CCP PROJECT FACTSHEET

TESTING PIPERAZINE SOLVENT FOR CAPTURING CO_2 FROM FLUE GAS

OVERVIEW

Identifying potential solutions for reducing the cost of capturing CO_2 from oil and gas industry applications is one of the central objectives of the CCP (CO_2 Capture Project).

Testing site of the PZ solvent at the University of Texas, Austin.

Aqueous piperazine is a second-generation solvent that has superior kinetics, favourable vapor-liquid characteristics, large operational CO_2 carrying capacity, and good resistance to thermal and oxidative degradation. When used with an advanced stripper configuration, it can be regenerated at elevated pressures with reduced energy consumption. Previous work funded by the U.S. Department of Energy (Award number DE-F0005654) established that Piperazine with the Advanced Stripper (PZAS) is a superior technology for CO_2 capture from flue gas with ~12 vol% CO_2. Modelling studies suggested that the PZAS technology may be uniquely suitable for application to low CO_2 concentration flue gases.

CCP was interested in PZAS application to lower-concentration flue gases that are more prevalent in the oil and gas industry. CCP worked with the University of Texas at Austin and the National Carbon Capture Center (NCCC), a U.S. Department of Energy-sponsored research facility in Wilsonville, Alabama to pilot the use of PZAS technology. The pilot tested PZAS technology for capturing CO_2 from low CO_2 (4 vol%) flue gas, representative of flue gas from Natural Gas Combined Cycle (NGCC) power plants. Leveraging existing pilot facilities at NCCC, CCP sponsored a series of tests with 4% CO_2 flue gas. In July 2019, CCP deemed the pilot tests a success, providing significant data to scale up the PZAS technology for low-CO_2 concentration applications such as flue gas from NGCC power plants.

THE PROJECT

Goals

The main goals of the project were:

1. **Demonstrate the application of PZAS to low-CO_2 flue gas to achieve high capture rate at reasonable energy consumption**
2. **Generate data from model evaluation for scale-up, especially under different process conditions and configurations**
3. **Demonstrate long-term operability of PZAS under low-CO_2 conditions, evaluating emissions, degradation, corrosion and other operational performance.**

Results

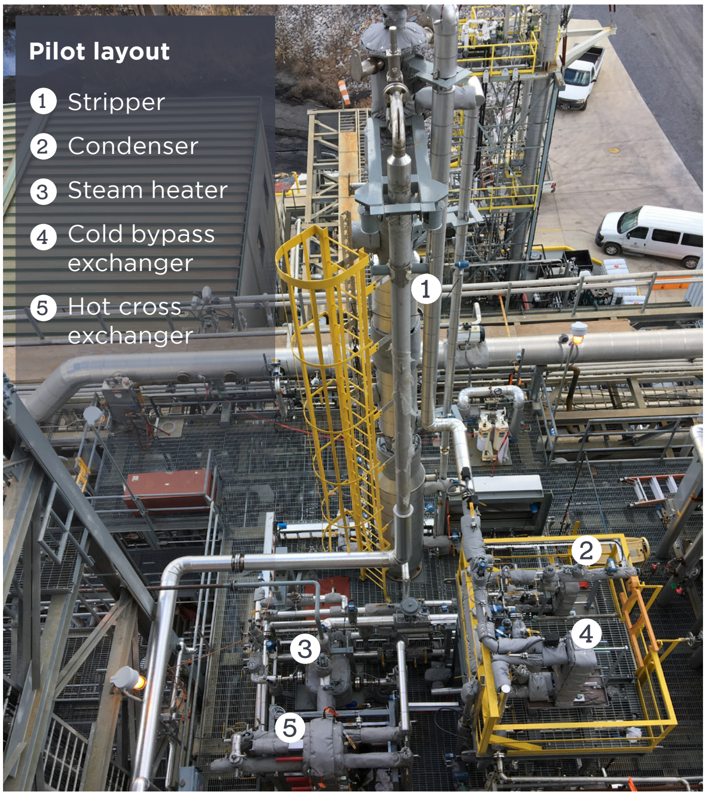
The test campaign, including performance testing under different operating conditions and long-term tests for stability, lasted 2,100 hours and was completed in June 2019. New process configurations for absorber intercooling and process intensification concepts, to combine direct contact cooler with absorber cooling, were tested and confirmed. CO_2 removal rates of up to 96% were demonstrated and energy performance at 90% capture was around 2.35 GJ/tonne CO_2. Solvent degradation, emissions, corrosion and operation were generally similar to other applications. The pilot data used for model validation under a variety of operational conditions and model performance shows that the PZAS technology is ready for scale-up to large pilot applications (>100 tonne CO_2 captured/day).

