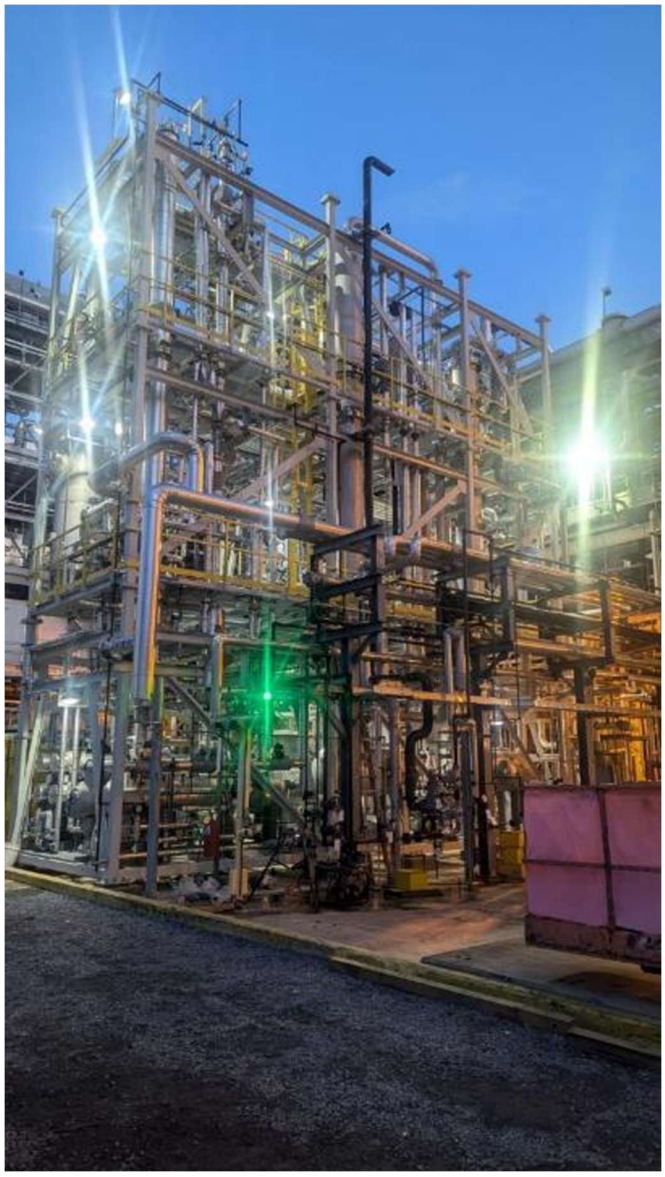
Engineering-scale Demonstration of the Mixed-Salt Process (MSP) for CO_2 Capture

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Introduction

This report summarizes the planning, fabrication, installation, commissioning, operation and decommissioning of SRI International's Mixed Salt Process (MSP) demonstrated at engineering pilot scale at the National Carbon Capture Center (NCCC) in Wilsonville, AL. The work at NCCC was part of Budget Periods 4 and 5 of the U.S. Department of Energy (DOE) project award # FE0031588. The MSP test campaigns at NCCC occurred in Fall 2025 and Spring 2026. Completion of the demonstration at NCCC was crucial for benchmarking the competitiveness of the MSP technology and collecting data for further scale-up.

Project Team

The project team for the MSP demonstration at NCCC is described in Figure 1. Responsibilities of each team member were as follows:

SRI: Technology developer; overall project management, procurement, skid testing and operation, data collection and decommissioning of the skid.
NCCC: Host site; provision of flue gas, utilities, and skid installation
Trimeric Corporation: Engineering partner; preparation of the Process Design Package (PDP) for the pilot, support of the modular fabrication effort and Techno-Economic Analysis (TEA).
OLI Systems: Modeling partner; optimization of the process flowsheet for the 0.5 MW_e pilot and modeling of the 550 MW_e power plant integration scenario (NETL Case B12B) for TEA
EPIC Systems: Modular MSP system fabricator; procurement, construction, and delivery of the modular system.
Baker Hughes (BH): Technology licensee, cost-sharing industry partner for DOE-funded work, funder for additional operation and data acquisition capabilities for Spring 2026 run campaign. Baker Hughes is actively participating in finding opportunities for technology deployment and future scale-up.

