The National Carbon Capture Center

Topical Report
Budget Period Four

Reporting Period: August 1, 2017 – May 31, 2018
Project Period: June 6, 2014 – May 31, 2020

DOE Cooperative Agreement
DE-FE0022596

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Abstract

Managed and operated by Southern Company, the U.S. Department of Energy's (DOE's) National Carbon Capture Center (NCCC) is a world-class neutral research facility working to advance technologies to reduce carbon dioxide (CO_2) emissions from natural gas- and coal-fueled power plants. The center explores the most promising, cost-effective carbon capture processes from third-party developers and bridges the gap between laboratory research and large-scale demonstrations. Located in Wilsonville, Alabama, the facility provides realistic testing conditions plus the infrastructure to evaluate multiple technologies at various levels of maturity. Through testing and collaboration with national and international stakeholders, the NCCC plays a key part in advancing carbon capture deployment.

The NCCC includes multiple slipstream units that allow development of carbon capture concepts using fossil fuel-derived flue gas in industrial settings. Because of the ability to operate under a wide range of flow rates and process conditions, research at the NCCC can effectively evaluate technologies at various levels of maturity and accelerate their development to commercialization.

During the Budget Period Four reporting period, spanning from August 1, 2017, through May 31, 2018, efforts at the NCCC focused on post-combustion carbon capture technology development. Testing was conducted with multiple membrane technologies and advanced solvents and solvent systems during three major test runs. Preparations were underway to build new infrastructure to allow more testing of carbon capture technologies for natural gas power plants.

Acknowledgement

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List of Abbreviations

AEP	American Electric Power
AFS	Advanced Flash Stripper
BP4	Budget Period Four
BP5	Budget Period Five
CO_2	Carbon Dioxide
DOE	Department of Energy
GC	Gas Chromatograph
GTI	Gas Technology Institute
L/G	Liquid-to-Gas
MEA	Monoethanol Amine
NCCC	National Carbon Capture Center
NETL	National Energy Technology Laboratory
OSU	Ohio State University
PO-1 through 9	Post-Combustion Runs 1 through 9
PSTU	Pilot Solvent Test Unit
RTI	Research Triangle Institute
SO_3	Sulfur Trioxide
SSTU	Slipstream Solvent Test Unit
UT-Austin	University of Texas at Austin

1.0 EXECUTIVE SUMMARY

Sponsored by the U.S. Department of Energy (DOE), the National Carbon Capture Center (NCCC) is a world-class neutral research facility working to advance innovative fossil energy technology solutions. Bridging the gap between laboratory research and large-scale demonstrations, the NCCC evaluates carbon capture processes from third-party developers, focusing on the early-stage development of the most promising, cost-effective technologies for future commercial deployment.

The center provides test sites and wide-ranging support to researchers developing lower-cost carbon capture technologies that will enable fossil fuel-based power generation to remain a key contributor to the energy mix. The facilities accommodate a range of equipment sizes and operating conditions and provide commercially representative settings that allow results to be scaled confidently to commercial application, a crucial element in shortening development times.

Project Partnership with DOE

The DOE Office of Fossil Energy's National Energy Technology Laboratory (NETL), in cooperation with Southern Company, established the NCCC in 2009 to become a cornerstone for U.S. leadership in advanced clean coal technology development. After the successful completion of the first contract period, which comprised testing and advancement of numerous post-combustion carbon capture, gasification, and pre-combustion carbon capture technologies, the DOE renewed its support of the project with another cooperative agreement spanning from June 2014 through May 2020. As of July 2017, NCCC concluded its gasification and pre-combustion carbon capture programs due to changes in the project scope to focus more on post-combustion capture for natural gas and coal power generation. Work to progress post-combustion carbon capture technologies is expected to continue through the end of the current cooperative agreement.

Reporting Period

This report covers the work performed during Budget Period Four (BP4), from August 1, 2017, through May 31, 2018, of the NCCC's second cooperative agreement with DOE, DE-FE0022596.

Post-Combustion Test Site

The NCCC's post-combustion carbon capture facilities utilize flue gas from Alabama Power's Plant Gaston Unit 5, a base-loaded, 880-MW gross supercritical pulverized coal boiler fired with bituminous coal. The unit meets all environmental requirements utilizing state-of-the-art controls; thus, the flue gas extracted for testing is fully representative of commercial conditions. As shown in Figure 1, the center provides both pilot-scale and bench-scale test sites. The pilot-scale area houses the Pilot Solvent Test Unit (PSTU) and two bays for technology developers' test skids. The bench-scale area includes the Slipstream Solvent Test Unit (SSTU) and five test bays to accommodate technology developer equipment.

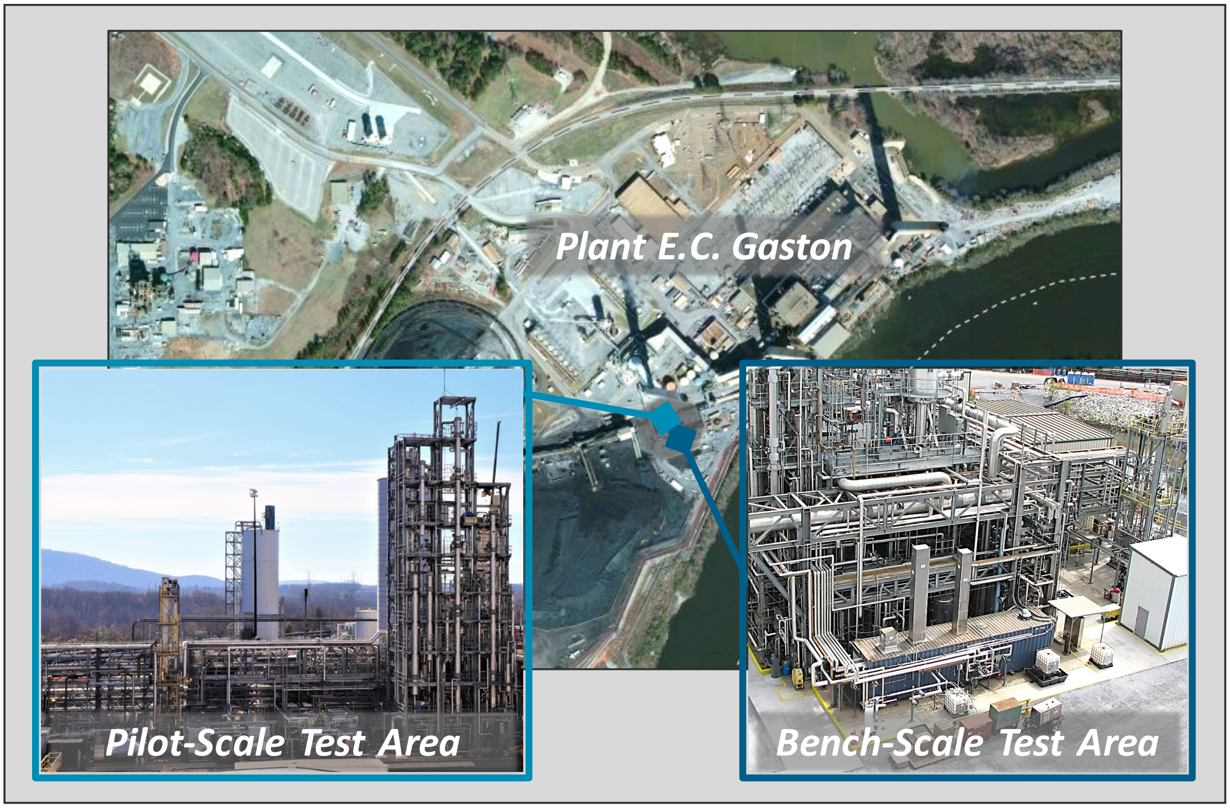

Figure 1. Photographs of Post-Combustion Carbon Capture Test Facilities

Accomplishments

During the reporting period, the NCCC supported multiple carbon capture projects during three periods of operation:

