary conditions (in terms of non-dimensional temperatures, to ensure generality of the proposed analysis). To the authors’ best knowledge, this is the very first comparison using non-dimensional temperatures: Figures 3 – 5, thus, can be interpreted as operational maps of ejector based systems. In particular, Figure 3 displays the relationships between COP and system design [1], as a function of the the reduced temperature of the evaporator, $T_{\text{REVAP}}$. As expected, COP increases when increasing $T_{\text{REVAP}}$. Higher COP values are obtained for TEERS and CERS system as a result of the system configuration (i.e. the presence of a mechanical compressor) which allows reaching higher compression ratios. Considering the TEERS system layout, COP is in the range of 2.5 – 7, when the system operates with a lower reduced
temperature; conversely $COP$ is in the range of $1 - 4$ when the reduced temperature is approximately $T_{R,EVAP} = 0.9 - 1$. $SERS$ and $SERS-WP$ have lower $COP$ values, while $SD-ERS$ are promising solutions when the reduced temperature is in the range of $0.6 - 0.7$. Figure 4 displays the relationship between $COP$ and the reduced temperature of the condenser, $T_{R,COND}$, for the different system configurations. As shown for the reduced temperature at the evaporator, the overall best performances are reached by $TEERS$ and $CERS$. For $CERS$ system, $COP$ is almost constant and approximately equal to 2; conversely for $TEERS$, $COP$ decreases from 4.5 to 1.5 when rising $T_{R,COND}$. Thus, for these systems, it is recommended to operate with a reduced temperature of the evaporator in the range $T_{R,COND} = 0.8 - 0.9$. When the reduced evaporator temperature is in the range of $0.4 < T_{R,COND} < 0.5$, $SERS$ systems operate with $COP = 1$, which is higher compared with other system configurations. However, in these systems a slight reduction of $T_{R,COND}$ causes a drastic decrease in the whole system performance. It is worth noting that $SD-ERS$ systems are generally used in a limited range of the condenser temperature, i.e. $T_{R,COND} = 0.6 - 0.7$. This can be explained by the fact that the thermal collectors, which are used as generator, should be operated in a narrow temperature range.

![Figure 3. Relationships between $COP$, system layout [1] and reduced temperature of the evaporator, $T_{R,EVAP}$.](image)

![Figure 4. Relationships between $COP$, system layout [1] and reduced temperature of the condenser, $T_{R,COND}$.](image)
Finally, Figure 5 displays the relationship between COP with the reduced temperature of the generator, $T_{\text{R,GEN}}$. In this analysis, TEERS are not taken into account as the generator is not present in TEERS design. It is observed that CEARS, SERS-PCPH and SD-ERS systems have interesting performances, owing to their particular configuration that allows a better use of the thermal exchanges with the high-temperature source (viz., high $T_{\text{R,GEN}}$). Indeed COP value for CEARS and SERS-PCPH is approximately equal to 1; conversely, in the case of SD-ERS systems, COP reaches a maximum value of approximately 1.5. COP value for SERS, SERS-PCPH and SD-ERS systems tend to lowers when increasing the reduced temperature of the generator. Thus it is recommended to operate with generator temperature in the range of $T_{\text{R,GEN}} = 0.6$ for SERS-PCPH systems, $T_{\text{R,GEN}} = 0.7-0.8$ for both SERS and SD-ERS systems. Conversely, CEARS performances are not strongly influenced by variations in $T_{\text{R,GEN}}$.

![Figure 5](image_url)

**Figure 5.** Relationships between COP, system layout [1] and reduced temperature of the generator, $T_{\text{R,GEN}}$.

3. **Conclusions**
Ejector refrigeration is a promising technology for producing a cooling effect by using low-grade energy sources with different refrigerants. This paper builds upon a very large dataset, gathered from the literature and encompassing a wide range of system design, operating conditions and refrigerants and proposed a comprehensive comparative analysis. The results presented in Figures 1 – 5 are supposed to be of guidance for perspective researchers and practitioners interested in selecting suitable ejector-based systems.

**Acknowledgements**
This work has been financed by the Research Fund for the Italian Electrical System in compliance with the Decree of Minister of Economic Development April 16, 2018.

**References**
[2] United Nations Briefing 2017 *Note on Ratification of the Kigali Amendment UN Environment Ozone Secretariat*