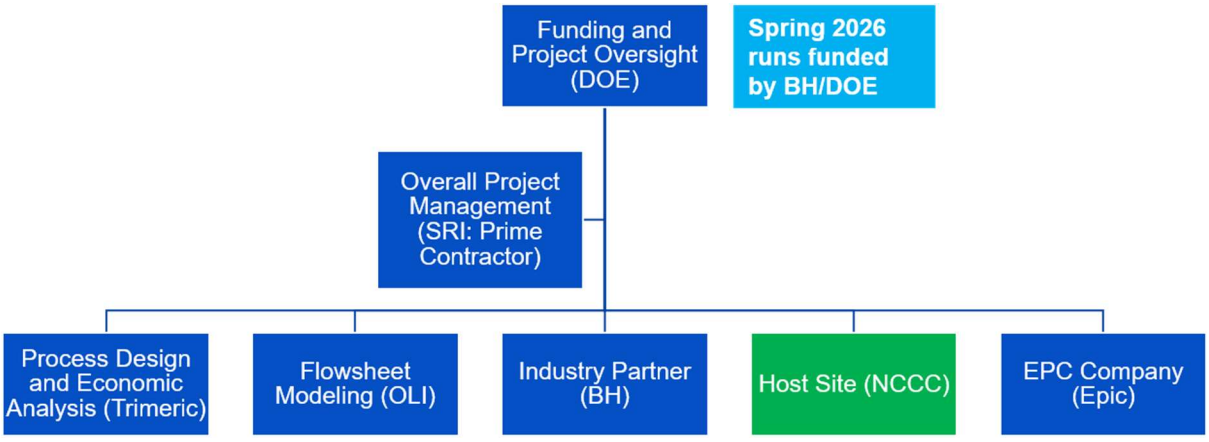


Figure 1. Project Team for MSP Engineering Pilot Demonstration at NCCC

MSP Technology Background

SRI invented the Mixed Salt Process (MSP) technology in 2012, as a step-change improvement upon the Chilled Ammonia Process (CAP) which was previously developed by SRI. The MSP solvent is composed only of inexpensive, commercially available inorganic material (potassium and ammonium salts) which do not degrade upon use, are widely known and have the potential for easy permitting in many localities, and are compatible with well-understood process engineering which enables accelerated development. Benefits of the MSP (based on testing and modeling results compared to standard post-combustion CO_2 capture processes) are listed below:

- Enhanced CO_2 capture efficiency (> 95% capture)
- High CO_2-loading capacity
- High-pressure release of CO_2 (10-12 bar)
- Reduced energy consumption (~ 2.3 MJ/kg-CO_2 for coal-based flue gas)
- Capture from low-concentration CO_2 sources in addition to high-concentration
- Removes common acid pollutants and particulates from flue gas