- Run PO-6, beginning in Budget Period Three, in June 2017, through mid-August 2017
- Run PO-7, occurring from November 2017 through mid-April 2018
- Run PO-8, beginning in mid-April 2018 and continuing through mid-August 2018, into Budget Period Five (BP5)

Accomplishments in the post-combustion carbon capture program are highlighted below.

Gas Technology Institute (GTI) 0.5-MW Membrane Contactor

GTI is developing a hollow fiber gas-liquid membrane contactor to replace conventional packed-bed columns in solvent systems to improve CO_2 absorption and desorption efficiency. The 0.5-MW system operated during all three runs of the reporting period. GTI resolved all technical challenges and performed parametric and long-term testing. The system demonstrated 90% CO_2 capture with CO_2 purity greater than 97%. GTI will continue testing through the end of the PO-8 run.

Slipstream Solvent Test Unit

The SSTU provides for solvent testing under a complete absorption/regeneration cycle for post-combustion carbon capture at bench-scale using 500 lb/hr of flue gas (0.05 MWe equivalent). Following the previous commissioning with monoethanol amine (MEA) solvent, the SSTU was operated for a 300-hour test run to gain additional baseline data with MEA. MEA baseline testing is critical for future comparisons of solvent-based technologies that may be tested with the SSTU. The SSTU operated most efficiently at a liquid-to-gas weight ratio of 3.14, at which point the heat of regeneration was 2,198 BTU/lb of CO_2 captured. The SSTU oxygen and nitrogen mass balances were within 5% of closure, which was encouraging considering the small flow rates involved. Future testing is planned using MEA with the same liquid-to-gas ratio to further refine the heat of regeneration value as sources of error are identified and eliminated.

AECOM/ University of Texas at Austin (UT-Austin) Advanced Flash Stripper and Solvent

UT-Austin and AECOM are jointly developing an Advanced Flash Stripper (AFS) to reduce the energy requirements of stripping CO_2 from amine-based solvents. For testing at the NCCC, the AFS skid was installed in the PSTU structure, and provisions were made to operate the AFS integrated with the PSTU while bypassing the PSTU's regenerator. Parametric testing was completed with the PSTU and AFS while using piperazine solvent. For comparison, the PSTU and its regenerator were also operated with piperazine solvent. Based on the preliminary data, AECOM reported that the AFS system achieved promising regeneration energy in the range of 2.0 to 2.5 gigajoules/metric tonne (GJ/MT) CO_2, while the regeneration energy with the PSTU regenerator was 3.5 to 4.0 GJ/MT CO_2. Long-term testing of the AFS began and will continue through the end of the PO-8 run.

Air Liquide 0.3-MW Cold Membrane

Air Liquide is developing a CO_2 capture process using hollow fiber membranes operating at sub-ambient temperatures. Building on previous operation in 2015 and 2016, Air Liquide continued testing of the cold membrane process and evaluation of membrane materials. Current testing is focused on continued development and scale-up of the novel PI-2 membrane material featuring significantly higher CO_2 flux than commercially available material. Multiple 6-inch PI-2 membrane bundles were tested at -45°C (-49°F) and 200 psig from late 2017 through May 2018. Results will be published in subsequent reports.

NETL Bench-Scale Membranes

As a continuation of previous testing, NETL will operate its post-combustion membrane skid to identify materials with acceptable CO_2 separation performance in the presence of water vapor and minor contaminants. The test skid and equipment were installed, and testing is to begin in July 2018.

TDA Research 0.5-MW Alkalized Alumina Sorbent

TDA is developing a CO_2 capture process using dry, alkalized alumina sorbent, which is regenerable using low-pressure steam and operates at near isothermal conditions and at ambient pressure. Equipment was installed, and commissioning began. Testing is planned in late 2018.

Research Triangle Institute (RTI) Non-Aqueous Solvent

RTI is planning for long-term operation of the SSTU with a non-aqueous solvent beginning in July 2018. Modifications were made to the SSTU to accommodate the solvent. Following evaluation at the NCCC, the solvent will be tested at a larger scale with coal-derived flue gas at SINTEF in Norway.

Ohio State University(OSU)/American Electric Power (AEP) Membranes

Plans were underway for testing of OSU's CO_2 membrane modules, which will build on OSU's previous membrane evaluations at the NCCC in 2015. Sponsored by AEP, the project is focused on the development of a cost-effective design of spiral-wound membrane modules. OSU plans to deliver the membrane skid to the site in mid-July to begin four weeks of testing. The skids will be installed in the NCCC's new lab-scale test unit.

Site Modifications

Progress continued for enhancing site testing capabilities, with work including preparations to build new infrastructure to allow more testing of carbon capture technologies for natural gas power plants and the installation of a generator furnace to inject sulfur trioxide (SO_3) directly into the flue gas stream to facilitate amine aerosol research. A lab-scale test unit was installed to house the NETL and OSU/AEP membrane projects and other future projects. Engineering and field work began to prepare for decontamination, decommissioning, and dismantling of the gasification and pre-combustion carbon capture equipment.

2.0 TEST FACILITES

The NCCC's post-combustion carbon capture facilities utilize flue gas from Alabama Power's Plant Gaston Unit 5, a base-loaded, 880-MW gross supercritical pulverized coal boiler. The unit meets all environmental requirements utilizing state-of-the-art controls, including a selective catalytic reduction unit for control of nitrogen oxides, sodium bicarbonate injection to control SO_3 emissions, hot-side electrostatic precipitators, a wet flue gas desulfurization unit to control sulfur dioxide emissions, and a baghouse using activated carbon to capture heavy metals. Hence, the flue gas extracted for testing is fully representative of commercial conditions. As shown in Figure 2, the center provides two test areas: the pilot-scale area houses the PSTU and two bays for technology developers' test skids, and the bench-scale area includes the SSTU and five test bays for technology developer equipment. An air dilution system is available to simulate natural gas flue gas conditions.

