# CHAPTER I

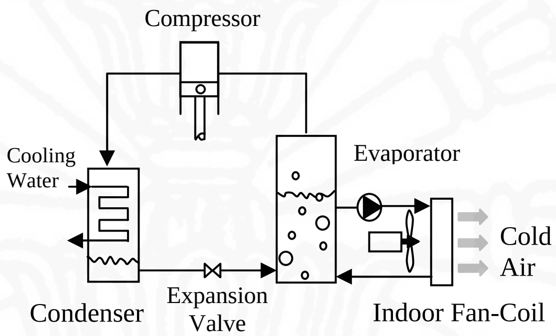
# INTRODUCTION

## 1.1 Motivation and Background

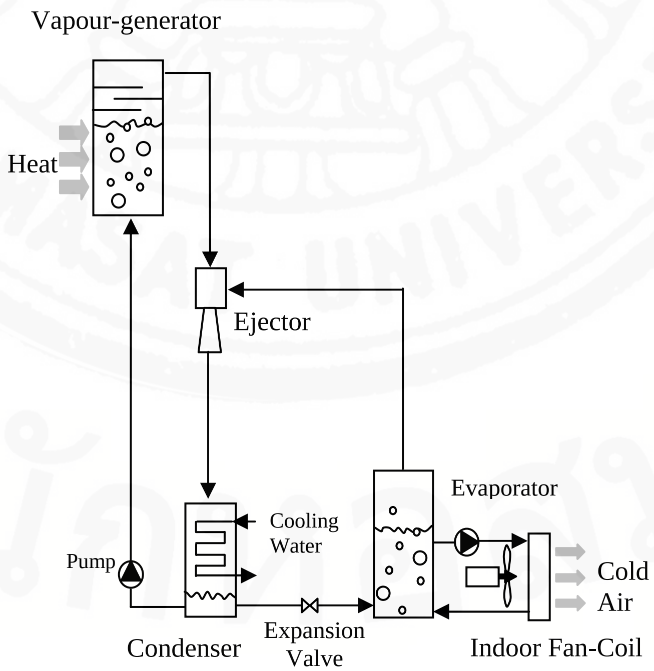
At present, the world energy consumption is increased steadily. Use of refrigeration and air conditioning application is one of the most heavy energy usages and also produces significant environmental hazard. Many inventions have been proposed to reduce the energy use of the typical refrigeration and air conditioning systems. For the vapour compression refrigeration cycle (Figure 1.1a), the most widely used air conditioning system; a mechanical compressor is a part that consumes more energy, mostly in the form of electrical energy, than other parts of the system. If this mechanical compressor is replaced with other devices such as an ejector (thermo-compressor), the system would become less dependent on electricity.

An ejector refrigeration system or Jet refrigeration system can be considered as one of the most suitable refrigeration systems for the present energy and environment situations. It utilizes a low temperature thermal energy (100-200°C) from inexpensive or even free sources such as industrial waste heat or a solar collector.

The first ejector refrigeration system was invented by Maurice Leblanc in 1910 [1]. Early in the 1930's, it was used widely for air conditioning of large buildings. Figure 1.1b shows a schematic diagram of the ejector refrigeration cycle. In the system, a vapour-generator, an ejector, and a pump are used to replace the role of the mechanical compressor of a conventional vapour compression refrigeration system. As heat is added to the vapour-generator, a high pressure and temperature refrigerant vapour is evolved and used as a primary fluid for the ejector. The ejector draws a low pressure refrigerant from the evaporator as its secondary fluid. This causes the refrigerant to evaporate at low pressure and produce a useful refrigeration effect. The ejector discharges its exhaust to the condenser where it is liquefied by rejection heat to ambient. Part of the liquid condensate refrigerant is pumped back to the vapour-generator whilst the remainder is returned to the evaporator via an expansion valve. The operating condition of the vapour-generator, evaporator and condenser of an ejector refrigeration cycle are determined by heat source, refrigerated purpose and local climate, respectively.