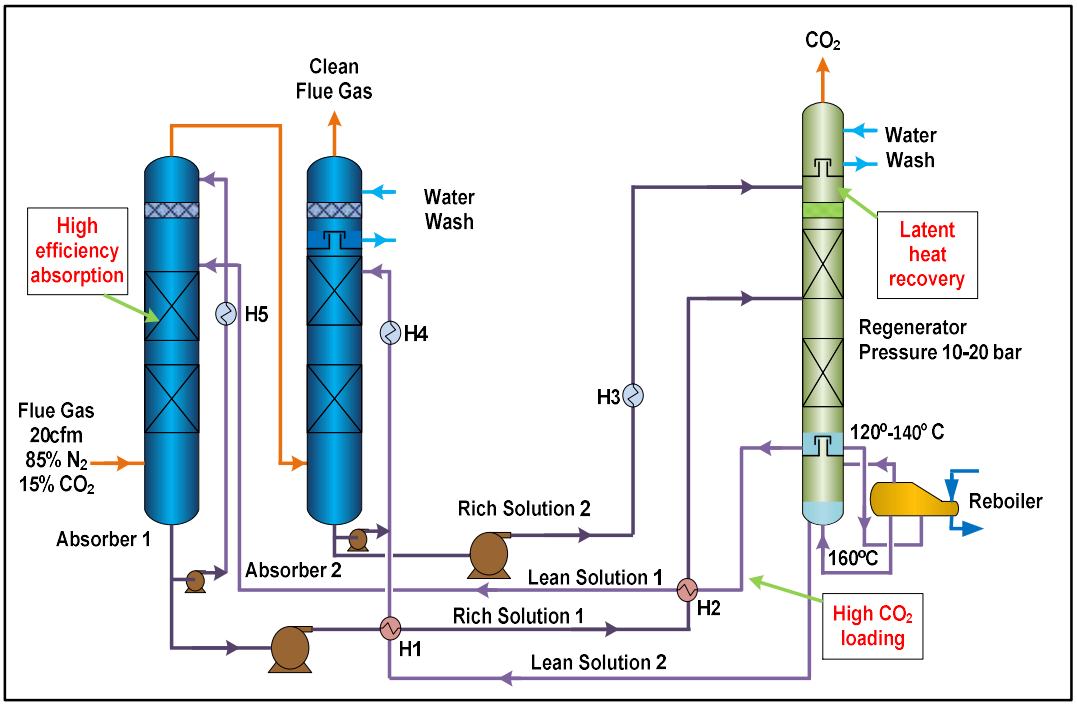


Figure 2. Basic process flow diagram of Mixed Salt Process

Process Skid

For the demonstration pilot at NCCC, the MSP was constructed by EPIC as a modular process skid incorporating the below unit operations:

- Flue gas and vent gas conditioning
- CO_2 absorption and water wash
- Solvent regeneration, CO_2 product wash, and solvent heat exchange
- Ammonia stripping and recovery

Utilities and Process Supporting Equipment

NCCC provided flue gas supply/return, process water, nitrogen, instrument air, and electricity to the MSP boundary. Additionally, SRI installed ancillary equipment off-skid to support the process:

- Gas analyzers (sampling lines routed from process)
- Vent header/knockout tank
- Solvent make-up (NH_3 to replace trace losses)
- Vent gas conditioning makeup (H_2SO_4 to remove trace NH_3)
- Chilled water (rental chiller)

Process Analysis Equipment

Prior to the Spring 2026 test campaign, BH supplied additional gas and liquid analyzers to SRI for installation and operation with the goal of collecting additional process data during operation:

- Gas analyzers within an enclosure
    - 8 sampling lines routed from process skid
    - Vent and relief lines routed to existing SRI vent header/KO tank
- Liquid analyzers (Raman, FTIR) within liquid analyzer cabinet
    - No liquid routed to analyzer cabinet
    - Process piping on-skid was modified to include probes and flow-through cells for liquid analysis
    - Fiber optic cables from probes and flow-through cells were routed from the process skid to the liquid analyzer cabinet
- Transformer to provide power to BH gas and liquid cabinets

Project Objectives and Design Criteria

The MSP pilot plant at NCCC was sized to an engineering scale of 0.5 MW_e with an inlet flue gas capacity was 11.5 (~ 3.5) tonne/day for PC (NG). The MSP pilot is designed to achieve 90% CO_2 capture efficiency from a flue gas slipstream with a flow rate of approximately 5,445 lb/hr and a CO_2 composition of 12.9%.

The above values were based on scaling from the primary design case utilized in the techno-economic analysis (TEA), with a material balance based on flue gas conditions from the DOE/NETL baseline report (Case B12B, coal-fired boiler) and a flue gas flow scaled to the pilot facility basis (0.5 MWe).

Uniquely, the MSP pilot at NCCC was designed to operate on either a coal or natural gas flue gas feed. Dual flue gas and steam supply lines were installed so that the MSP pilot could operate on coal flue gas when coal was in use at the Gaston power plant, and natural gas flue gas from NCCC's package boiler when coal was not in use.

The major objectives of the Fall 2025 test campaign were to:

- Test the MSP at engineering scale (0.5 MW_e equivalent)
- Demonstrate the MSP can capture CO_2 at 90%
- Regenerate CO_2 with 95% purity
- Collect data for long-term testing periods under dynamic and steady state conditions with a real flue gas stream

The major objectives of the Spring 2026 BH test campaign were to:

- Conduct parametric testing to collect high-quality data for process model validation
- Collect additional operating hours for MSP system to support future scale-up opportunities

The target integrated operational runtime for the MSP demonstration was a total of 1,000 hours. To ensure achievement of this goal, the MSP pilot plant components were designed for a lifetime of 2,000 hours.