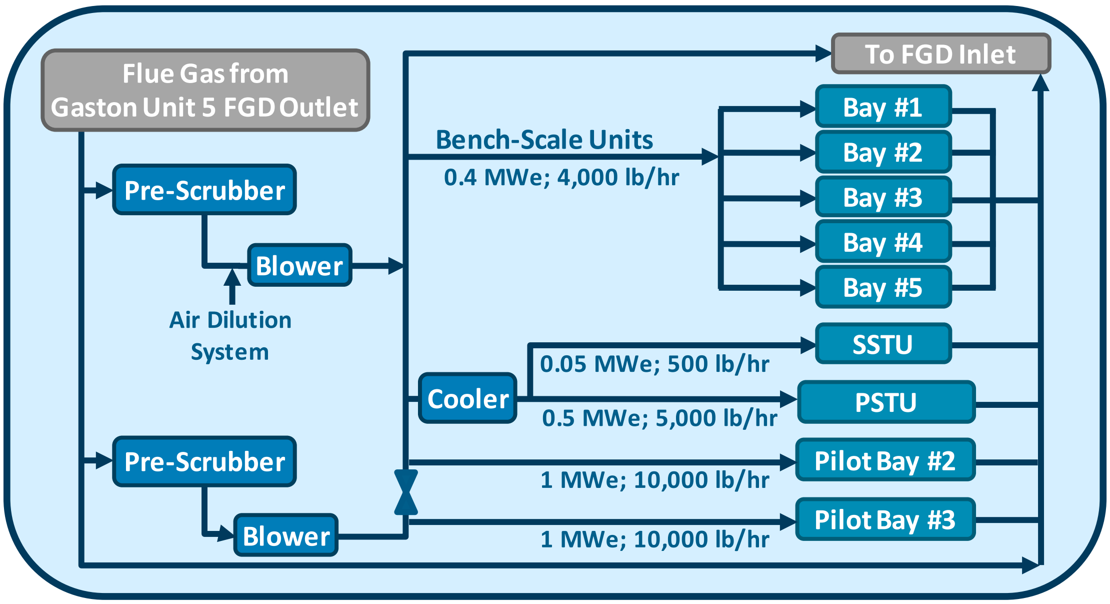

Figure 2. Schematic of Carbon Capture Site Layout

Table 1 lists the average composition and conditions of the flue gas used for testing.

Table 1. Average Values of Coal-Derived Flue Gas Components and Conditions

Flue Gas Component	*Value*
CO_2, vol%	12.1
Oxygen, vol%	7.1
H_2O, vol%	7.6
Nitrogen oxide, ppm	41.0
Nitrogen dioxide, ppm	6.5
Temperature, °F	155
Pressure, inH_2O	20

3.0 RESULTS

During the reporting period, the NCCC supported multiple carbon capture projects during three periods of operation:

- Run PO-6, beginning in Budget Period Three, June 2017, through mid-August 2017
- Run PO-7, occurring from November 2017 through mid-April 2018
- Run PO-8, beginning in mid-April 2018 and continuing into Budget Period Five (through mid-August 2018)

3.1 Gas Technology Institute 0.5-MW Membrane Contactor

GTI, under DOE funding, is developing a hollow fiber gas-liquid membrane contactor to replace conventional packed-bed columns to improve CO_2 absorption and desorption efficiency. It is a hybrid system that combines the advantages of membrane gas separation and solvent absorption mechanisms. Use of a hollow fiber membrane configuration provides five to ten times higher gas/liquid contacting surface area than a conventional packed bed column, offering a significant capital cost reduction. After completing a small bench-scale project at another location, GTI is moving the technology forward with a small pilot-scale, 0.5-MW process installed at the NCCC in 2017. Figure 3 provides a photograph of the installed equipment.

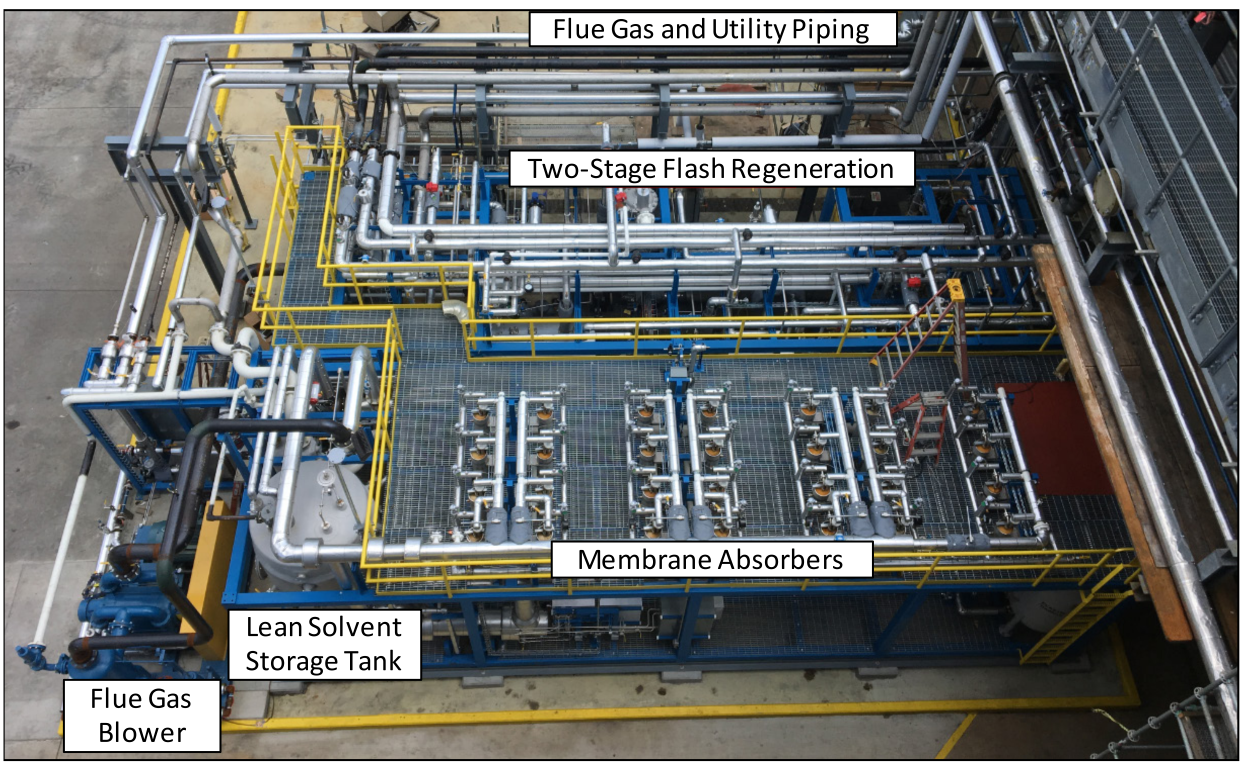

Figure 3. Gas Technology Institute Membrane Contactor

Parametric testing began in late June 2018 with four membrane modules in service to gather performance data under various process conditions. Initial membrane performance met the 90% CO_2 capture rate target at greater than 95% purity. Figure 4 shows an example of early test results with flue gas.

