PILOT TESTING OF A MEMBRANE SYSTEM FOR POST-COMBUSTION CO_2 CAPTURE

Operational History at NCCC for the 20 TPD Small-Pilot System

FINAL REPORT

submitted by

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prepared for

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This final report describes the operational history and high level performance results for the MTR 20 ton/day (TPD) system at the National Carbon Capture Center (NCCC).

Commissioning of the 20 TPD System. NCCC started site preparation for the system on April 30, 2014, which kicked off the installation work. The system installation was completed in mid-July 2014. Shakedown and commissioning activities while running the system on air were completed by mid-January 2015. In early January, six MTR engineers completed a three day operator training session for the 20 TPD system at NCCC. These engineers rotated to the NCCC site over the duration of the PO-2 and 3 test campaigns (January through June 2015) to support operation of the system. They were responsible for analyzing field data, troubleshooting any skid issues, and communicating with both NCCC and MTR personnel. Figure 1 shows the footprint of the installed membrane system next to other CO_2 separation technology systems sized to remove similar amounts of CO_2 at the PC4 site.

Figure 1. CO_2 capture rate of the 20 TPD system during the PO-2 post combustion flue gas campaign

20 TPD System Operation During the PO-2 Post-Combustion Campaign. The MTR system was commissioned on flue gas on January 18 with both the first step (cross-flow) and second step (sweep) operating with conventional spiral-wound modules. The system ran intermittently

during the PO-2 campaign with shut downs due to cold weather and miscellaneous system issues. When running, the daily performance fluctuations were minimal and ambient temperature had less of an influence on performance for the 20 TPD system than it did for the smaller 1 TPD system also located at NCCC. Possible reasons for this include better heat tracing and insulation of the skid to insulate the system from ambient conditions and improved temperature control of the flue gas fed to the first step modules on the 20 TPD system. The cumulative run time of the 20 TPD system on flue gas during the PO-2 campaign was approximately 400 hours with CO_2 capture rates ranging from 85% to 95%.

Commissioning of the Plate-and-Frame Skid. In April, while flue gas was unavailable between NCCC campaigns PO-2 and 3, MTR commissioned the plate-and-frame skid with air. This skid, which was installed during PO-2, tests an advanced sweep module developed with funding from the DOE. Based on laboratory tests, the plate-and-frame module should have significantly lower sweep-side pressure drop compared to spiral-wound sweep modules tested previously during the PO-2 campaign. A picture of the plate-and-frame skid is shown with connecting piping in Figure 2, and its position relative to the 20 TPD skid is shown in Figure 3.

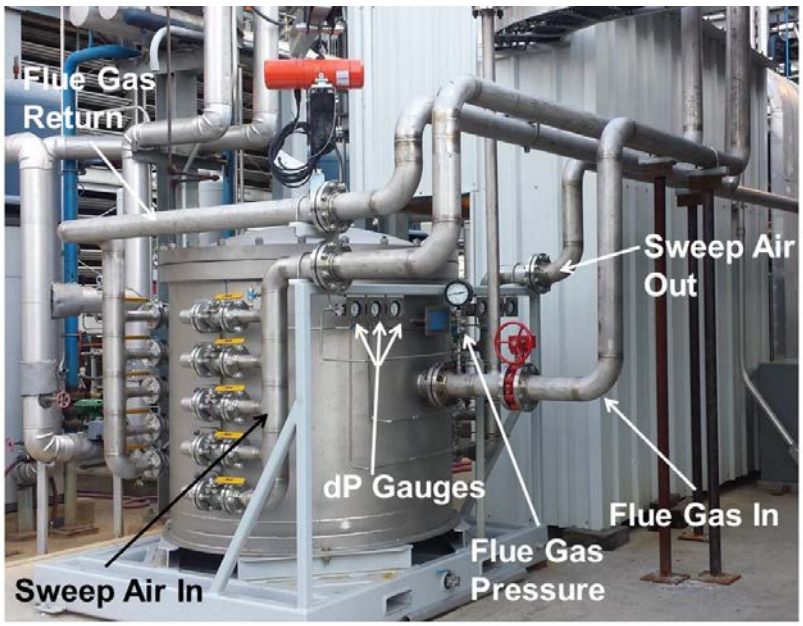

Figure 2. Plate-and-frame sweep skid after installation at NCCC.

