CO₂ Mitigation: A Techno-Economic Assessment

Objective:
Design of a retrofit addition to an existing pulverized coal-fired power plant to remove carbon dioxide from flue gas steam

Steam Team:
Provided energy penalty data for economic analysis
30MW average energy penalty required for ammonia regeneration

Flue Crew:
Developed models of Absorber and Stripper
Performed economic analysis to compare relationship of dimensions with efficiency of CO₂ capture and removal

Results

Recommendations

- 25% CO₂ removal system is economically feasible in coal fired plants
- Higher removal rate results in higher energy penalties
- Sequestration: Coalbed Methane (based on cost calculations)
- Location: Approximately 100-150km from power plant
- Compressor: RG Man Turbo Compressor

Sponsor:
Sargent & Lundy LLC

Faculties:
Professor Don Chmielewski
Professor Satish Parulekar
Paula Moon
Key Tasks:
- Created Matlab model of supercritical steam cycle
- Determined flow rate of CO\(_2\) annually before removal
- Modify cycle to provide steam to run CO\(_2\) removal unit
- Cool flue gas before entering CO\(_2\) removal unit

Challenges/Obstacles
- Not having access to T-S diagram for supercritical cycle until final weeks
- Changing from a sub critical model to a supercritical model with limited time
- Few team members were acquainted with Matlab coding

Key Tasks:
- Produce a CO\(_2\) removal unit design with removal percentages of 25%, 50%, and 90% for absorbent inlet temperatures of 35°F
- Determine the energy requirements of our stripper operation
- Perform economic analysis on each case

Reaction:
\[(\text{NH}_4)_2\text{CO}_3 + \text{H}_2\text{O} + \text{CO}_2 \leftrightarrow 2\text{NH}_4\text{HCO}_3\]
Forward reaction In Absorber
Backward reaction in Stripper

What is Absorber and Stripper?
Absorber: CO\(_2\) absorbed from flue gas into stagnant liquid
Stripper: separate and regenerate CO\(_2\) from solution

Heat integration:
Steam from the plant used to combine heat difference between steam cycle and CO\(_2\) technology process

Sequestration Team
- Research various sequestration methods
- Recommend the most cost effective methods

Four major sequestration methods:
- Coalbed Methane: injection of CO\(_2\) into exhausted coal seams to displace and recover methane
- Enhanced Oil Recovery: injection of CO\(_2\) into oil wells to boost oil recovery by 10-20%
- Saline: injection of CO\(_2\) into porous rocks to be trapped over a long period
- Terrestrial: use of forestry to remove CO\(_2\) from the atmosphere and store it in wood

RG Man Turbo Compressor
Ideal Compressor - Type RG multistage integrally geared centrifugal compressor manufactured by Man Turbo
Volumetric flow rate – 2,000m\(^3\)/h to 500,000m\(^3\)/h
Maximum Discharge pressure – 225bar
Estimated compressor capital costs - $55 million.