Project Timeline and Activities

Fabrication and Installation

Prior to the arrival of the MSP skid at NCCC, the following tasks occurred:

- Detailed engineering, procurement, fabrication, delivery, and installation and shakedown of modular system
- Test plan development, chemical procurement, and solvent preparation.
- Process Hazard Analysis (PHA) 11/16/2023
- 90% Design Review 12/30/2023
- Factory Acceptance Testing 08/14/2024

The MSP skid was designed and constructed as a modular system rather than being site-constructed. This minimized the timeframe for occupying space at NCCC by enabling most fabrication and assembly work to take place at the EPIC fabrication facility in St. Louis, MO. 3D models of the skid (Figure 3) were developed prior to commencing construction. After each module was fabricated and factory acceptance testing was complete, the four modules of the skid were trucked to NCCC in Wilsonville, AL, and stacked and connected by NCCC contractors (Figure 4). Once the skid modules were bolted together, NCCC proceeded to connect flue gas supply and return piping, steam, nitrogen, instrument air, process water, and electrical power while SRI connected ancillary equipment to support the skid operations. NCCC provided a cubicle space above their main control room for SRI's use while onsite, and routed signal cables from the MSP skid into the SRI cubicle. After completion of installation activities, NCCC hosted a pre-startup safety review meeting where SRI presented the details of the MSP test plan, operation procedures, and safety systems to the full NCCC team including management, process, electrical, mechanical, and safety experts. After this meeting, NCCC approved the initial power release to the SRI skid. After power release, SRI completed Site Acceptance Testing of the modular skid, which included dry testing of all equipment, wet testing (water and/or nitrogen fill and circulation), electrical panel testing, control software testing, and safety systems testing (E-stop and interlocks).



Figure 3. 3D model of MSP skid modules in stacked configuration



Figure 4. Assembly, shipping, and installation of modular MSP skid

Pre-Commissioning

Prior to the initial commissioning process, minor issues including instrument/programming errors and pump misalignments were fixed. During this time period, the SRI operations team, which consisted of 10-12 research engineers and scientists, began training by familiarizing themselves with the P&ID, general arrangement, and standard operating procedures of the MSP process and equipment.

Once the plant was operable, SRI moved into testing of the system's startup and shutdown sequences including flue gas and steam introduction, while the system was filled with water prior to initiating solvent testing. These tests using water were also used as hands-on training on process control and safety procedures for the operations team. EPIC senior process and control engineers were on-site for two weeks to provide additional training and support. After initial operation using water, the startup strainers that had been temporarily installed upstream of all pumps in the system to catch any fabrication debris were removed from the system and the pumps were realigned

Final pre-commissioning tasks included the following:

- Installing a rental chiller and booster pump/buffer tank to supply cooling water to the system to enable precise temperature control of the MSP system to mitigate environmental factors. The chiller installation task was complex and required extensive coordination with NCCC electrical experts to ensure that power could be safely supplied to the chiller after identifying that the short circuit current resistance (SCCR) of the chiller unit was not compatible with the NCCC SCCR requirements. The chiller vendor was able to supply a transformer unit to rectify this issue. The chiller system piping design was updated from the original design, replacing flexible hoses with rigid pipes due to space and operational constraints. NCCC contractors installed rigid piping based on an updated design from EPIC.
- After the initial safety inspection by NCCC process safety staff, additional ammonia detectors were installed in key areas of the make-up ammonia supply piping, with alarms integrated into the system. After this modification, SRI's anhydrous ammonia make-up subsystem, which was designed to supply very small ammonia flow rates to the MSP to make-up for ammonia losses during operation, was approved by NCCC.

After completion of water testing and verification that there were no system leaks, SRI received NCCC approval to proceed to fill the system with solvent and begin initial process operations testing.

Commissioning

MSP system testing during the commissioning phase occurred only during daytime hours and focused on testing subsystems of the process and then moving to testing the entire integrated process. Process controls such as level, flow, and temperature control loops were fine-tuned and the systems were tested under dynamic and steady state conditions. In particular, the startup and shutdown procedures were repeatedly tested to ensure robustness and safety of the procedures, since these procedures included the most manual monitoring and interventions by SRI operators.

In steady state operation, very little manual intervention from operators was required to operate the system.

