Process simulations of an aqueous CO\textsubscript{2} removal system applied to an Australian coal fired power plant

Rod Boyd\textsuperscript{1}, Ashwin Mankodi\textsuperscript{1}, Maximilian Gorensek\textsuperscript{2}, Gerald Blount\textsuperscript{2}, Kathleen O’Neil\textsuperscript{2}

\textsuperscript{1}Aurecon Australia Pty Ltd
\textsuperscript{2}Partnering in Innovation Inc.

Abstract

This paper describes the results of a process simulation study of a novel aqueous CO\textsubscript{2} removal system that is being developed by Partnering in Innovation Inc. (PI), USA. The simulation study has been funded by the Australian National Low Emissions Coal Research & Development (ANLEC R&D) and carried out by Aurecon Australia Pty Ltd. The aqueous process, which has been extensively described elsewhere\textsuperscript{i}, uses high pressure water to selectively absorb CO\textsubscript{2} from thermal power plant flue gas. The absorbed CO\textsubscript{2} is later released as the water pressure is reduced and then collected for subsequent compression and re-use or disposal. A proportion of the energy used to compress the flue gas is recovered via expansion turbines.

The chemical process simulation package, Aspen Plus V10, was used to assess the process in the context of its applicability to Australian black coal fired power plants. The Australian black coal industry is characterised by large mine mouth power plants, utilising low grade domestic coal in hot, arid conditions. The simulations performed generally supported earlier PI predictions based on smaller North American plant, and allowed the process to be simulated under full scale utility plant conditions, with Australian plant specification, coal properties and ambient conditions.

The main expected advantage of the technology over existing amine based processes is that water is both inexpensive as a solvent and is projected to more easily meet environmental requirements for disposal. This study presents a comparison of the aqueous process with a typical amine scrubbing process utilised at a large Australian coal fired plant. Aspects compared include parasitic load, impact on the thermal efficiency of the existing plant, ongoing operation costs, plant integration requirements and expected retrofit challenges. The comparison is conducted for an inland wet cooled, ultra-supercritical 695MW Unit.

The aqueous process was compared to an amine process for the 695MW unit described in a recent report on prospective Australian power generation technologies.\textsuperscript{ii} The comparison of the impact of the CCS processes on overall plant performance found that:

- The reported net power output of the plant fitted with an amine carbon capture process was 461MW. This included the standard plant auxiliary loss of 45MW, an equivalent 100MW

\textsuperscript{i} CO\textsubscript{2}-Dissolved and Aqueous Gas Separation, G. Blount; M. Gorensek; L. Hamm; K. O’Neil. 13th International Conference on Greenhouse Gas Control Technologies, GHGT-13, 14-18 November 2016, Lausanne, Switzerland.
loss due to steam extraction from the LP turbine (for amine regeneration) and a CO$_2$ system load of 88MW.

- The predicted net power output of a similar plant fitted with the aqueous carbon capture process was 470MW. This included the standard plant auxiliary loss of 45MW, and the 180MW CO$_2$ system net parasitic load, after energy recovery from the high pressure scrubbed flue gas was considered.

- The overall performance metrics for the two processes are:
  - Amine: Total parasitic load of CO$_2$ capture system of 27.1\%, and an equivalent Unit sent out efficiency of 27.2\%
  - Aqueous: Total parasitic load of CO$_2$ capture system of 25.9\%, and an equivalent Unit sent out efficiency of 27.7\%

The comparison demonstrates similar energy consumption values for the two processes, with a marginal benefit in favour of the aqueous process.

Another critical aspect of the feasibility of retrofit of a carbon capture process to an existing power plant is the nature and number of plant interfaces and the extent of required integration between the power plant and the CO$_2$ scrubbing system. A preliminary qualitative comparison of the integration requirements of the aqueous system has been made against the integration requirements of an amine system$^{iii}$. The main findings of this comparison include:

- The amine system requirement of significant mass flow of low pressure steam extracted from the steam turbine for the capture system's reboiler is not necessary with the aqueous system. The requirement for an associated steam condensate return is therefore not required either.
- Both systems require flue gas extraction from the main flue gas duct at the bottom of the stack and return of treated flue gas from the capture plant to main power plant stack.
- Apart from the flue gas interconnection, the main interface requirement of the aqueous system is the significant electrical input required for flue gas compression.
- Both systems require integration of the controls systems of the main plant and CO$_2$ scrubbing facility. Other utilities such as compressed air, demineralised water and fire services would involve a similar degree of integration of the two systems.

The ASPEN process simulations found that there are a number of key design elements that will be critical to the successful application of the technology. One of these elements is the heat integration of the compression and expansion stages of the process. Optimised integration is necessary to minimise the parasitic power consumption of the process.

Another area for future study is the potential for integrated pre-treatment (i.e., removal of sulphur oxides (SOx), nitrogen oxides (NOx), and vaporized mercury) in the initial compression steps. This has the potential to reduce system costs by avoiding the need for traditional flue gas scrubbing processes.

The next stage of the investigation will involve a cost and techno-economic assessment of the technology under Australian conditions. An integral element of this will be the sizing of equipment which will allow practical aspects of the retrofit of the aqueous system at existing plants to be fully evaluated.