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A Review of Pre-combustion Carbon Capture Technology

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ABSTRACT
Global warming is one of the most significant challenges that people are facing today. As a result, capturing greenhouse gases especially carbon dioxide becomes a necessary technology for releasing climate change. This paper mainly focuses on introducing three physical solvents and processes, including Selexol Process, Purisol Process, and Morphysorb Process, used in pre-combustion carbon capture. The paper finds that Selexol Process is a physical removal process that uses the mixture of dimethyl ether and propylene glycol as the solvent to capture carbon dioxide and hydrogen sulfide from the syngas. Purisol Process usually uses N-Methyl-2-Pyrrolidone as the solvent in the IGCC power plant to capture carbon dioxide, hydrogen sulfide, and Carbonyl sulfide. Morphysorb process is a relatively new process comparing to the other two processes. It uses N-Formylmorpholine and other morpholine derivatives to remove CO_2 and H_2S.

Keywords: *Carbon capture and storage, physical solvent, Selexol process,Purisol process,Morphysorb Process*

1. INTRODUCTION

In recent years, global warming, which is caused by the accumulation of greenhouse gases like CO_2 in the atmosphere, is one of the most significant problems that different countries try to deal with. The rising temperature will cause serious and unpredictable natural disasters like droughts, storms, and rising sea level. In this case people need to pay attention to the greenhouse gases emission. To begin with, fossil fuels is an extremely important and currently irreplaceable energy source (figure 1 shows that fossil fuels have occupied 80% of energy consumption in U.S.).

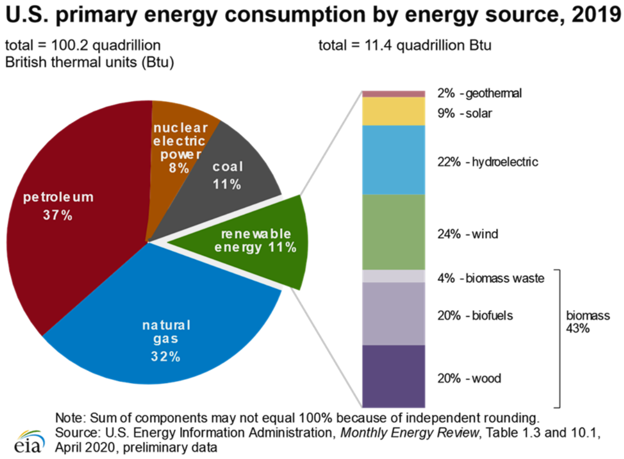

Figure 1 U.S. primary energy consumption by energy source

As a result, carbon capture and storge (CCS) plays a really important role in tackling climate change at this stage.

Carbon capture and storage technology are not mature and still need to spend a lot of time on research. Currently, many researchers are focusing on capturing carbon dioxide by using bioenergy, such as using plant waste like trunks. These topics are mainly focusing on finding new CCS technologies materials. This reseach is focusing on some existing physical industrial carbon capture techniques. Giving a detailed review of these CCS techniques, can help factories managers to choose which technologies they are going to choose.

The purpose of this paper is to list and discuss some existing physical pre-combustion carbon capture and storage technology. In the following discussion, three physical carbon capture processes, including what solvents are used, how they capture acid gases, and the overall working principles. This research can help factories that want to lower their carbon emission and also provide information about some existing physical solvents that are commercially used by scholars.

2. PRE-COMBUSTION CAPTURE

The pre-combustion carbon captures technique mainly focuses on extracting carbon dioxide from fossil fuel or biomass fuel before the combustion processes generate energy. Generally, this pre-combustion capture technology is used in the process of gasification of coal, natural gas, and biomass, which can generate syngas and in natural gas power plants[1].

Typically, a pre-combustion carbon capture system starts at the gasification of fossil or biomass fuels to form syngas, which contained mainly hydrogen, carbon monoxide, and carbon dioxide. Usually, the syngas is used to power the turbine generator and produce electricity, so pre-combustion carbon capture technology usually extracts carbon dioxide out of the syngas before the gas is combusted in the turbine[1]. To achieve this, syngas is shifted to water-gas-shift (WGS) reactions, which will create extra hydrogen and convert the carbon monoxide in syngas into extra carbon dioxide. The increasing density of carbon dioxide after the WGS reaction will make the carbon capturing process be more effective. The whole procedures are shown in Figure 2. The post combustion capture, in general, has four aspects to study, including solvent-based carbon capture, sorbent-based carbon capture, membrane-based carbon capture, and novel concepts[1].

