Department of Chemical & Biomolecular Engineering

CHBE 446: TEAM 3

Purifying Emissions of a Coal Power Plant

Allison Chung, Zachary Gaston, Jess Gorski, James Ko, Esther Tan

A. James Clark School of Engineering

Project Motivation

Coal power plants have been used as a primary source of energy and power since the 19th century.[1] Coal power plants emit a plethora of different pollutants: sulfur dioxide (SO_2), nitrogen dioxide (NO_2), carbon dioxide (CO_2), mercury, and others. These pollutants can have disastrous effects on health and the environment. The Brandon Shores Generating Station, located in Anne Arundel County, Maryland, is one of the largest coal-fired power plants in the state and will be used as the reference point for this project. It is a large coal power plant facility, consisting of two coal-burning units with a combined capacity of approximately 1,300 MW.[2] While it can supply electricity to hundreds of thousands of homes in Maryland, the plant has been a significant source of greenhouse gases and air pollutants in the region. The goal of this project was to design a process to remove SO_2, NO_2 and CO_2 from the flue gas stream of the coal power plant and release safe, clean air at the end of the process.

Reaction Design

Reaction 1 - SO_2 Dry Scrubbing[3]

$SO_2\ (g) + CaCO_3\ (s) \rightarrow CaSO_3\ (s) + CO_2\ (g)$

This reaction occurs at the start of the process. It enters a reactor of 750 m^3 held at 150°C, 1 bar. This reaction is used to scrub out the sulfur dioxide from the flue gas.

Reaction 2 - NO_2 Catalytic Converter[4]

$2NO_2\ (g) \rightarrow N_2\ (g) + 2O_2\ (g)$

The removal of NO_2 involves the reduction of NO_2 into N_2 and O_2 as expressed in the following reaction which takes place within a plug-flow reactor (PFR) using platinum as the catalyst and is the same process commonly seen in catalytic converters. The PFR is held at 300°C, 1 bar, with a 2-m diameter and a 10-m length.

Reaction 3 - CO_2 Scrubbing[5]

The CO_2 scrubber uses two solvents that react with CO_2 to remove it from the flue gas. The two solvents are monoethanolamine (MEA) and piperazine (PZ). These two solvents create a series of reactions that react with CO_2 to adsorbs it to remove it from the flue gas stream to be separated later in the process.

Final Design

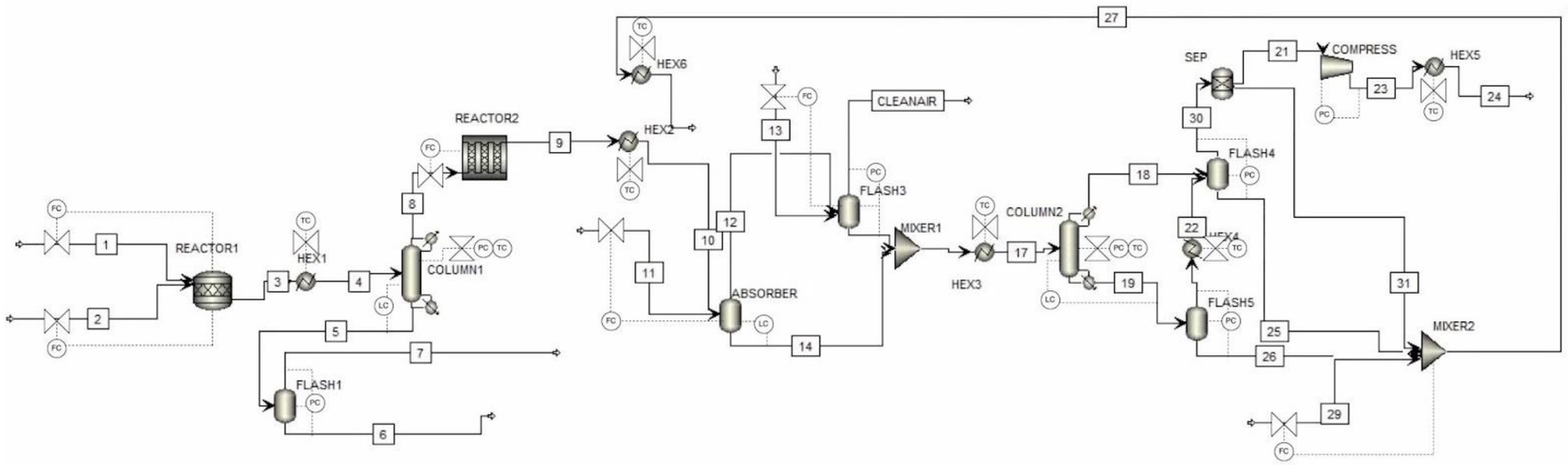

Figure 1. Full process design with instrumentation made in ASPEN Plus. The flue gas first enters a SO_2 scrubber system using a dry $CaCO_3$ scrubber to remove SO_2 from the gas. Then it enters a reactor where NO_2 is reduced into N_2 and O_2. Finally, it enters a CO_2 removal system that uses MEA and PZ.

Process Alternative

This design uses an absorber-stripper system to separate NO_2 from the main process stream by reacting it with water to form HNO_2 and HNO_3. The resulting acids are fed to a reactor to react with NaOH to form salts, shown in Figure 2. Downstream of the reactor is a flash to evaporate off excess water, and then a series of crystallizers and filters to retrieve the final $NaNO_2$ and $NaNO_3$ salt products.

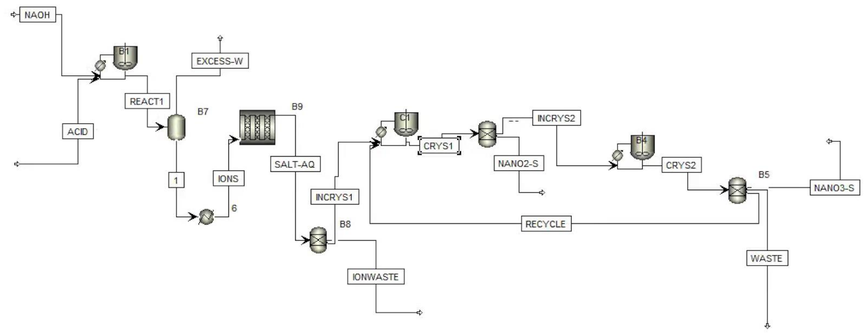

Figure 2. Alternative design to produce $NaNO_2$ and $NaNO_3$ salts from the results of NO_2 scrubbing.

Conclusions

This process has successfully removed pollutants from the inlet gas stream. SO_2 and NO_2 were removed completely, and enough CO_2 was removed such that the clean air stream releases CO_2 at concentrations below the approximate atmospheric level, 400 ppm. These results show that the process was able to remove an acceptable amount of the pollutants from the exhaust of a coal power plant and would improve the environmental impacts of gas pollutants.

The recommendation from this project would be to use the three separator systems in series being a SO_2 scrubber, a catalytic converter, and a CO_2 scrubber. However, this system is not recommended to be put into practice as it too energetically and financially expensive.

Component	Flue Gas	Clean Air
H_2O	0.1345	0.0695
CO_2	0.07773	9.95E-05
O_2	0.14871	0.1757
N_2	0.63901	0.7547
NO_2	0.00003	0
SO_2	0.00002	0

References

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