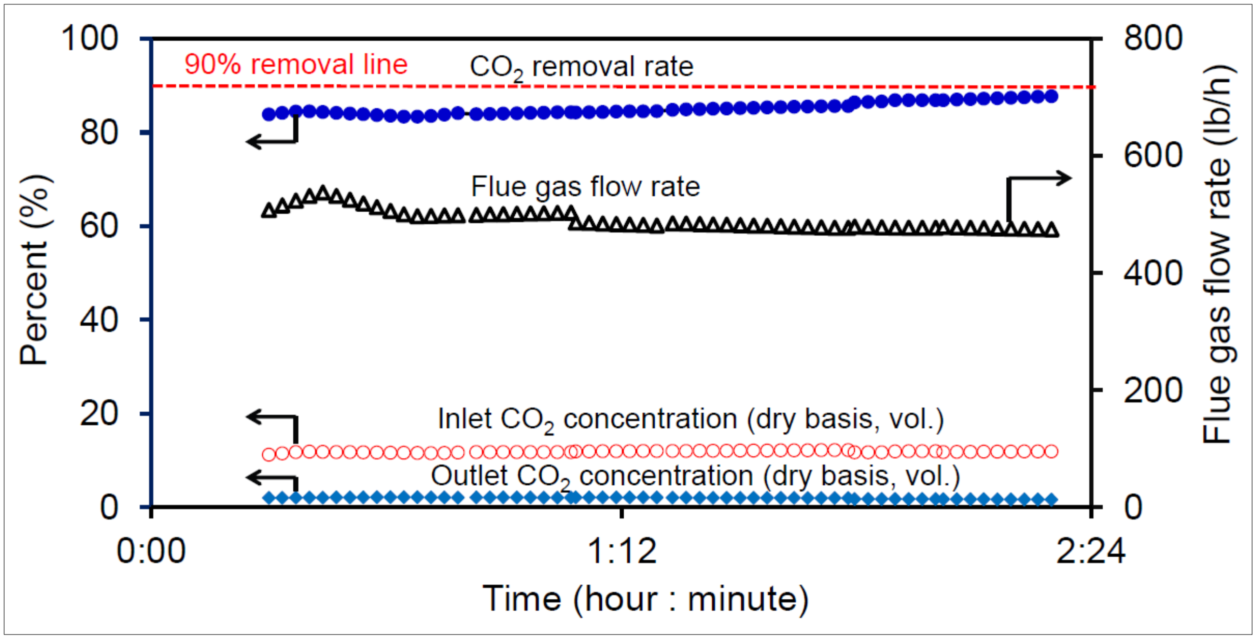

Figure 4. Inlet and Outlet CO_2 Concentrations and Capture Rate for the GTI Membrane Contactor

Based on initial membrane performance, several modifications were made, such as changing the membrane configuration and lowering the solvent concentration. After performance was validated with these new modifications, GTI installed full-scale membrane modules, a total of 28 modules in seven clusters, and began long-term testing in May 2018. This was the first time the system was operated at full capacity. The system operated without interruption, although some of the modules were removed due to lower-than-expected membrane performance. Operation continued with the remaining modules, and GTI plans for further testing during the next run.

3.2 Slipstream Solvent Test Unit

The SSTU provides for solvent testing under a complete absorption/regeneration cycle for post-combustion carbon capture at bench-scale using 500 lb/hr of flue gas (0.05 MWe equivalent). The SSTU, as depicted in Figure 5, is conceptually and functionally similar to the PSTU, at about 1/10 of the scale. The SSTU requires about 10% of solvent volume needed for the PSTU (400 gallons rather than 4,000 gallons), making it well-suited for testing prospective solvents that are at early stages of development. Commissioning of the unit with MEA began in late 2015, and following system modifications, additional operation with MEA was conducted through August 2017. MEA baseline testing is critical for future comparisons of solvent based technologies that may be tested with the SSTU.

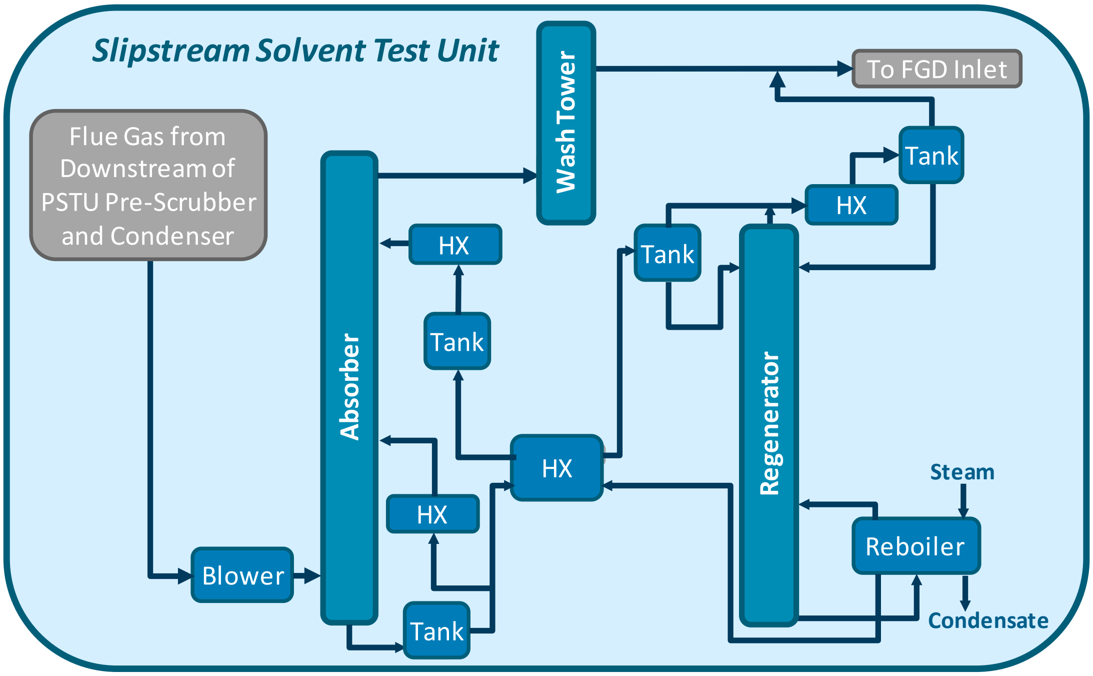

Figure 5. Schematic of SSTU

The NCCC made several major modifications to the SSTU:

- To increase overall CO_2 capture and recovery rates and to minimize the required energy of solvent regeneration, a rich solvent flash tank was installed between the rich-lean heat exchanger and the regenerator. A control valve upstream of the flash tank reduces the solvent pressure, which causes some of the dissolved CO_2 to desorb. The desorbed CO_2 stream from the flash tank is combined with that from the regenerator; the solvent from the flash tank is pumped into the regenerator.
- To reduce solvent carryover into the treated gas line and to recover it for reuse, NCCC designed and installed a wash tower downstream of the absorber. This column uses circulating water to capture droplets of solvent solution entrained in the treated gas stream leaving the absorber. The captured solvent solution is also returned to the lean tank periodically to replace water lost by evaporation in the absorber and regenerator.
- A pre-scrubber that was part of the original unit was removed from service as unnecessary equipment since the inlet flue gas is pretreated in the PSTU pre-scrubber.
- After initial commissioning, the blower was relocated from downstream to upstream of the absorber. This helped create positive pressure in the absorber and dramatically improved system performance.

