Carbon Dioxide Capture from Flue Gas Using Dry, Regenerable Sorbents

Quarterly Technical Progress Report

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Abstract

This report describes research conducted between October 1, 2005, and December 31, 2005, on the use of dry regenerable sorbents for removal of carbon dioxide (CO_2) from flue gas from coal combustion. A field test was conducted to examine the extent to which RTI's supported sorbent can be regenerated in a heated, hollow screw conveyor. This field test was conducted at the facilities of a screw conveyor manufacturer. The sorbent was essentially completely regenerated during this test, as confirmed by thermal desorption and mass spectroscopy analysis of the regenerated sorbent. Little or no sorbent attrition was observed during 24 passes through the heated screw conveyor system.

Three downflow contactor absorption tests were conducted using calcined sodium bicarbonate as the absorbent. Maximum carbon dioxide removals of 57 and 91% from simulated flue gas were observed at near ambient temperatures with water-saturated gas. These tests demonstrated that calcined sodium carbonate is not as effective at removing CO_2 as are supported sorbents containing 10 to 15% sodium carbonate.

Delivery of the hollow screw conveyor for the laboratory-scale sorbent regeneration system was delayed; however, construction of other components of this system continued during the quarter.

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1.0 Executive Summary

The objective of this project is to develop a simple and inexpensive process to separate carbon dioxide (CO_2) as an essentially pure stream from a fossil fuel combustion system using a regenerable sorbent. The sorbents being investigated in this project are alkali carbonates—particularly sodium carbonate (Na_2CO_3), which is converted to bicarbonate or to an intermediate salt through reaction with CO_2 and water vapor. The sorbent is regenerated to carbonate when heated, producing a nearly pure CO_2 stream after condensation of water vapor.

A field test program was conducted which confirmed that a preloaded supported sorbent could be satisfactorily regenerated during passage through a heated screw conveyor. The regenerated sorbent was then tested at RTI using temperature programmed desorption (TPD) and mass spectroscopy to confirm that essentially complete regeneration had been accomplished. Particle size analysis of the supported sorbent indicated that no attrition took place after 24 cycles through the screw conveyor.

Unsupported calcined sodium bicarbonate was used in three downflow contactor tests. Maximum CO_2 removals from a simulated water-saturated flue gas were between 57 and 91% during these tests.

2.0 Introduction

Fossil fuels used for power generation, transportation, and by non-utility sectors are the primary sources of anthropogenic CO_2 emissions. Although there are many potential approaches to limiting greenhouse gas (GHG) emissions, including increased energy efficiency and use of carbon-free fuels, it is clear that CO_2 capture and sequestration will play an important role in mitigating the progress of global warming. In the near future, CO_2 capture efforts will likely focus on large stationary sources, such as fossil-fueled power plants because these sources emit the largest quantities of CO_2 and will offer the benefits of economy of scale. It is for this reason that the United States Department of Energy’s (DOE’s) Carbon Sequestration Program, administered by the Office of Fossil Energy and managed by the National Energy Technology Laboratory (NETL), conducts and funds research to develop CO_2 capture and sequestration technologies.

The focus of this project is to develop a simple and inexpensive process to remove CO_2 from the flue gas of existing power plants using a dry, regenerable sorbent. This capture technology is based on the reversible reactions between CO_2 and sodium carbonate. Using a cyclic thermal-swing process, an essentially pure CO_2 stream can be removed from flue gas for subsequent sequestration or reuse. Capture of CO_2 from low-temperature flue gas using Na_2CO_3-based sorbents results in the reversible formation of sodium bicarbonate ($NaHCO_3$) and/or Wegscheider's salt ($Na_2CO_3 \cdot 3NaHCO_3$), as shown in Reactions 1 and 2:

- Reaction 1

$$Na_2CO_3(s) + CO_2(g) + H_2O(g) \leftrightarrow 2NaHCO_3(s) \qquad \left[\Delta H_r^o = -32.4 \text{ kcal/mol } CO_2\right]$$

- Reaction 2

$$Na_2CO_3(s) + 0.6\ CO_2(g) + 0.6\ H_2O(g) \leftrightarrow 0.4\left[Na_2CO_3 \bullet 3NaHCO_3(s)\right] \qquad \left[\Delta H_r^o = -32.5 \text{ kcal/mol } CO_2\right]$$

Both forward reactions (CO_2 absorptions) are exothermic. The equivalent reverse reactions (sorbent regeneration) are endothermic and produce equal molar quantities of CO_2 and H_2O. Condensation of H_2O from the regeneration product results in a pure CO_2 stream that is suitable for sequestration or reuse.

This report describes activities conducted between October 1, 2005, and December 31, 2005, by RTI International (RTI). Activities conducted this quarter include testing of sorbent regeneration in a heated screw conveyor and laboratory testing of CO_2 removal from simulated flue gas in a downflow reactor using calcined sodium bicarbonate.