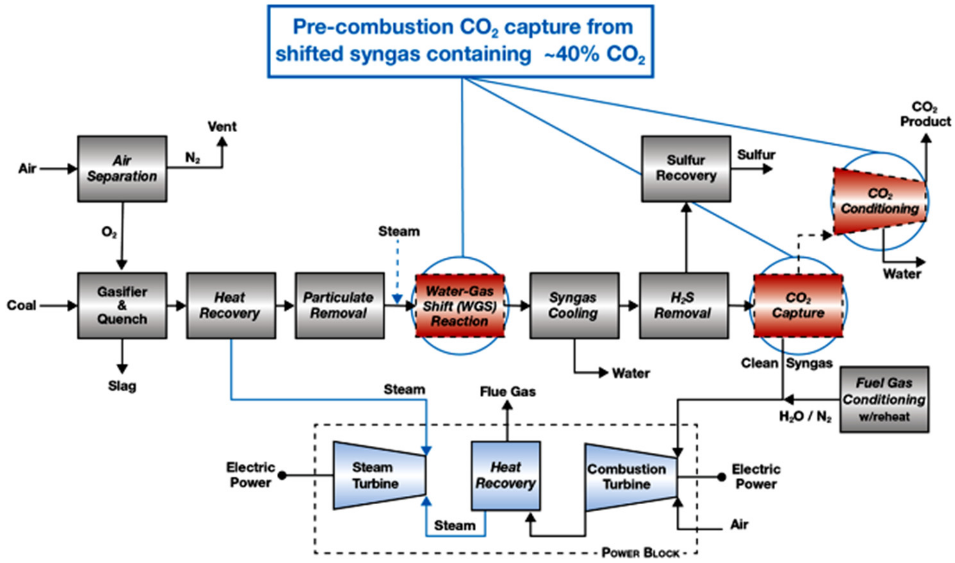

Figure 2: Process diagram carbon capture and compression for an IGCC power plant[1]

3. SOLVENT-BASED CARBON DIOXIDE CAPTURE

At present, physical solvents are widely used in many industrial manufacturing processes, such as synthesis gas, natural gas, hydrogen production and other industries. When carbon dioxide is under great pressure, usually more than 10 bar[1], physical solvents are used to capture carbon dioxide. Physical solvents usually have a larger absorption limit than chemical solvents under a large pressure condition. Proven by Electric Power Research Institute (EPRI), the physical solvent can capture around 70% of carbon dioxide produced from the Integrated gasification combined cycle (IGCC) power generation facilities and have only 4% lost[2].

Generally, there are some existing commercial processes that used physical solvents to extract carbon dioxide. For instance, the Selexol Process uses dimethyl ether or propylene glycol to capture both carbon dioxide and hydrogen sulfide under a low temperature condition. The Purisol process, which uses N-Methyl-2-Pyrrolidone as a solvent in the IGCC power generation facilities to withdraw carbon dioxide from the syngas. Morphysorb process, a relatively new process, usually employs N-Formylmorpholine and other morpholine derivatives as solvents to extract carbon dioxide and hydrogen sulfide.

4. THREE TYPES OF PROCESS

4.1Selexol Process

The selexol process is a physical acid gas removal process that uses the mixture of dimethyl ether and propylene glycol as the solvent to selectively capture carbon dioxide and hydrogen sulfide out of the syngas. Usually, we call Selexol a dual-stage process. The hydrogen sulfide will be removed at the first stage, then the carbon dioxide will be removed at the second stage. The overall principle of the selexol process can be shown in the following figure.