The Absorber-Regenerator (MSP core system) performed very well during initial operation. The ammonia stripper system consisting of a stripper column was a new addition to the MSP system, which was not tested at the pre-pilot scale. It took the engineering team a few weeks to find stable operating conditions for this system. However, solid clogs were encountered at the top of the stripper column. After careful and thorough investigation, the clogging issue was attributed to the low temperatures at the top of the stripper column, which was caused by insufficient heat tracing and insulation at the ammonia stripper column gas outlet. The excessive heat losses to the environment led to low temperatures and process inability to achieve design temperatures at the stripper column top. Similar issue was identified at the top of regenerator column as well. After identification of these issues, SRI worked with NCCC and EPIC to find a feasible solution. After thorough considerations, adding steam heat tracing at the affected areas was agreed upon as the most feasible solution. The new steam tracing lines were powered by steam from an existing low pressure steam header which had adequate capacity, followed by extra insulation on the affected areas to minimize heat losses. As seen in Figure 5, after the installation of steam heat tracing and insulation, the top temperatures of the regenerator and ammonia stripper were well above the minimum temperature for solids formation (176 F) where previously these temperatures had been below 176 F.

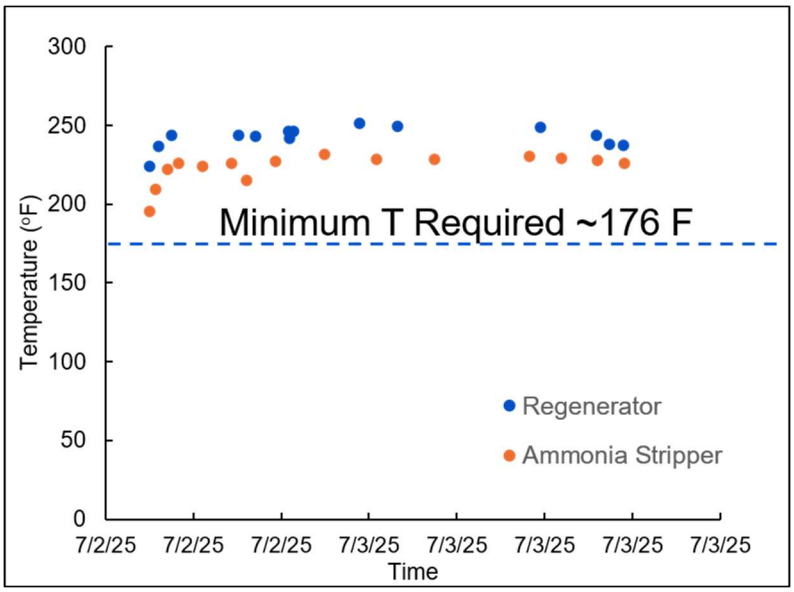


Figure 5. Top temperatures of the ammonia stripper and regenerator after installation of heat tracing in June 2025

Testing

The timeline for the activities at NCCC is displayed in Figure 6.

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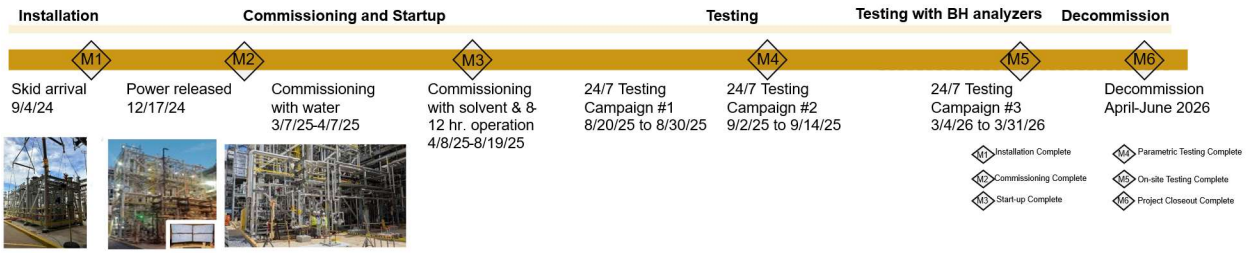


Figure 6. Timeline of major events for MSP demonstration at NCCC

After the conclusion of commissioning and daytime-only integrated plant testing, SRI moved into 24/7 plant operations. Typically, SRI maintained a staff of 6 personnel in Alabama at any given time, arranged into three 8-hour shifts per day, with two people per shift to ensure safe operations. Three 24/7 test campaign periods took place: two in Fall 2025 under DOE funding, and one in Spring 2026 under BH funding. The 2025 test campaign is summarized below:

