CHAPTER 1
INTRODUCTION

1.1 GENERAL BACKGROUND

1.1.1 Non Condensable Gases (NCGs)

Non-condensable gases (NCGs) as the name implies, are the gases that are not able to condense and change their state into liquid form. This can have a serious impact on system operating conditions, energy efficiency, and lifetime of a system. The most common NCGs are air, nitrogen, argon, hydrogen and Carbon dioxide. These gases possess boiling points so low that made them to be in a gaseous state throughout any system.

NCGs can leak into system that has; (1) Inadequate turbine shaft sealing either in the system valve or control malfunction, if the gland seal is defective; (2) Expansion Joints, on any item affected by the condenser vacuum system and the main turbine exhaust; (3) Industries involving the usage and production of NCGs such as petro-chemical down-stream industries, Ammonia industries and (4) Feed water injection; feed water might have a percentage of NCGs in its solution.

1.1.2 Effect of NCGs on the operating parameters of the condenser in a steam power plant

The presence of NCGs (such as air), even in a small amount, degrades the condensation heat transfer (Collier, 1972) [1] (Watanawanavet, 2008) [2]. Having

said that air is one of the major insulators, possessing a thermal conductivity of 0.000049 W/(m·K) compared to water's value of 0.002 W/(m·K). NCGs lower the partial pressure of the vapor, reducing the saturation temperature of the condenser (Hassan et al. 1993)[3] thus reducing the vacuum pressure of the condenser and resulting in deteriorating the work output of a turbine. Thus, for a given power output to operate the compressors in a rankine cycle, more mass flow of steam needed to compensate the loss in the turbine's work and thus more costs will be incurred. For further explanation of the rankine cycle with the aid of a temperature and entropy graph, refer to appendix A1.

The presence of NCGs in the system is counter measured by incorporating Steam Jet Ejectors (SJE) to form a discharge pressure to suck the non-condensable gases.

1.1.3 Real-world problems of vacuum ejector performance

Croll Reynolds and McGovern (2012) [4] have emphasized that even though the ejector system primary and most common function is to remove non-condensable gases, but when a system suffers from an excess load of NCGs over the capacity of the ejector myriad deteriorations of the system shall be the consequence and hereby affecting the operating parameters.

According to Croll Reynolds, an expertise company in the field of ejector system (2013), and G.R. Martin (1997) [5], there are a lot of potential process that might lead to the deterioration of the jet systems affecting their operating parameters. The most frequent problems in ejector system can be a result of high non-condensable gas load over the process gas load, as previously mentioned above, ejector inter-condenser fouling and low motive steam pressure to the ejector system. All problems shall lead for more steam consumption, as cited on Croll Reynolds' website (2013), which is not favorable as it leads to more cost. But the most critical problem among all according to Croll Reynolds is the excess of NCGs.

1.1.4 Effect of excess NCGs load over the process load on the performance and the operating parameters of the ejector

Steam Jet Ejector will remove the NCGs from the system within its designated capacity or in technical terms the process load. The constant capacity of an ejector is determined by the choking of the secondary fluid before it mixes with the primary fluid. Since both the primary and secondary flows are choked, the entrainment ratio (the mass flow of the secondary fluid over the mass flow of the primary fluid) will remain constant, as seen in figure 2 after Scot el al. [6], until the condenser vacuum pressure increases to a point that the secondary flow is no longer choked (Munday et al. 1977) [7]. But with the excess of NCGs in the condenser the vacuum pressure will decrease leading to a choking effect in the jet ejector system and this will vitiate the ejector's performance.

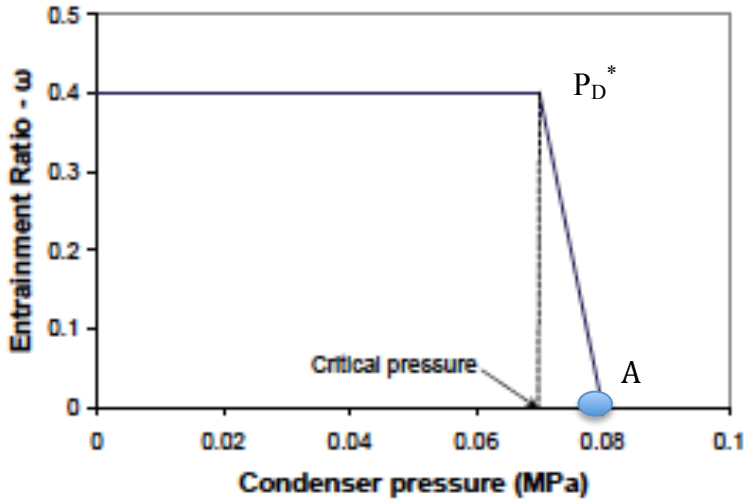

Figure 1 after Scot et al. (2008) shows the ejector's characteristic

1.2 PROBLEM STATEMENT

When the non-condensable gases' load are higher than the process gas load of the ejector, the operating parameters of the ejector will change due to choking effect [4],[7]. Consequently, the condenser's conditions will change vitiating the overall steam power plant performance. In such cases, modeling the ejector mathematically is a suggested method to relate its operating parameters and its design conditions with the relevant assumptions.

1.3 OBJECTIVES & SCOPE OF STUDY

This study is aiming for ,

1. Deriving a mathematical model for steam jet ejector's main parts including the nozzle, mixing chamber (choking effect) and diffuser.

2. Validating the mathematical model with the aid of data from the available literature or any case study relevant to the scope of study.

3. Parametric study to suggest the maximum operational conditions and parameters for maximizing the ejector's efficiency at the ejector's maximum capacity.