3.0 Experimental

3.1 Field Test of Heated Screw Conveyor Sorbent Regeneration

Sorbent regeneration testing was conducted at the facilities of Therma-flite, Incorporated in Benicia, California. A supported sorbent (SCI-090905-1) composed of 10% Na_2CO_3 on a ceramic support was used. Properties of this material were reported in the previous quarterly report (Green, et al., 2005a). Prior to the Therma-flite field test, the sorbent was run through a series of carbonations in RTI's downflow contactor (Green, et al. 2005b). The sorbent was essentially completely loaded with CO_2 and then three buckets of this material were shipped to Therma-flite for testing.

The tests were conducted in Therma-flite's dual-screw, bench-scale testing conveyor. This apparatus is approximately 5 feet in length and contains two "holo-flite" screws that rotate together and are housed in a metal jacket. The conveying speed is set by adjusting a variable speed motor which drives both screws. The rotational speed can be varied from 0 to 8 revolutions per minute. The system's jacket has three vent ports at approximately 1.5 feet, 3 feet, and 4.5 feet from the feed end of the conveyor. Sorbent temperature can be measured through these three ports using a hand-held thermocouple. The bench-scale unit also has a feed inlet port and a feed outlet port. The system is heated by tempered oil that flows through the inside of the screw shafts and flights. The jacket is solid metal and is therefore not heated with oil. Figures 1 and 2 show Therma-flite's testing system. Testing was done in a horizontal configuration, because no vertical testing conveyors were available.

Figure 1. Therma-flite's bench-scale screw conveyor test unit

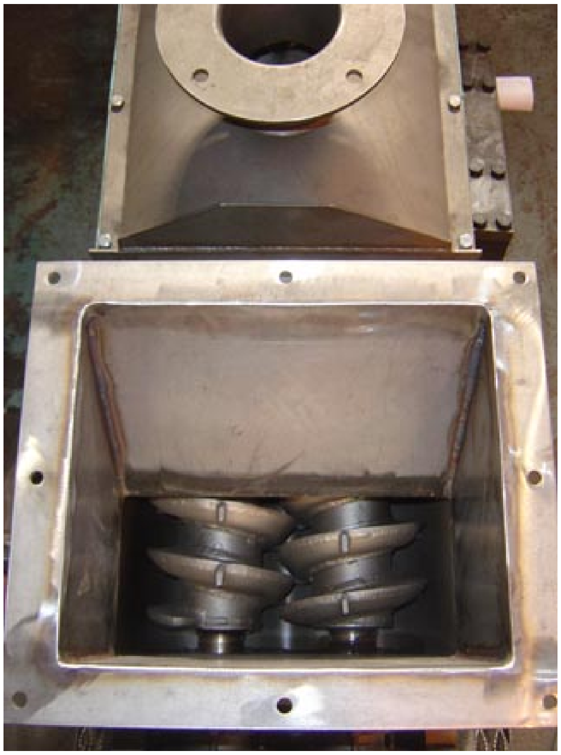

Figure 2. Feed inlet of Therma-flite's bench-scale test unit

3.1.1 Regeneration Tests

A total of seven regeneration tests were conducted. The desired regeneration temperature was 120ºC, however, the vent ports provided an escape route for some heat, so a higher oil temperature was used to compensate for heat loss. In Tests #1 - #6, the temperature of the oil was 149ºC. In Test #7, the oil was heated to 166ºC to determine if there was a noticeable difference in the amount of CO_2 released after Test #7 under these conditions. Other system settings for each regeneration test are listed in Table 1.

Table 1. Regeneration test conditions

Test	1	2	3	4	5	6	7
Sorbent Source	Bucket 1 "system prime"	Bucket 2 1st pass	Bucket 3 1st pass	Bucket 3 2nd pass	Buckets 1 & 2 2nd pass	Bucket 3 3rd pass	Buckets 1 & 2 3rd pass
Sorbent residence time (min:sec)	5:30	3:50	2:45	2:45	3:50	NA	2:45
Rotation Rate (rpm)	6	6	8	8	6	4	8
Vertical Pitch (deg)	0	0	0	0	0	0	0
Mass at inlet (lbs)	31.5	25	29	~ 24	~ 38	~ 24	~ 38
Mass at outlet (lbs)	14	24	24	~ 24	~ 38	~ 24	~ 38
Oil setpoint temperature (deg C)	149	149	149	149	149	149	166
Inlet sorbent temperature (deg C)	20	20	20	49	50	50	55
Screw surface temperature (deg C)	120	120	120	120	120	120	NA
Samples (sample #)	1,2,3	4,5,6	7,8	9,10	11,12	13,14	15,16
Sampling Notes	Samples taken at beginning of output, middle and end	Beginning, middle, and end	Beginning and end	Beginning and end	Middle and end	Beginning and end	Beginning and end