2025 (August and September) 24/7 Test Campaigns

- Completed ~500 hours of 24/7 operations in two separate ~10-day runs, operating on 4 combinations of flue gas and steam:
    - Natural Gas FG (4% CO_2, LP Steam: 111.6 hours
    - Natural Gas FG (8% CO_2, LP Steam): 257.6 hours
    - Coal FG (~11% CO_2, LP Steam) : 102.7 hours
    - Coal FG (5-17% CO_2, MP Steam): 100.4 hours
- **Key parameters varied**
    - Flue gas type
    - Steam type
    - Inlet flue gas flow rate
    - Liquid/Gas ratio (L/G)
    - Liquid recycle rate between absorption and regeneration sections
    - Regenerator pressure and temperature
- **Key achievements**
    - Ammonia emissions <10 ppm in clean flue gas
    - >99% CO_2 purity
    - Stable operation up to 4,750 lb/hr flue gas, reaching our maximum blower capacity
    - Achieved CO_2 capture efficiencies comparable to large bench testing at similar solvent ammonia concentrations
    - Demonstrated agility of MSP through rapid changeovers in flue gas type (natural gas to coal) and steam (low pressure to high pressure) without a full process shutdown
- **Key challenges**
    - While ammonia losses during 24/7 process operations were small and within expected range, we lost much more ammonia than expected from our solvent during the commissioning phase due to frequent stops, starts, and upsets while troubleshooting our equipment. Our ammonia makeup system was sized only to maintain ammonia concentrations during steady state operation and was not able to

make up all the ammonia lost during commissioning. Therefore, our solvent ammonia concentration, and therefore our capture rates, were lower than planned.
- Frequent manual sampling and analysis (via titration) of our solvent and process water streams were required in order to obtain sufficient data on process performance. The plant was designed with online gas analyzers, but no online liquid analyzers.
- This was the first project at NCCC in some time that had operated on coal flue gas, and the availability of coal flue gas was very brief during our operations period. This limited the ability of NCCC and SRI staff to properly adjust process settings for smooth operation on coal gas, with the result that the inlet flue gas CO_2 content was not constant over the several days we were able to run on coal flue gas.

After the conclusion of the 2025 tests, the MSP skid was flushed and decontaminated, and then underwent piping modifications to enable installation of liquid analyzers (flow cells and probes) designed by BH to enable collection of higher-quality real-time liquid composition data and reduce the need for manual, offline sampling and analysis as well as providing real-time process performance data for process optimization. Installation of the BH analyzers and required utilities (power, nitrogen, etc.) took several months in addition to the piping modifications which were engineered by EPIC and installed by NCCC contractors. Highlights of the 2026 test campaign are summarized below:

2026 (March) Test Campaign

- Completed heat loss assessment study as follows, prior to refilling system with solvent:
  - Designed and performed experiment to measure heat losses to environment during operation (water, steam, flue gas were circulating)
- Adjusted MSP solvent composition
  - Utilized a high-potassium solvent to enable operation at higher absorber temperatures without the need for chilled water
- Completed ~600 hours of 24/7 operation, operating on natural gas flue gas (8% CO2) and low pressure steam (90-100 psia) from NCCC
- **Key parameters varied**
  - Solvent composition
  - Inlet flue gas flow rate
  - Liquid/Gas ratio (L/G)
  - Liquid recycle rate between absorption and regeneration sections
  - Absorber temperatures
  - Liquid levels within columns and vessels
  - Internal absorption column recirculation rate
  - Regenerator pressure and temperature
- **Key achievements**
  - Collected parametric test data (Figure 7) at ~20 distinct operating points
  - Reduced manual liquid sampling frequency to ~10% of previous, enabling us to view the solvent composition in real time and adjust our operations accordingly
  - Demonstrated stable operations at elevated absorber temperatures removing the need for chilled water

- **Key challenges**
  - The electrically heated ammonia stripper within the MSP, which was designed to recover ammonia from the process wash water and regenerate clean water to recycle back to the process, was found to be underpowered. This limited the flow rate of wash water through the stripper, which in turn reduced the capacity of the wash water to recapture ammonia stripped from the solvent into the flue gas, with the end result that the overall flue gas flow rate through the system needed to be reduced in order to avoid excessive ammonia slippage into the clean flue gas.

After conclusion of the 2026 test, the MSP skid was decommissioned and removed from NCCC. The skid removal task concluded on June 19, 2026.