The most recent MEA baseline test campaign in the SSTU was performed in July and August 2017 for over 300 hours. Liquid-to-gas (L/G) ratios were varied between 2 and 5 while 90% carbon capture was maintained throughout these tests. The heat of regeneration was calculated for each steady-state operating condition. Regression analysis showed that optimum L/G ratio for minimal heat of regeneration was 3.14, at which condition the heat of regeneration was

2,198 BTU/lb CO_2. This value was calculated by running a regression analysis on the test results and finding the minimum value on the resulting curve. This value is somewhat higher than what was experimentally observed at a nearly identical liquid-to-gas ratio during testing, but it considers the results of every set of test conditions. Figure 6 displays the data points, regression curve, and the regression curve equation.

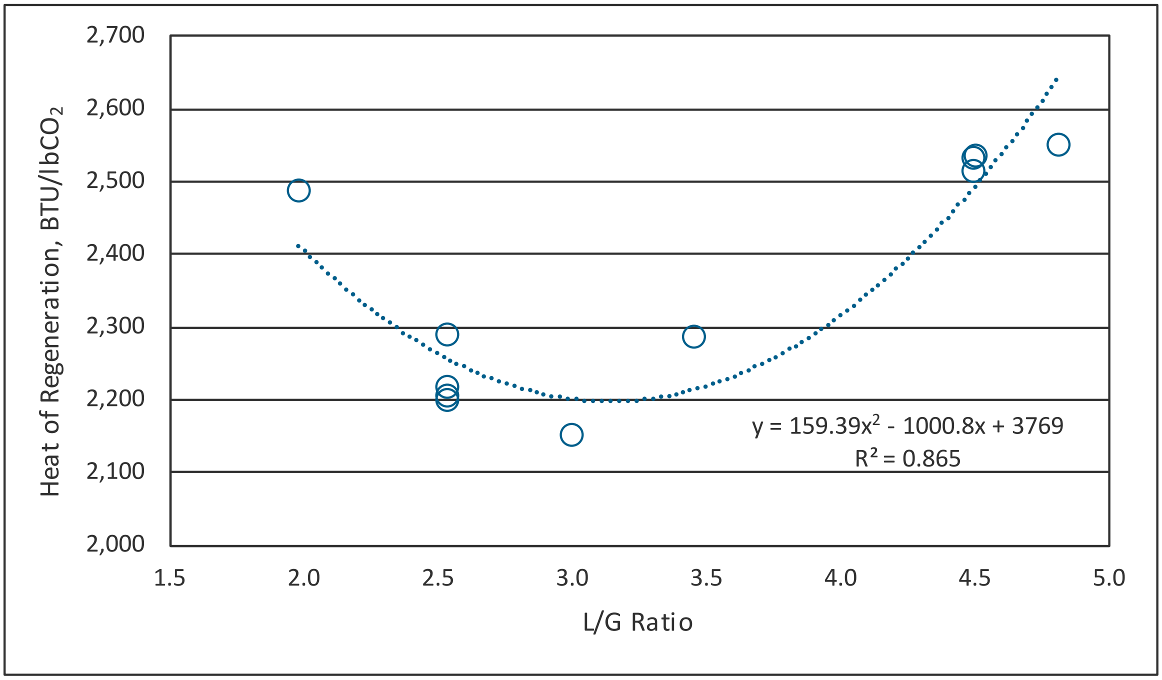

Figure 6. Heat of Regeneration vs L/G Ratio

This data provided a solid baseline for SSTU operation and will allow the evaluation of other solvents against this standard. Mass balance closures for the non-reactive gases (nitrogen and oxygen) were within 5%. An area for needed improvement was the closure of the CO_2 mass balance, which was 12.6%. The measured CO_2 flow into the system was consistently higher than the measured CO_2 flow out of the system. For improved accuracy and operational stability in future testing, adjustments were made to the CO_2 product flowmeter, and enhancements to process controls were implemented. Further MEA testing is expected to be interspersed between future developer solvent tests.

3.3 AECOM/UT-Austin Pilot-Scale Advanced Flash Stripper and Solvent

UT-Austin and AECOM are jointly developing an advanced flash stripper to reduce the energy requirements of stripping CO_2 from amine-based solvents. The AFS skid, shown in Figure 7, was installed in the PSTU structure to operate in place of the PSTU regenerator. While testing the AFS integrated into the PSTU, piperazine solvent is used for the CO_2 absorption process, and the CO_2-rich solvent bypasses the PSTU regenerator and is regenerated in the AFS. Several novel approaches to heat integration are being evaluated, with the goal of reducing capital and operating costs for future commercial systems.

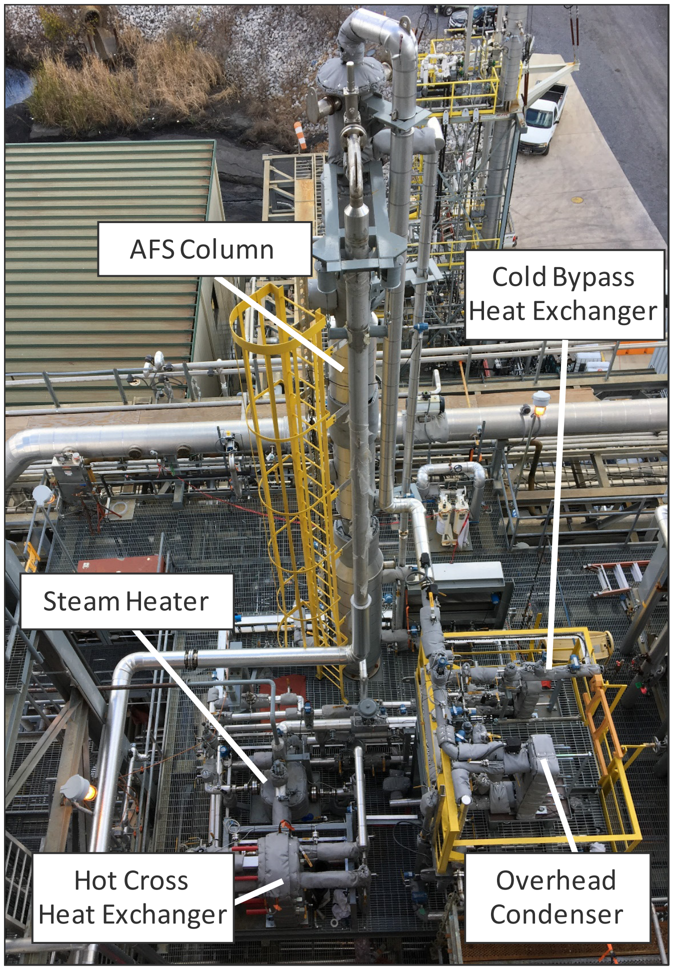

Figure 7. AECOM/UT-Austin Advanced Flash Stripper Skid

Shakedown and commissioning were completed in late 2017, and the solvent was delivered in early 2018 as commercial-grade 68 wt% piperazine in solid form. The solvent was melted, diluted to a 5-molar concentration, and testing began. Based on initial test results, modifications were required to increase the steam supply pressure to achieve the desired AFS sump temperature of 302°F. Parametric testing under 35 different process conditions concluded in mid-April 2018. Initial results indicated the AFS with piperazine achieved regeneration energy in the range of 2.0 to 2.5 GJ/MT CO_2. When adjusted for heat loss, the regeneration energy may be below 2.0 GJ/MT CO_2.