a) A typical vapour compression refrigeration cycle




b) A typical ejector refrigeration cycle

**Figure 1.1** Typical vapour compression and ejector refrigeration cycle.

The input required for the pump is typically less than 1 percent of the heat supplied to the vapour-generator, thus the Coefficient of Performance (COP) [2] may be estimated as:

$$\text{COP} = \frac{\text{refrigeration effect at the evaporator}}{\text{heat input at the vapour} - \text{generator}} = \frac{\dot{Q}_{\text{evap}}}{\dot{Q}_{\text{generator}}} \qquad (1.1)$$

The major disadvantage of the ejector refrigeration cycle is its relatively low Coefficient of Performance (COP), compared to other types of refrigeration cycles. However, in most industrial processes, some heat is rejected to the surrounding as waste. If this waste heat can be further used in the ejector refrigeration to produce refrigeration effects, more efficient energy use is the result.

From a summary of the important works in the literature of ejector refrigeration systems, an ejector can be considered as the most important part in the system. The performance of an ejector refrigeration system is directly related to the performance of the utilized ejector. Basically, an ejector is designed so that the supersonic high-pressure fluid exiting from the vapour-generator entrains the lower pressure fluid from an evaporator to produce the refrigeration effect. These two fluids mix and return their kinetic energy to pressure energy at the diffuser end and settle at a pressure between the two incoming pressures. It can be said that a high performance ejector is an ejector that could entrain the maximum amount of entrained lower pressure fluid at the highest possible discharged pressure. The design and the performance study of ejectors have been of interest for a considerable time. Perhaps one of the reasons for this interest is the complexity of the flow phenomena in the ejectors. The refrigerant flow in the ejector is complex, since it involves the speed of the flow ranging from low speed to supersonic speed. In order to design and develop a high performance ejector, a clear understanding of the flow and mixing inside the ejector is first needed. Although a number of investigations have been carried out covering both experimental and theoretical aspects in the field of ejectors and their refrigeration cycles, there are still some areas where experimental data are insufficient and where CFD techniques are rarely applied.

## 1.2 Objective of the Study

The aim of this study is to investigate the use of CFD in predicting performance of an R141b ejector used in refrigeration applications and to reveal the complication of the flow and the mixing process within the R141b ejector. With the built-up R141b experimental ejector refrigerator, the validation of the CFD results was satisfied. It was able to analyze the flow phenomena inside the ejector when its operating conditions and geometries were varied. Using the applications provided by the CFD software, the flow structure of the modeled ejectors could be created graphically, and the phenomena inside the flow passage were explored.

## 1.3 Organization of the Thesis

This thesis is composed of 9 chapters. The literature review on past researches and the basic backgrounds in the field of ejector and its application in refrigeration are described in Chapter II. In Chapter III, the information based on the constructions of a current R141b ejector refrigerator is provided. Furthermore, details of the constructed ejectors' components are also explained. In Chapter IV, the criterions of creating calculation domain and grid elements, including the concept of setting up the CFD simulation models of the R141 ejector, are described. In Chapter V, the validations of the calculated models with the experimental data are presented. At the end of the chapter, it was concluded that the CFD method shows the proficiency in predicting the accurate ejector performance over other ejector performance prediction models, both the entrainment ratio and the critical back pressure. Due to successful achievement of the validation process in Chapter V, the detailed analyses of contours of Mach number and the static pressure distribution along the ejector's centerline obtained from the CFD package, simultaneously, introduce the concepts explaining the flow structures and the mixing processes of the R141b ejector in Chapter VI. Also the significant differences between the flow structures of the R141b ejector and the steam ejector are also discussed. In Chapter VII and Chapter VIII, the influences of various operating conditions and various ejector's geometries on the ejector performance are proposed. At the study of each parameter, not only the effect of the parameter on ejector performance, but the changes of flow structure inside the ejector are also proposed. In the last chapter of this thesis, Chapter IX, there are the conclusions and the recommendations for future study.