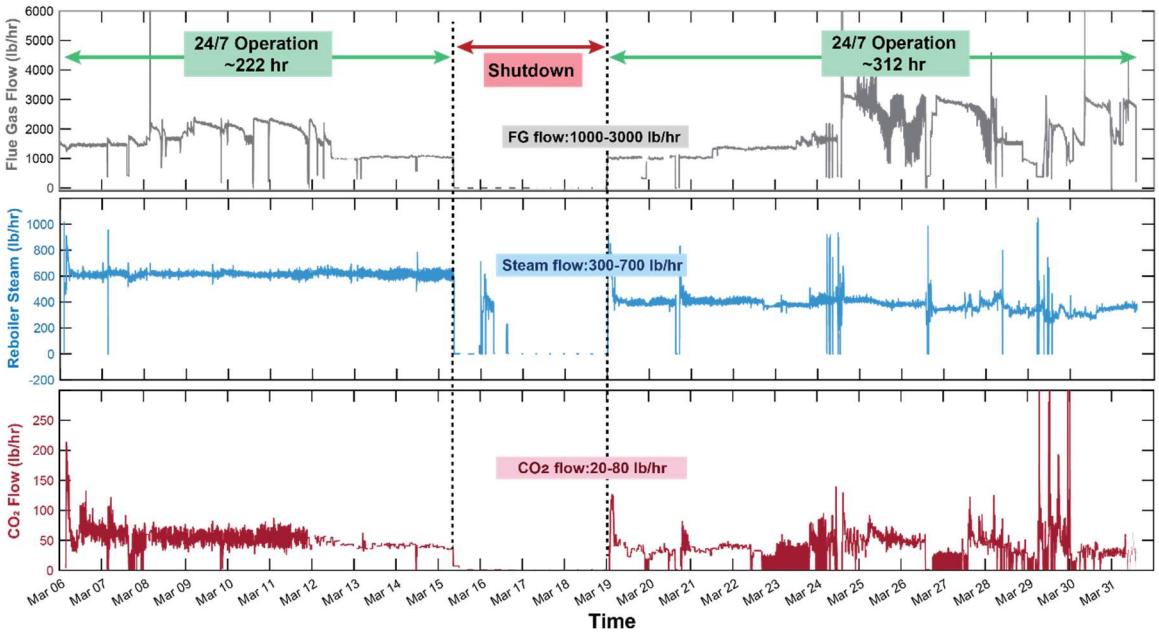


Figure 7. Steady state (March 6-15) and parametric (March 19-31) testing of the Mixed Salt Process

Overall MSP Performance

Key Results

Overall, the MSP pilot at NCCC was operated for over 1100 hours of 24/7 integrated operations during our 2025 and 2026 test campaigns. The operation hours are broken down by flue gas and steam characteristics in Table 1.

Table 1. MSP operation on 4 combinations of flue gas and steam pressure

Flue gas type	Inlet CO_2 content	Steam type	Hours of operation
Natural gas	4%	LP	112
Natural gas	8%	LP	792
Coal	11%	LP	103
Coal	Varying 5-17%	MP	100

The key results demonstrated by the MSP pilot testing are categorized below:

Stability

- >1000 hours of pilot-scale testing achieved
- Stable operation (liquid levels, pressures, temperatures, flow rates) could be maintained for ~12 days at a time (including parametric testing periods)

Ammonia Emissions

- Very low ammonia (**NH_3**) concentration in the clean flue gas, **<10 ppm,** was achieved. Some spikes were observed due to optimization of acid dosing rate, process disruptions, or dynamic tests.
    - NH_3 emissions from the absorbers were as expected based on comparisons to large bench scale data
    - NH_3 emissions from the water wash were higher than designed, attributed to the underperformance of the ammonia stripper.
        - NH_3 stripper was not included in our bench scale system; this project was our first experience with design and operation of this unit
        - Underperformance of the ammonia stripper was mitigated by reducing water flow to stripper to enable low ammonia in stripper bottoms. However, this reduction in stripper capacity limited the flue gas flow rate the system could handle.

CO_2 Capture Rates

- CO_2 capture rates met expectations (informed by bench scale testing and process modeling) for a given solvent NH_3 concentration, flue gas flow rate, and flue gas CO_2 content.
    - The solvent concentrations used in 2025 operations were lower-strength (i.e. lower capture capacity) than originally planned due to loss of NH_3 during system startup, commissioning, and troubleshooting.
    - The solvent strength in 2026 was guided by BH and did not target high capture rates. SRI does not have bench scale data for such low strength solvents used in 2026.