For comparison of the AFS performance with that of a conventional stripper, the PSTU operation was transitioned from the AFS to the PSTU regenerator in late May. Two weeks of parametric tests were completed before transitioning back to the AFS for long-term operation. The regeneration energy with the PSTU regenerator and piperazine solvent was 3.5 to 4.0 GJ/MT CO_2.

During all the testing, emissions and aerosols will be continuously measured at the absorber inlet and outlet and the wash tower outlet using a Fourier Transform Infrared analyzer and a Phase Doppler Interferometer. Liquid samples will be collected at various locations to determine solvent degradation. Solvent corrosivity will also be evaluated with corrosion coupons in various locations and with an electrical resistance probe. Testing will conclude in mid-August 2018.

3.4 Air Liquide 0.3-MW Cold Membrane

Air Liquide is developing a CO_2 capture process using hollow fiber membranes operating at sub-ambient temperatures. Air Liquide's lab testing showed that these membranes, when operated at temperatures below -20ºC (-4ºF), yield two to four times higher CO_2/nitrogen selectivity with minimal CO_2 permeance loss compared to ambient temperature values. Performance data were used to design a 0.3-MW small pilot-scale process, shown in Figure 8, to demonstrate commercial-size membrane performance using actual flue gas. Two materials are being evaluated, a commercially available PI-1 membrane material from Air Liquide and a next-generation polyimide membrane material, PI-2, for application in the cold membrane hybrid process.

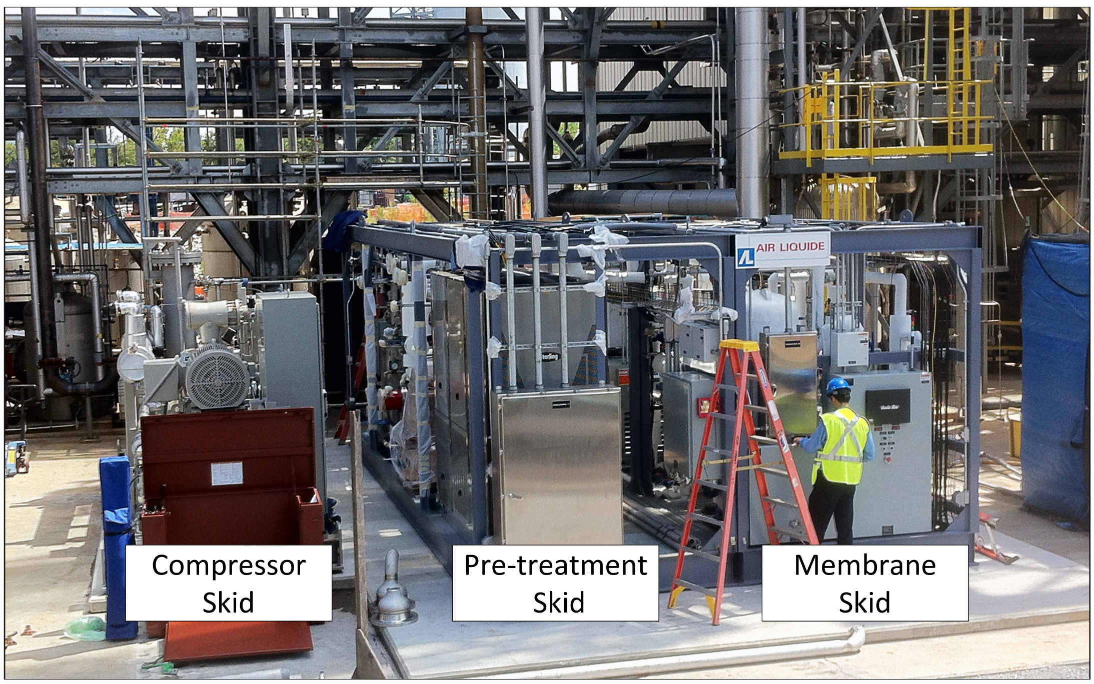

Figure 8. Air Liquide Cold Membrane Process Skids

Evaluation of the pilot system was completed for over 3,000 operating hours under a previous DOE award, successfully validating the cold membrane performance in real flue gas using a 12-inch commercial PI-1 membrane bundle and a 1-inch advanced PI-2 membrane permeator. A subsequent award from DOE has allowed continued development and scale-up of the novel PI-2 membrane with significantly higher CO_2 flux. This material was tested at NCCC between November 2017 to May 2018. Multiple six-inch PI-2 membrane bundles were tested for more than 500 hours at -45°C (-49°F) and 200 psig. Testing concluded in late May 2018, and data analysis was underway as of this writing. Results will be published in subsequent reports.

3.5 NETL Bench-Scale Membranes

As a continuation of previous membrane testing, NETL will operate its Post-Combustion Membrane Skid for evaluation of membrane materials. The skid, shown in Figure 9, allows testing of either hollow fiber modules or flat sheet modules and features automatic operation and flue gas pre-treatments of pressurizing, filtering, and dehumidifying. Mixed gas analysis is provided by a gas chromatograph (GC). Equipment installation was completed, but issues with electronic communication between the skid and the GC prevented testing during BP4. Testing will begin in July 2018.

