

Capital Cost Evaluation for Optimum Process Design of Cryogenic Air Separation

Diploma Thesis
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1 Introduction

Air separation technology, or – more generally speaking – gas separation technology, lies at the heart of the modern process industry. Highly pure oxygen and nitrogen are used in many industrial applications. Modern power generation processes, such as the currently developed OXICOAL process, rely on incineration with pure oxygen to produce flue gases with very high carbon dioxide content for further storage. Nitrogen is essential to many widely used processes such as the production of ammonia in the Haber-Bosch synthesis, as fertilizer or in many organic reactions.

2 Air Separation Technology

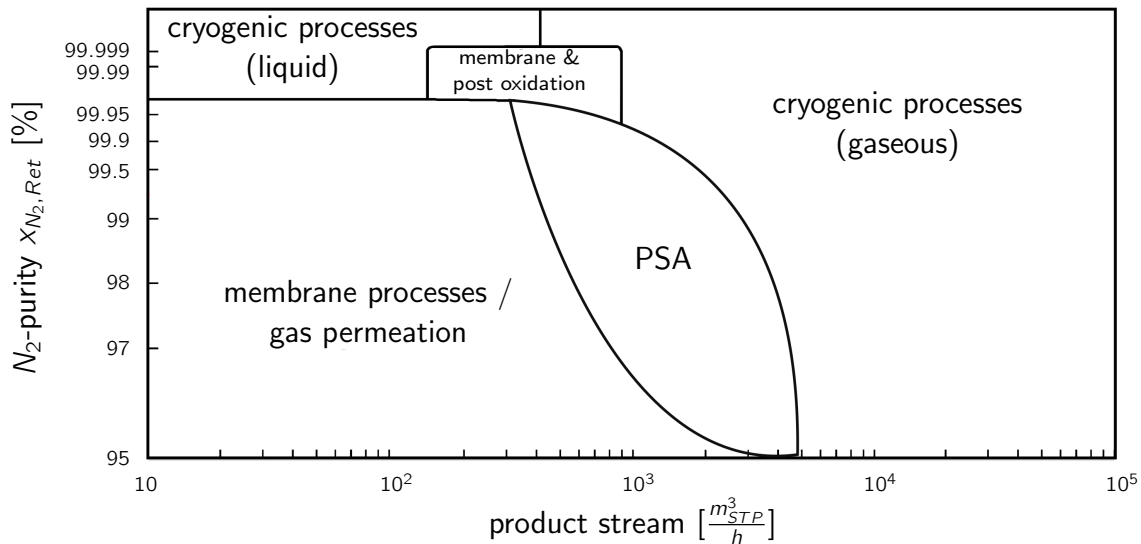


Figure 2.1: Comparison of Air Separation Technologies [1].

There are several ways besides cryogenic air separation that can be employed to separate gas mixtures. In this chapter different competing technologies and their main applications will be discussed. The predominately used technologies are cryogenic distillation, pressure swing adsorption (PSA) as well as gas permeation (GP). In the distillation process the gas is first liquefied. Separation is achieved by the different concentration differences in vapor and liquid phase. PSA relies on the different affinities of gaseous species to adsorb to certain materials in order to extract a component from a mixture. During gas permeation membranes are used. Each species migrates in different quantities through a given membrane depending on process parameters and membrane structure.

Fig. 2.1 illustrates the most economically viable processes depending on product purity and product stream volume. It can be seen that alternative air separation processes cannot supply the high quality or quantity of the cryogenic process. Due to that cryogenic air separation is thought to be the main supplier of highly pure gases in industrial quantities for years to come [2]. The alternative processes however offer some very appealing characteristics, which make them the favorable choice when lower quantities of product or more moderate purity is required. The cryogenic process is always connected with a considerable energy consumption for the liquefaction and compression. Due to that smaller implementations of the process are very unlikely to yield economically sound solutions to a separation problem.

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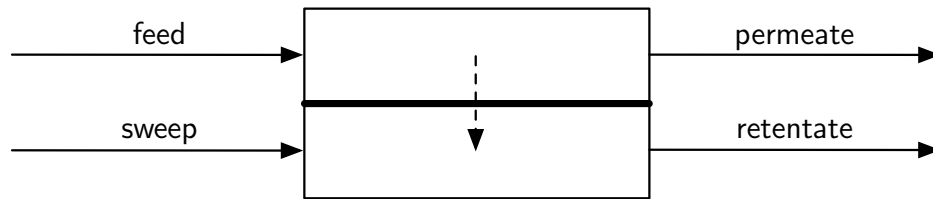


Figure 2.2: Gas permeation process.

2.1 Cryogenic Air Separation

2.2 Pressure Swing Adsorption

2.3 Gas Permeation

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The separation of mixed gases by membrane process is called gas permeation. Its main strength in comparison with alternative processes are the low energy consumption and the possibility to produce flexible mobile units. As mentioned before it is not however capable of producing high quantity highly pure product streams. As Fig. 2.1 illustrates the main application for the gas permeation process are small to moderate product streams at intermediate purities.