Figure 3. Picture showing the plate-and-frame sweep skid next to the larger MTR 20 TPD small pilot unit at NCCC.

During commissioning with air, the feed and sweep side pressure drops through the new modules were measured at various flow rates. The resulting pressure drops through the modules were below the values used in the MTR systems analysis (0.1 bar or 1.5 psi) and consistent with lab data under similar flow conditions.

20 TPD System Operation During the PO-3 Post-Combustion Campaign. Flue gas was introduced to the 20 TPD system on May 8 for the start of the PO-3 post combustion campaign. The main goal of the PO-3 campaign was to operate the plate-and-frame sweep skid as the second step of the 20 TPD system for a minimum of 500 hours to validate the lab performance values and demonstrate the stability of the new module design under real coal-fired flue gas conditions. Another goal was to determine the various operating parameters of the 20 TPD system under summer conditions (ambient temperatures of 90°F and higher) compared to the sub-freezing winter conditions of PO-2.

Downtime for the 20 TPD system was minimized during PO-3 due to lessons learned during PO-2. Figure 4 shows that the 20 TPD system with the plate-and-frame sweep skid consistently captured CO_2 at a rate of 85% or higher throughout the test campaign. The 20 TPD system treated flue gas more than 70% of the time between May 8 and June 30, with the majority of downtime due to flue gas outages outside of MTR's control. NCCC did strive to make flue gas available as much as possible and even provided flue gas to the system through a different blower when the blower and pre-scrubber to Bay 3 (the location of the 20 TPD system) were down for repairs.

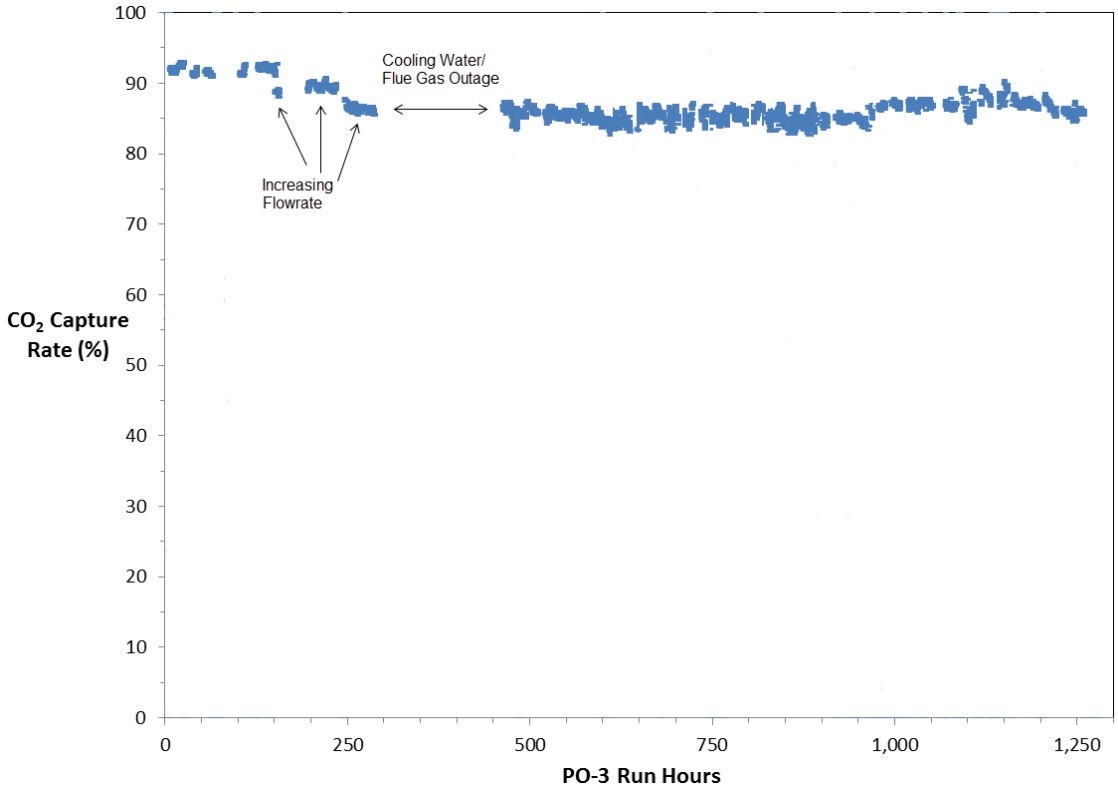

Figure 4. CO_2 capture rate of the 20 TPD system during the PO-3 post combustion flue gas campaign