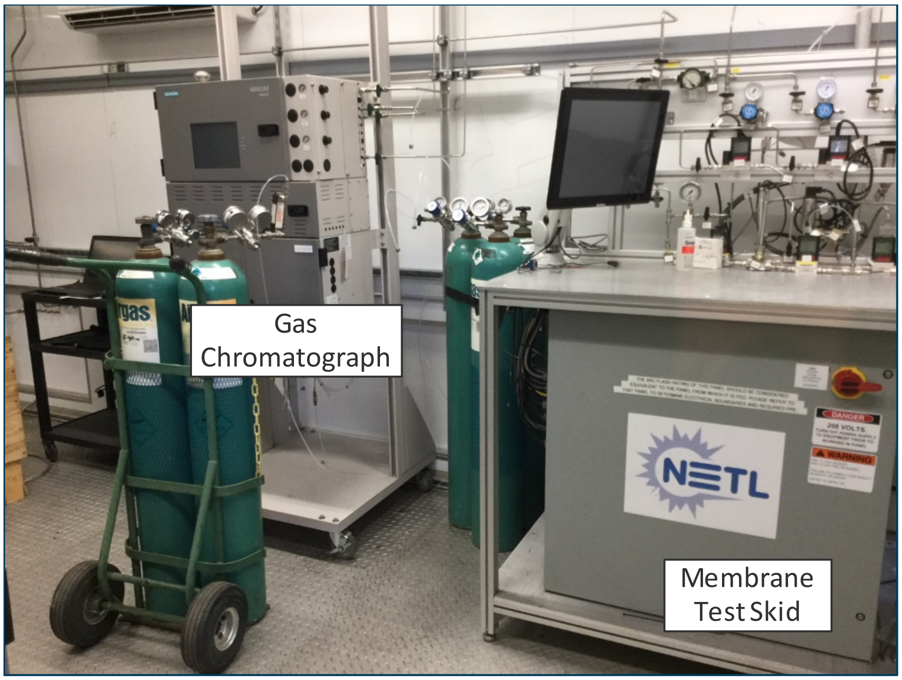

Figure 9. NETL Membrane Test Equipment

3.6 TDA Research 0.5-MW Alkalized Alumina Sorbent Process

TDA is developing a CO_2 capture process using dry, alkalized alumina sorbent, which is regenerable using low-pressure steam and operates at near isothermal conditions and at ambient pressure. TDA's sorbent features durability, low cost, and extremely low heat of adsorption (15 kJ/mole). The sorbent process uses counter-current operation to maximize capture efficiency and sorbent loading, operates at near isothermal conditions (at 140 to 160°C) and ambient pressure, and achieves sorbent regeneration with low-pressure steam.

The major equipment, including two reactor skids and a service skid, were installed in October 2017, as shown in Figure 10, and sorbent material was loaded into sorbent beds. Commissioning began in January 2018, and the sorbent beds were heated to the design operating temperature of about 120°C (250°F). Before flue gas testing with the sorbent, degradation issues were identified during lab testing. TDA determined that reprocessing the sorbent would mitigate the issues. The sorbent was removed from the reactors and returned to the manufacturer for reprocessing, which is to be completed in July 2018. Following confirmation of improved sorbent performance in lab testing, TDA will complete commissioning. TDA plans to begin testing during late 2018.

Figure 10. TDA Research Sorbent System

3.7 Research Triangle Institute Non-Aqueous Solvent

RTI is developing a carbon capture technology using non-aqueous solvent, which was previously refined and tested with simulated flue gas at RTI facilities. The current project, funded by DOE, is the result of collaboration of RTI and Norway's SINTEF organization, and will be used to support further scale-up and demonstration at SINTEF facilities. At the NCCC, RTI will test the solvent in the SSTU to gather performance, emission, and degradation data under long-term operation.

Testing preparation focused on two primary areas: addressing the lower flash point of one of the two chemicals used in the solvent, and preventing solvent and waste water from entering the environment through leaks or spills. Modifications, involving engineered air circulation and fire detection and suppression measures, were incorporated to bring the SSTU into compliance with applicable electrical codes while operating with the low-flashpoint chemical. To prevent escape of solvent, pipe unions in the solvent loop were seal-welded, relief valves were rerouted from the atmosphere to drums, and a sealed catch pan was installed under the SSTU.

Additional SSTU modifications were completed to accommodate RTI's test objectives, such as installing a flue gas sampling port between the absorber outlet and the wash tower inlet and ports for corrosion coupons and replacing incompatible materials in the SSTU. Water commissioning began in May 2018, and operation is expected to begin in June.

3.8 Ohio State University Bench-Scale Membranes

OSU will test a novel prototype membrane with a thin selective amine-containing layer over a nanoporous polymer support in a spiral-wound configuration. AEP is sponsoring the project, which will build on OSU's previous membrane testing but will utilize a higher flow rate. Operation will begin in July 2018 and will last about four weeks. The NCCC installed the lab-scale test unit to house this and other projects.

3.9 Site Modifications

Natural Gas Flue Gas Testing Infrastructure

In collaboration with DOE, the NCCC is preparing to install infrastructure for enhanced testing of carbon capture from natural gas flue gas. A primary benefit of the addition is to provide operational independence from the Gaston power plant. In addition to flue gas, the natural gas flue gas source will provide process steam needed for carbon capture testing. Other benefits to the new infrastructure include increasing the range of testing options at the site and allowing commissioning of new projects on natural gas flue gas before transitioning to coal-fired gas. Conceptual design began in early 2018.

To provide the most operational flexibility and reliability, a natural gas package boiler was selected for use at the site. These units, typically used for commercial or small industrial heating applications, offer ease of operation and a wide range of turndown ratios. The boiler will produce more steam than will be required by the carbon capture processes, so a condenser and cooling system will be required to handle the excess steam. Figure 11 provides a preliminary process flow diagram of the planned test equipment. In BP5, NCCC will select and procure major equipment and perform detailed design of interconnections. Construction and installation are expected in the fourth quarter of 2018.

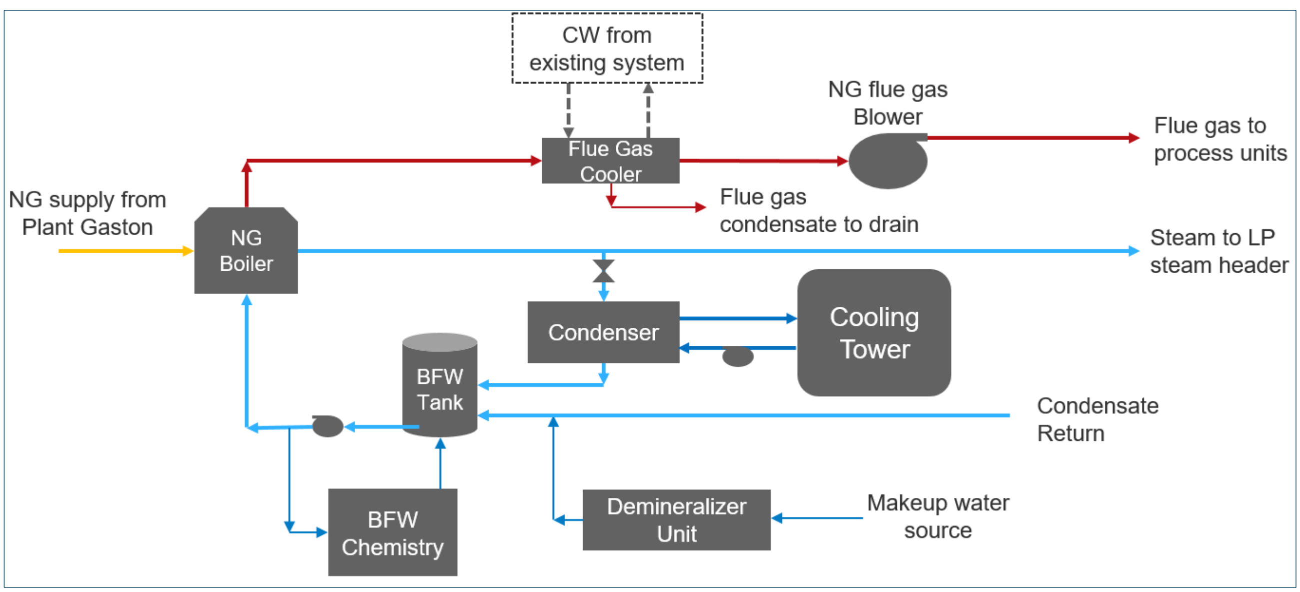

Figure 11. Preliminary Process Flow Diagram for Natural Gas Infrastructure

SO_3 Generator

This project involves the addition of an SO_3 generator furnace to inject SO_3 directly into the flue gas stream so that amine aerosol research can continue since the addition of the baghouse on Unit 5. The baghouse significantly reduced SO_3 aerosols in the flue gas and thus amine emissions. UT-Austin, who provided the generator, and AECOM are particularly interested in evaluating the emissions with piperazine solvent during the AFS testing. The generator furnace was delivered and installed, as shown in Figure 12. The first operation of the equipment will be completed in support of the AFS test in July 2018.