Fig. 2.2 shows the schematic for a single stage membrane unit. Within the feed stream the gaseous mixture is fed into the unit, which can quickly be implemented. Within the unit one or more species migrate favorably through the membrane. In this case mostly dense polymer membranes are employed used. There have been some impressive results with metallic membranes, but due to the very high material costs they have not been adapted by the industry. Furthermore, since gaseous phases often have rather small molecular species, porous membranes cannot achieve desired separation. The driving force the separation process is a difference in partial pressure or species activity across the membrane. According to the molecular structure of each species, the structure of the separating membrane as well as the process parameters pressure and temperature, they permeate through the membrane in different quantities.

The process of permeation can be subdivided into three separate steps. Sorption at the membrane / feed interface, diffusion through the mostly dense polymer membrane and finally desorption at the permeate side of the membrane.

3 Process Design

3.1 Process Model

3.2 Uncertainty in Process Modeling

3.3 Economic Considerations

4 Cryogenic Air Separation

4.1 Process Model

4.2 Process Economics

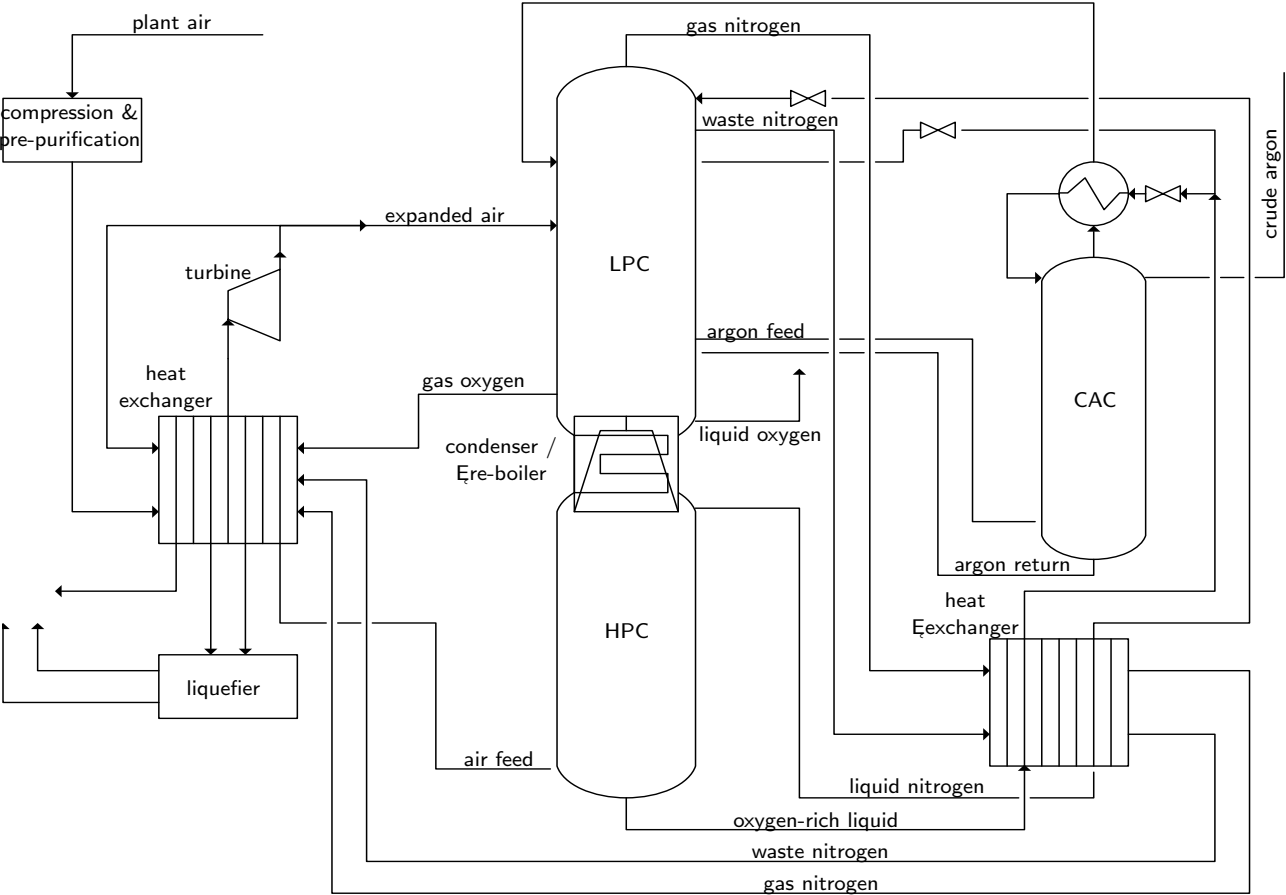


Figure 4.1: Schematic representation of the cryogenic air separation process.

5 Conclusion and Further Research

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