High-pressure regeneration

- Steady state high-pressure CO_2 generation was successfully demonstrated. The system effectively captured CO_2 (mostly from NG flue gas with 8% CO_2, though coal flue gas with 11% CO_2 and NG flue gas with 4% CO_2 were tested for several days each in 2025) and released it at **115–145 psia** (Figure 8).

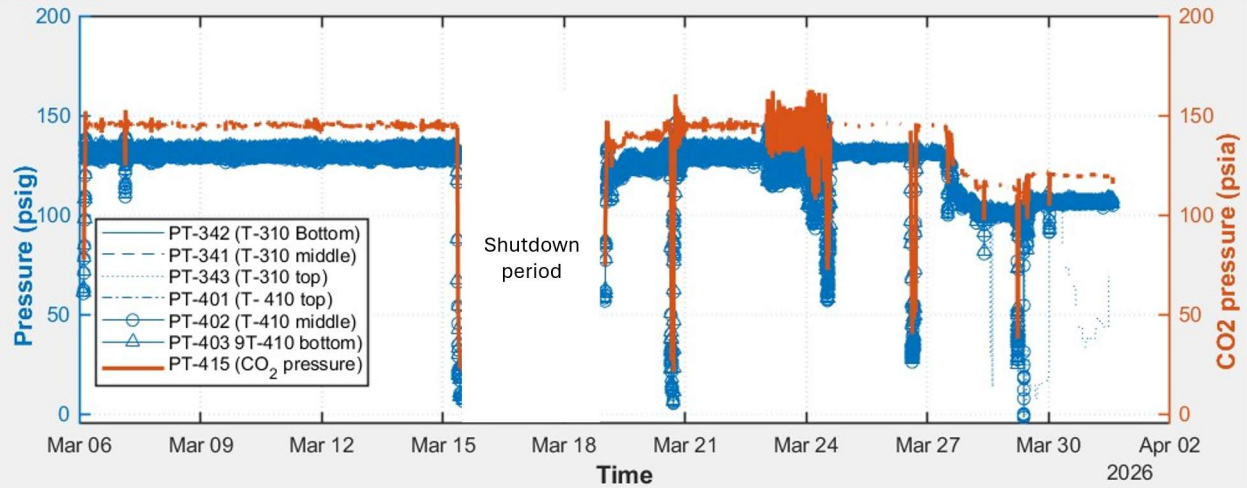


Figure 8. CO2 generation pressure from MSP throughout March 2026 pilot run. Note: MSP pilot was shut down between March 15-19.

A comparison of achieved performance against project objectives is provided in Table 2.

Table 2. Project objectives vs. actual performance of MSP pilot.

Project Objectives	MSP Pilot Performance
Test at engineering scale (0.5 MWe equivalent) for 1000 hours of integrated operations	Completed **~1100 hours** of integrated operations up to 4,750 lb/hr flue gas across multiple test campaigns between 2025-26
Regenerate CO_2 with 95% purity and at pressure	Regenerated **CO_2 purity >99%** and at high pressure **(~145 psia)**
Demonstrate the MSP can capture CO2 at 90%	• Solvent composition was changed to low-strength due to high NH_3 loss during start-up and troubleshooting • CO_2 capture rates met targets (from bench scale) for given solvent strength, flue gas rate, and CO_2 content • CO_2 capture rates ranged between **30%-90%** • NH_3 emissions <10 ppm
Long-term testing periods under dynamic and steady state conditions with a real flue gas stream	Stable process operations were maintained for **>12 days** at a time under dynamic and steady state operations using low/medium pressure steam and coal/natural gas flue gas streams

Determine the pathway to reaching DOE targets for CO_2 capture costs (<$30/tonne by 2035)	• MSP Pilot: CO_2 capture at **$35.26/tonne**
	• Pathway to further cost reduction:
	  ○ Reduce flue gas compression cost by reducing the number of individual equipment items/combining some pieces of equipment
	  ○ Reduce electricity consumption by reducing fluid demand pressure head in equipment

Summary and Acknowledgements

SRI's successful demonstration of the Mixed Salt Process on real flue gas at pilot scale would not have been possible without the support of many organizations. We would like to acknowledge the contributions of the following teams who were essential to execution of this project:

- National Carbon Capture Center (NCCC)
- DOE/NETL
- Baker Hughes
- Epic Systems
- Trimeric
- OLI Systems

We would like to extend special thanks to NCCC for hosting our project, assisting with numerous tasks including installation, planning, and decommissioning, and ensuring our safe operations throughout the entire duration of our campaign.