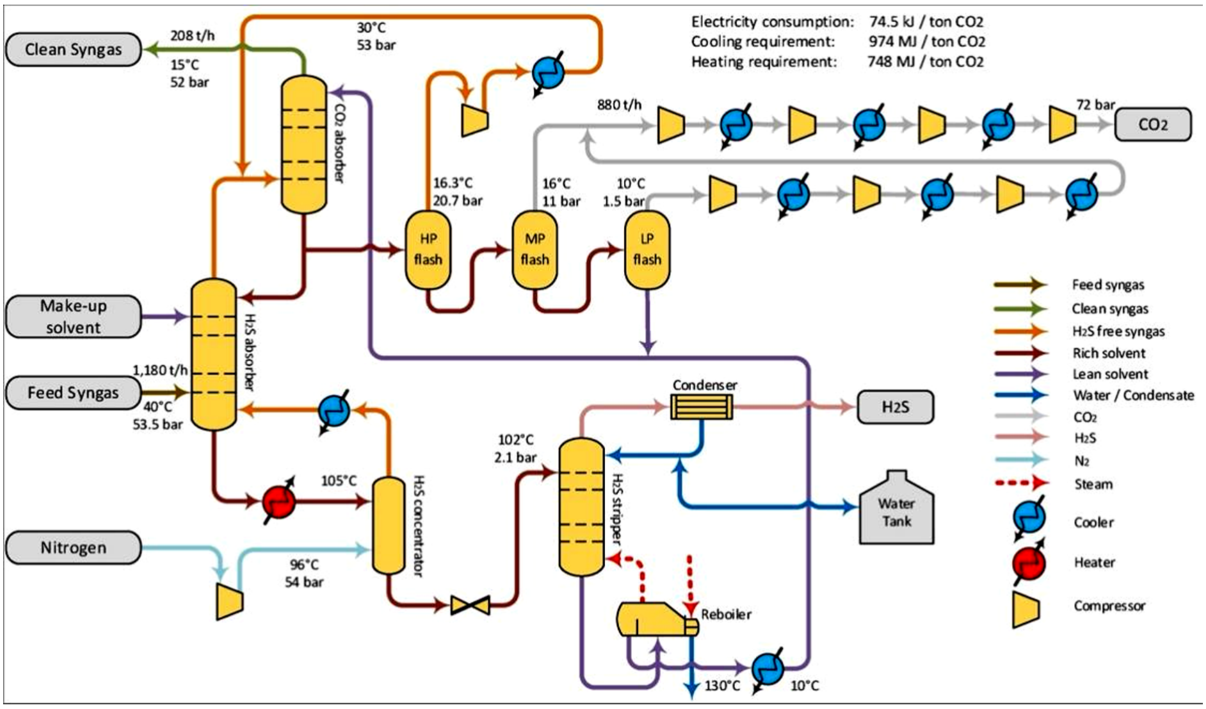

Figure 3: Simplified process flow chart of the Selexol process configuration[1]

The high-pressure syngas at the beginning will enter the H2S absorber at 40 Celsius. Almost 20% of the total solvent in the H2S absorber is recirculated from the CO_2 absorber[1]. The H2S concentrator's main function is to accumulate H_2S. When the H_2S absorber is heated to around 100 Celsius, it will then travel to the H_2S concentrator. Inside the concentrator, nitrogen gas will be injected to separate the absorbed carbon dioxide in solvent and then flow back to the H_2S absorber. The H_2S in reserve will be sent to the concentrator and then be removed. The CO_2 containing syngas will travel to the CO_2 absorber and produce clean syngas.

4.2 Purisol process

Purisol process usually adopts N-Methyl-2-Pyrrolidone as the solvent in the IGCC power generation facilities to withdraw carbon dioxide from the syngas at high pressure and high content of CO_2 and eliminate the Carbonyl sulfide impurity. The overall operation flow chart is shown in the following figure.

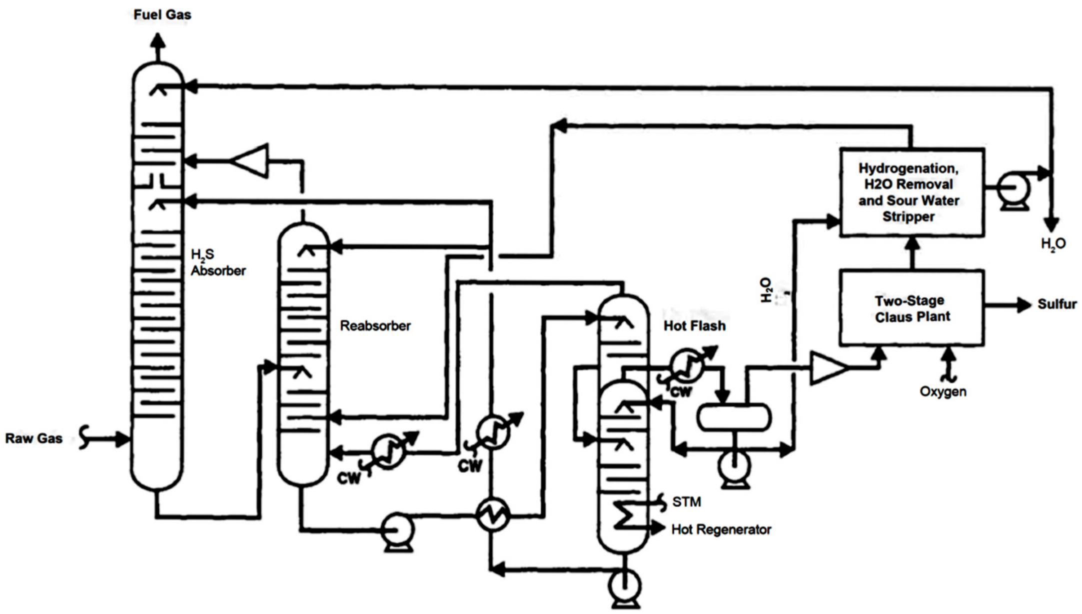

Figure 4: optimal Purisol Process for IGCCI

In the beginning, in the H_2S absorber, some H_2S and CO_2 are removed from the injecting raw gas. The solvents will be adjusted to a low pressure then pass through the reabsorber (selectively absorb H_2S) before it is recycled to the main gas stream. Then the acid gas like carbon dioxide and hydrogen sulfide will be totally removed by the reboiled stripping operation. The gas from the Hot Flash, which is purified and recycled, will be sent to an oxygen-blown Claus unit. The Claus unit will generate some tail gas that contains H_2, CO, H_2O, and CO_2, as well as any untreated H_2S and SO_2. Finally, the tail gas will be sent to a hydrogenation part and the remaining sulfur compounds will be converted to hydrogen sulfur. The tail gas will be also cooled to remove water and the remaining carbon dioxide.