Figure 12. SO_3 Generator Furnace and Controller in Ventilated Enclosure

Lab-Scale Test Unit

The lab-scale test unit, which will initially house the NETL and OSU/AEP membrane projects, was set in place, and flue gas and utility supply lines to the building were installed. Figure 13 provides a photograph of the building. The unit will be operational in BP5.

Figure 13. Lab-Scale Test Unit

Retirement of Gasification and Pre-Combustion CO_2 Capture Equipment

Since the discontinuation of the gasification and pre-combustion CO_2 capture programs in 2017, the NCCC has been preparing to decommission the test site and equipment. A decontamination, demolition, and disposal plan was developed, and field work began.

4.0 CONCLUSIONS AND LESSONS LEARNED

The post-combustion runs conducted in BP4 included:

- PO-6, beginning in Budget Period Three, from June 12, 2017, through August 16, 2017
- PO-7, occurring from November 13, 2017, through April 15, 2018
- PO-8, beginning on April 15, 2018, and continuing into Budget Period Five (through mid-August 2018)

Conclusions and lessons learned from the test runs are listed below.

Gas Technology Institute 0.5-MW Membrane Contactor

GTI continued advancing the hollow fiber gas-liquid membrane contactor technology forward with a 0.5-MW process installed and first tested at the NCCC in 2017. Initial membrane performance met the 90% CO_2 capture rate target at greater than 95% purity. To improve system performance, several modifications were made, such as changing the membrane configuration and lowering the solvent concentration. While GTI operated the system at full capacity, membrane performance of some modules declined, and were removed. Operation continued with the remaining modules, and GTI plans for further testing during the next run.

Slipstream Solvent Test Unit

Following the previous commissioning with MEA solvent, the SSTU was operated for a 300-hour test run to gain additional baseline data with MEA. MEA baseline testing is critical for future comparisons of solvent-based technologies that may be tested with the SSTU. The SSTU operated most efficiently at a liquid-to-gas weight ratio of 3.14, at which point the heat of regeneration was 2,198 BTU/lb of CO_2 captured. The oxygen and nitrogen mass balances were within 4% of closure, which was encouraging considering the small flow rates involved. The CO_2 mass balance averaged an error of 12.6%, with the measured in-flow consistently higher than measured out-flow. Adjustments were made to the CO_2 product flowmeter and process controls.

AECOM/UT-Austin Pilot-Scale Advance Flash Stripper and Solvent

UT-Austin and AECOM are jointly developing an advanced flash stripper to reduce the energy requirements of stripping CO_2 from amine-based solvents. The AFS skid was installed in the PSTU structure to operate in place of the PSTU regenerator. Based on initial test results, modifications were required to increase the steam supply pressure to achieve the desired AFS sump temperature of 302°F. Parametric testing under 35 different process conditions concluded in April 2018. Initial results indicated the AFS with piperazine achieved regeneration energy in the range of 2 to 2.5 GJ/MT CO_2. When adjusted for heat loss, the regeneration energy may be below 2.0 GJ/MT CO_2. For comparison, the regeneration energy with the PSTU regenerator and piperazine solvent was 3.5 to 4.0 GJ/MT CO_2.

Air Liquide 0.3-MW Cold Membrane

Air Liquide is developing a CO_2 capture process using hollow fiber membranes operating at sub-ambient temperatures. The current project is focused on scale-up of the novel PI-2 membrane material, which features a significantly higher CO_2 flux than commercially available material. Multiple six-inch PI-2 membrane bundles were tested at -45°C (-49°F) and 200 psig. Testing concluded in May 2018, and data analysis was underway.

NETL Bench-Scale Membranes

As a continuation of previous membrane testing, NETL will operate its Post-Combustion Membrane Skid for evaluation of membrane materials. The skid was installed, although the start of testing was delayed due to issues with electronic communication between the skid and the GC. Testing will begin in July 2018.

TDA Research0.5-MW Alkalized Alumina Sorbent

TDA is developing a CO_2 capture process using dry, alkalized alumina sorbent, which is regenerable using low-pressure steam and operates at near isothermal conditions and at ambient pressure. Following equipment installation, sorbent loading, and commissioning, the sorbent was removed for reprocessing. Testing is planned for the last part of the PO-8 run and for the following run.

RTI Non-Aqueous Solvent

RTI is developing a CO_2 capture technology using non-aqueous solvent, which will be tested in the SSTU to gather performance, emission, and degradation data under long-term operation. Testing preparation focused on two primary areas: addressing the lower flash point of one of the two chemicals used in the solvent and preventing solvent and waste water from entering the environment through leaks or spills. Modifications, involving engineered air circulation and fire detection and suppression measures, were incorporated to bring the SSTU into compliance with applicable electrical codes while operating with the low flashpoint chemical. To prevent escape of solvent, pipe unions in the solvent loop were seal-welded, relief valves were rerouted from the atmosphere to drums, and a sealed catch pan was installed under the SSTU. Operation will begin in BP5.

OSU/AEP Bench-Scale Membrane

OSU will test a novel prototype membrane with a thin selective amine-containing layer over a nanoporous polymer support in a spiral-wound configuration. AEP Engineering is sponsoring the project, which will build on OSU's previous membrane testing but will utilize a higher flow rate. Operation will begin in July 2018 and will last about four weeks.

Site Modifications

In collaboration with DOE, the NCCC is preparing to install infrastructure for enhanced testing of carbon capture from natural gas flue gas. A primary benefit of the addition is to provide operational independence from the Gaston power plant. Conceptual design began in early 2018, and construction and installation are expected in the fourth quarter of 2018.

Other projects included:

- A generator furnace was installed to inject SO_3 directly into the flue gas stream so that amine aerosol research can continue since the addition of the baghouse on Unit 5. UT-Austin, who provided the generator, and AECOM are particularly interested in evaluating the emissions with piperazine solvent during the AFS testing. The generator furnace was delivered and installed, and the first operation of the equipment will be completed in support of the AFS test.
- A lab-scale test unit was installed to house the NETL and OSU/AEP membrane projects and other future projects.
- Engineering and field work began to prepare for decontamination, decommissioning, and dismantling of the gasification and pre-combustion carbon capture equipment.