The plate-and-frame sweep skid was on-line as the second step of the 20 TPD system for the duration of PO-3. This allowed for direct performance comparison to the spiral-wound sweep modules used as the second step during PO-2 testing. Figure 5 compares the sweep-side pressure drop for the two types of modules under the same conditions during flue gas operation at NCCC. The field data for the plate-and-frame module is consistent with lab data and confirms the significantly lower pressure drop with the new module design. The plate-and-frame sweep module has roughly four times lower pressure drop compared to the spiral-wound sweep modules tested during PO-2. For a full scale power plant (550 MW_e), this reduction in pressure drop would amount to an energy savings of ~10 MW_e.

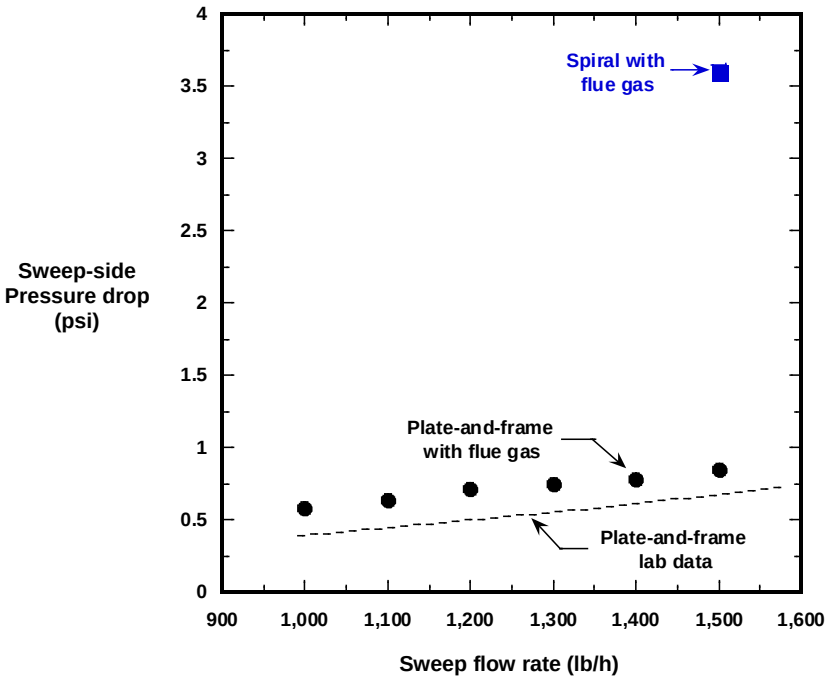

Figure 5. Sweep-side pressure drop comparison of plate-and-frame and spiral-wound sweep modules during testing with flue gas on the 20 TPD system at NCCC.

During the PO-3 operation, the 20 TPD system ran on flue gas for ~1,000 hours with stable CO_2 capture rates and minimal downtime. This campaign exceeded the goal of obtaining 500 hours of operation for the plate-and-frame sweep module, and demonstrated the superior pressure drop performance of this module. The 20 TPD system was shut down on June 30 by an MTR engineer, as previously scheduled, to begin the decommissioning and removal process of the system from the NCCC site. All skids associated with the 20 TPD system were removed from the NCCC site by the end of July 2015.

Overall, the 20 TPD system was successfully installed, commissioned, and operated during two post-combustion campaigns at NCCC. Highlights include:

- Stable system operation meeting design specifications under both sub-freezing winter conditions and high temperature, high humidity summer conditions;
- 400 hours of operation during PO-2 with CO_2 capture rates ranging from 85 to 95% with spirals as the sweep step;
- 1,000 hours of stable operation during PO-3 with CO_2 capture rates over 85% with the plate-and-frame module design as the sweep step;
- About 4 times lower sweep-side pressure drop for plate-and-frame sweep modules compared to spiral sweep modules operated under the same field test conditions.