Morphysorb process usually utilizes N-Formylmorpholine and other morpholine derivatives to remove the bulk of CO_2 and H_2S out of the natural gas and other gas streams in factories. The Morphysorb process's first commercial application is in DEGT Gas Transmission, Canada. A plant built in the Pine River area is used to remove acid gas. It can remove 50 MMscfd of carbon dioxide and hydrogen sulfide and generate 1,050 long tons/day of elemental sulfur at a recovery rate of 99%[1]. Another typical application is The Kwoen Gas Plant located also in Canada, focusing on reducing the acid gas generated in the Pine River Gas Plant. The following flow chart shows how the Kwoen Plant utilizes the Morphysorb process to capture carbon dioxide and hydrogen sulfide.

4.3 Morphysorb process

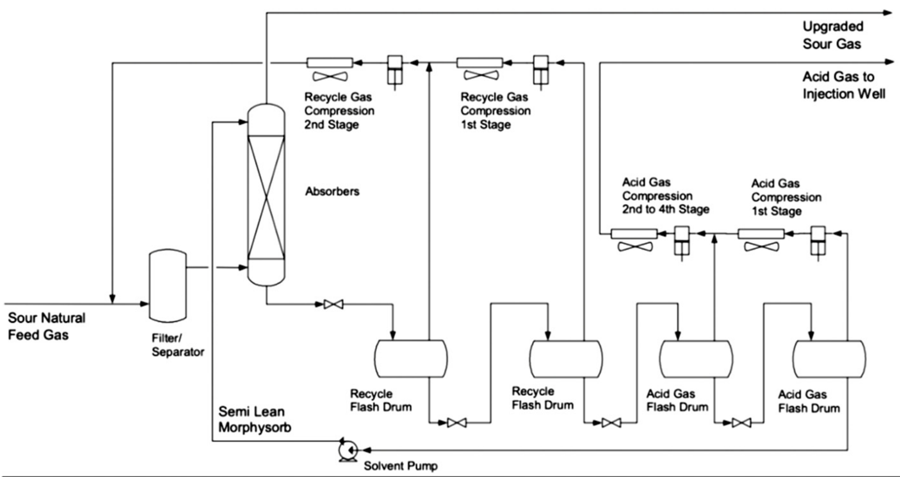

Figure 4: Process Flow Diagram for Kwoen Plant[1]

The gas that contains carbon dioxide and hydrogen sulfide will be absorbed into two absorbers. In the first and second Recycle Flash Drum, the Morphysorb solvent will be consecutively flashed and the flash gas will be compressed and recycled to absorber feed to avoid methane gas loss. In the third and fourth Recycle Flash Drum, they will generate the acid gas that will be compressed and liquefied to the downhole. Finally, the Morphysorb solution will flow back to the absorbers.

5. CONCLUSION

Capturing carbon dioxide and other acid gases is a significant step for releasing climate change. Currently carbon capture technology has three areas of studies, which are pre-combustion capture, post-combustion capture, and oxy-combustion capture. Pre-combustion capture technology is a relatively mature domain compared with the other carbon capture technologies. In the area of pre-combustion, the most frequently used and mature process is the Selexol process. The Selexol process uses a mixture of dimethyl ether and propylene glycol as the solvent to absorb H_2S and CO_2. The paper finds that, a process of simulation shows that the Selexol process can reach 95% of carbon capture efficiency[1]. Besides, the Purisol process and Morphysorb process are also widely used in industry. The Purisol process usually adopts N-Methyl-2-Pyrrolidone as the solvent in the IGCC power plant to capture CO_2, H_2S, and COS. It is well suited in high pressure and high content of CO_2 conditions. The Morphysorb process is first commercially applied in 2002, which is a relatively new process. This process mainly uses N-Formylmorpholine and other morpholine derivatives to remove the bulk of CO_2 and H_2S from the injected gas stream. These three processes are the most typical and widely used physical process. Their main restriction is these three processes can only be used on a large scale in factories, which is not a good sign in releasing the carbon capturing. However, currently, an area that focuses on using waste like woods, peanut shells, and Walnut shells, etc. to capture CO_2 has a lot of developing potentials. This post-combustion capturing technique can be achieved on a smaller scale and most importantly, using waste to capture CO_2 can greatly lower the cost of carbon capturing and utilize this technology on a bigger scale.

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