NATIONAL CARBON CAPTURE CENTER
AT THE
POWER SYSTEMS DEVELOPMENT FACILITY

TEST RUN SUMMARY REPORT

TEST RUN R01
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R01 Summary Report

R01, the first test campaign under the new contract, began in January 2009, with lignite feed initiated on February 4, 2009. The test run was concluded on February 25, 2009, accumulating 510 hours of gasification operation.

The fuel tested was high moisture lignite from North American Coal Corporation's Red Hills Mine located in Ackerman, Mississippi. Coal feed operation was reliable, with no significant coal feed stoppages, and the highest lignite coal feed rate to date (~6,000 lb/hr) was demonstrated. The first long term operation of the developmental feeder at high coal feed rates (~4,500 lb/hr) took place during the run. All gasifier-related parametric tests were completed, as were tracer gas tests to evaluate gasifier flow characteristics.

The syngas cleanup unit operated with a water-gas shift catalyst in catalytic filter elements and in a fixed bed reactor. CO_2 capture tests were completed with the bench scale Parr reactor and using the new 1,500 lb/hr syngas header. Testing of the palladium-based mercury sorbent from Johnson Matthey was performed. The PSDF also provided syngas, gas analysis support, and other services for testing of the Media and Process Technology hydrogen membrane.

1.0 Coal Preparation

The fluid bed dryer operated for 315 hours and processed 1,825 tons of lignite to support R01 operations. The system performed well with no operational problems. The lignite feed to the dryer varied from about 5,470 to 13,840 lb/hr to continue evaluation of the system at different flow conditions. Dryer operating temperature was maintained near 140°F. Table 1 list the performance indicators for fluid bed dryer operation.

Table 1. Performance of Fluid Bed Coal Dryer.

	Average Value
Inlet Coal Moisture Content, wt %	40
Outlet Coal Moisture Content, wt %	19
Moisture Content Reduction, %	52
Outlet Coal MMD, micron	470
Outlet Coal Oversize (>1,180 micron) Content, wt %	33
Outlet Coal Fine (<45 micron) Content, wt %	11

The dryer product was processed further in the existing coal mill pulverizers to reduce the amount of oversize material. The pulverizers reduced the MMD to about 380 microns and the content of oversize particles to about 18 weight percent. The additional pulverizing resulted in a small increase in fine material, which averaged about 16 weight percent, but did not significantly impact coal feeder operation.

2.0 Coal Feeding

Overall, both the original and developmental coal feeders operated well. The as-fed moisture content varied from about 15 to 18 percent. The as-fed moisture content was slightly lower than in TC25 due to operating changes required by the lower ambient temperatures. The MMD varied from 200 to 500 microns.

The developmental feeder, the Pressure Decoupled Advanced Coal (PDAC) feeder operated for 392 hours including independent operations for 36 hours. The feed rate varied from 1,600 to 4,060 lb/hr. The feed system operated well, providing a more stable feed rate than previously observed during the TC25 test campaign. However, the feed rate continued to fluctuate some, and further modifications were planned for the post-R01 outage. There were some periodic problems with plugging in the lock vessel due to a higher than desired percentage of fine material.

The original coal feeder operated for 480 hours and the feed rate varied from 800 to 4,450 lb/hr. The feed system operated well and provided a stable feed rate. The system was operated utilizing transport air for 78 hours. No temperature disturbances in the gasifer were observed.

3.0 Gasification Process

Gasifier temperature parametric testing (R01-2) started on February 8 and was completed on February 11, 2009, which included operation of the recycle gas compressor. The gasifier exit temperature was varied from 1640 to 1705°F.

The riser velocity/gasifier pressure parametric test (R01-3) took place from February 11 to February 14, 2009. The gasifier was operated at the highest pressure to date—270 psig at the gasifier outlet. At that pressure, the riser velocity was around 16 ft/s. Operations were stable during the test. The gasifier outlet pressure was decreased to 250 psig resulting in a riser velocity of about 18 ft/s. Operations were stable during the transition and steady state period. The gasifier outlet pressure was decreased again to 220 psig resulting in a riser velocity of about 24 ft/s.

The coal feed rate was increased and other parameters adjusted to start the standpipe level parametric test (R01-4) on February 15, 2009. Preliminary data was gathered for a high standpipe level test. The standpipe level was increased from 190 to 250 inH_2O and then decreased back to 190 inH_2O. The increase in the standpipe level increased the solids circulation rate and decreased the gasifier temperature differential as expected. Operations were stable and the effect on the circulation rate and the temperature differential was evaluated.

The standpipe and seal leg minimum aeration tests were successfully completed on February 19, 2009, and had no negative impact on gasifier solids circulation. The system was operated at steady state conditions until February 24, 2009, when a maximum coal feed rate test with a feed rate of 6,000 lb/hr was completed. Finally, the hydrodynamic

tests were performed on February 25, 2009, completing all of the R01 test objectives. Thirty-seven steady state periods were achieved to support gasifier characterization.