Project phases and considerations

Prior to the NCCC project, initial testing was done at University of Texas, Austin's Separation Research Program pilot plant to ascertain the feasibility of using piperazine on a low CO_2 concentration flue gas stream simulated by mixing CO_2 and air streams.

The project benefited from in-depth discussions with NCCC to understand their set-up and limitations. NCCC made modifications to the absorber by activating by-pass loops to the direct contact cooler and implementing flue gas heating to mimic higher temperatures, when diluted flue gas stream by-passes the direct contact cooler. NCCC also made modifications to the absorber intercooling loop to accommodate pump-around cooling as well as the larger cooling load and flow rates required in these experiments. A new Coriolis flow meter was also installed to collect solvent density data.

The project took advantage of existing capabilities to dilute coal flue gas with air to simulate natural gas flue gas, and flexibility to use one to two sections of packing within the absorber. Both experimental plan and data and sampling plan were designed by UT-Austin and iterated with NCCC prior to the start of the test campaign. Continuous communication between the technology developer and pilot plant staff contributed to the smooth execution of the entire test plan.



UT-designed Advanced Stripper skid installed at NCCC.

Results in detail

- PZAS was able to achieve high CO_2 removal rates with a very modest amount of packing (20-40 ft)
- At 90% CO_2 removal for 4% CO_2 flue gas, solvent loadings were similar to that achieved at 12% CO_2, indicating that there was sufficient driving force at the lean end
- Intercooling was effective at removing the heat released when CO_2 reacted with the amine solvent, removing any temperature limitation to mass transfer – another factor facilitating high loadings. Therefore, a smaller circulation rate of solvent was used per volume of gas and the energy performance at the regenerator on a per tonne CO_2 basis was similar to applications with higher CO_2, independent of inlet CO_2 concentration
- Pump around cooling increased the liquid rate at the bottom portion of the absorber and was found to be effective to cool flue gas entering at an elevated temperature to simulate the outlet of an NGCC power plant. The demonstration of this configuration brings credence to using process simulation models to optimize configuration for this application
- One condition was selected for long-term tests to ensure stable performance over weeks/months. CO_2 capture rates of 90% and energy performance of 2.2-2.4 GJ/tonne CO_2 were maintained throughout. During the long-term tests, particular attention was paid to the emissions of solvent and its degradation products, the monitoring of piperazine concentrations as well as those of heat stable salts, degradation products, and other elements that may be indicative of corrosion
- Piperazine emissions were effectively controlled by limiting upstream aerosol nuclei. Emission of ammonia, a degradation product, was limited. Accumulation of liquid phase degradation products did not impact process performance
- Corrosion coupons of various materials were inserted into the process to help understand the extent and mechanism of corrosion to inform the material of choice in scale-up designs. Carbon steel was confirmed to be stable for most low-temperature areas of the process. Activated carbon filtration as a means to reduce degradation products and control corrosion was tested and found to be promising.

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Images courtesy of the University of Texas.

ABOUT THE CCP

The CCP is an award-winning group of major energy companies working to advance the technologies that will underpin the deployment of industrial-scale CO_2 capture and storage.

To find out more visit www.co2captureproject.org