4.0 PCD Operation

Particulate Control Device (PCD) operations were very stable with a low baseline differential pressure as expected for these operating conditions. Outlet loadings were typical during startup with some slight corrosion products noted on the particulate sampling filters. Outlet loadings decreased from the startup values (~0.2 ppmw) to below the detectable limit (<0.1 ppmw) as expected. There was no evidence of any gasification ash present in the PCD outlet samples.

5.0 Ash Removal

Ash removal systems operated well but experienced some issues due to condensation and nitrogen supply valve mechanical problems. Modifications are planned during the outage to address the condensation and valve issues.

6.0 Advanced Syngas Cleanup

Water-Gas Shift Testing. The water-gas shift catalyst was tested in catalytic filter elements and in a fixed bed reactor. For the catalytic filter element testing, the catalyst (received in pellet form) was pulverized to two different particle size ranges. The fixed bed reactor testing employed the as-received pellet form. Prior to the testing, the catalyst was pre-sulfided on site. Table 2 lists the operating parameters for the water-gas shift testing.

Table 2. Water-Gas Shift Catalyst Operating Parameters.

	Filter Element 1	Filter Element 2	Fixed Bed
Catalyst Size, micron	100 to 200	500 to 800	----
Sour Syngas Exposure Time, hr	75	78	119
Pressure, psig	165	165	165
Temperature, ^{o}F	600 to 700	600 to 700	600 to 700
Syngas Flow Rate, lb/hr	50	50	40
Superheated Steam Flow Rate, lb/hr	0 to 5.5	0 to 5.5	0
Face Velocity, ft/min	2.1 to 2.7	2.1 to 2.7	----
H_2O-to-CO Molar Ratio	1.5 to 4.0	1.5 to 4.0	0.9 to 1.8
Shift Conversion, percent	40 to 80	40 to 68	48 to 75

Continuous syngas quality measurements were taken during the catalytic filter element testing. For the fixed bed reactor, gas analysis performed included continuous syngas quality measurements at the inlet and outlet of the reactor; low level carbonyl sulfide analyses when the necessary instrumentation was available; intermittent analyses for water, ammonia, and hydrocarbons; and relative measurements for HCN.

CO_2 Capture with Batch Reactor. The batch reactor system was used for multiple CO_2 and H_2S absorption and regeneration tests with the PSDF solvent. Both raw syngas with CO_2

spiked from a bottle and shifted syngas was used. The tests results show that, with deep regeneration, both CO_2 and H_2S can be efficiently captured to low levels.

A sample conditioning system was built for the regeneration sample point. CO_2 and H_2S analyses were completed on both absorption and regeneration phases of testing. The sulfur GC was dedicated to this testing. The calibration range of the GC was changed according to the needs of specific tests.

Commissioning 1,500 lb/hr Syngas Header. The new 1,500 lb/hr syngas header was commissioned during R01 with CO_2 capture testing. Initial commissioning did not deliver the expected syngas flow. The problem was traced to a check valve upon comparing observed pressure drops with detailed calculations that were done during the design phase. After repairs, the flow, temperature and pressure drops were as expected. The system is ready to supply syngas to multiple reactors in the syngas cleanup unit simultaneously. Prior to the addition of this syngas line, the syngas flow rate to the syngas cleanup unit was limited to about 50 lb/hr.

Johnson Matthey Mercury Sorbent. The Johnson Matthey mercury sorbent (with palladium as the active component) was tested in a fixed bed reactor in the syngas cleanup unit. About 10 lb of sorbent was used, and prior to testing it was pre-reduced. The mercury sorbent was tested for 170 hours with of sour syngas flowing at a rate of 40 lb/hr. The reactor operated at a pressure of 165 psig and a bed temperature of 500°F.

To estimate the removal rate of mercury and other trace metals in the syngas, PSDF gas analysis specialists collected samples at the inlet and outlet of the reactor. Seven Method 29 (impinger) samples were taken while the sorbent was online. Four Method 30B carbon traps were run for direct comparisons with the impinger tests. Data analysis in underway.

Syngas quality measurements indicated that the mercury sorbent shifted the syngas and resulted in CO conversions ranging from 40 to 60 percent.

Media and Process Technology (MPT) Hydrogen Membrane. MPT personnel tested their hydrogen membrane for over 100 hours with raw syngas. During initial tests, condensation in the vent header damaged the membrane tube. Modifications to remove any condensate before opening the syngas valve to hydrogen membrane unit and additional heat tracing were completed.

After modifications, the tests resumed and a replacement membrane was exposed to temperatures up to 500°F. The membrane remained stable, and the permeate contained over 90 percent hydrogen. The syngas sulfur and other contaminants did not appear to affect the membrane performance.

PSDF personnel provided analytical and mechanical support for this test effort. A process gas chromatograph (GC), along with a sample conditioning system, were dedicated to this membrane test. Because the GC did not provide reliable measurements in the early part of R01, a new column, inlet port, and inlet regulator were installed in the

GC. These additions, utilizing a micro-packed column approach, greatly increased the accuracy and stability of the GC. Other support included the addition of sample cylinders, regulators, and a vortex cooler. The PSDF supplied bottled gases such as CO_2, argon, helium, and nitrogen.