In Test # 1, approximately 31.5 pounds of room temperature SCI-090905-1 sorbent (from Bucket #1) was introduced to the heated screw conveyor. This was considered the "system prime". Since the screws are in a horizontal configuration and the system jacket is not flush against the screws, a portion of the initial feed lined the bottom of the system and essentially remained there through all subsequent tests. Table 1 shows that over half (~ 17.5 lbs) of the initial feed material remained in the system. About 14 pounds of sorbent was collected at the system outlet port during Test #1. In addition, three samples were collected during Test #1 for further analysis at RTI. These samples, labeled #1, #2, and #3, were collected when (1) the sorbent first began to flow through the outlet port, (2) at approximately the middle of the test, and (3) when the outlet flow was nearly finished. The "sorbent residence time" refers to the difference between the time when the sorbent was added and the time when the sorbent first started flowing through the outlet port. (Note that the Test #1 residence time is much longer than other tests with the same motor speed. This is because Test #1 was the only test where sorbent first lined the bottom of the apparatus before it was conveyed to the outlet port). A rotational speed of 6 rpm corresponds to a sorbent residence time of approximately 3 minutes and 50 seconds (as is shown in Tests #2 and #5).

In Test #2 (with the system "primed" from Test #1), 25 pounds of sorbent from Bucket #2 was introduced to the heated system. The same settings from Test #1 were used. Samples 4, 5, and 6 were taken at the beginning, middle, and end of the test. In Test #3, 29 pounds of sorbent from Bucket #3 was fed to the system. The screw conveyor speed was changed to 8 rpm to determine the effect of conveying rate on regeneration and sorbent degradation.

Test #4 represented the "2nd pass" of the sorbent from bucket #3. The reason for passing the sorbent through the conveyor more than once was to determine if any additional CO_2 was released from the sorbent during subsequent regenerations. The material, having just been removed from the heated screw conveyor, was introduced to the system at a temperature of about 50ºC. The system settings for Test #4 were the same as in Test #3. For Test #5, the sorbent originally contained in Buckets #1 and #2 was combined and fed to the screw conveyor. This represented the "2nd pass" of the sorbent from these two buckets. The settings for Test #5 were identical to those used in Tests #1 and #2. Test #6 represented the "3rd pass" of the sorbent from Bucket #3. The rotational speed of the screws was decreased to 4 rpm to determine whether a longer sorbent residence time allowed for more CO_2 to be released. Test #7 represented the "3rd pass" of the sorbent from Buckets #1 and #2. As mentioned above, the oil was heated to 166ºC in this test to determine whether a higher temperature would remove CO_2 that was not removed at a temperature of 149ºC.

The samples collected from Tests #1 through #6 were analyzed at RTI to determine the extent of decarbonation and degradation. Thermogravimetric analysis (TGA) was used to calculate the amount of CO_2 released during Test #1. This was done by heating a sample from Test #1 in the TGA system and measuring the weight loss. This weight loss was then compared to the weight loss experienced by a fresh (fully carbonated) sample. The TGA procedure involved loading a sample into the TGA system, heating to 120ºC in N_2 until a constant weight was observed, and then heating to constant weight at 160ºC in N_2.

A relative measure of attrition was established by determining the particle size distribution (using a Sympatec HELOS laser diffraction system) of each sample and comparing it to the "fresh" sample.

3.1.2 Sorbent Cycling Tests

All of the sorbent contained in the original three buckets was combined (except for reserved samples) for multi-cycle sorbent degradation testing. The combined sorbent was conveyed through the heated screw conveyor system 20 times in succession. The hollow screws were heated to 149ºC and were set to a rotational speed of 8 rpm for the multi-cycle testing. Samples were taken after cycle number 1, 5, 10, and 20 (the samples were labeled #17, #18, #19, and #20 respectively). These samples were sent to RTI for TGA, thermally programmed desorption (TPD)/Mass Spectroscopy, and particle size analysis. The main objective of these multi-cycle tests was to see if significant attrition of the sorbent occurred during multiple passes through the screw conveyor system. Relative degradation was characterized by particle size analysis.

3.1.3 Sample Identification

Sample identification is given in Table 2.

Table 2. RTI sample identification for samples taken during Therma-flite field test

Sample ID	Therma-Flite Sample Number	Description
100705a-PreTF	NA	Carbonated SCI-090905-1 (Pre Therma-flite)
101205a-TF	1, 2, 3	Test #1 samples
101205b-TF	4,5,6	Test #2 samples
101205c-TF	7,8	Test #3 samples
101205d-TF	9,10	Test #4 samples
101205e-TF	11,12	Test #5 samples
101205f-TF	13,14	Test #6 samples
101205g-TF	15,16	Test #7 samples
101205h-TF	17	Multi-cycle #1 sample
101205i-TF	18	Multi-cycle #5 sample
101205j-TF	19	Multi-cycle #10 sample
101205k-TF	20	Multi-cycle #20 sample

3.2 Downflow Reactor Tests Using Calcined Sodium Bicarbonate

Three tests were conducted in the downflow reactor system. The downflow system configuration is described in the annual report (Green, et al., 2005b). Calcined sodium bicarbonate (a mixture of Grade 3 and Grade 5) was used in these tests to capture CO_2 from simulated flue gas. The sorbent was regenerated between tests by heating to 140°C in an oven and was reused in subsequent tests. The tests were conducted with the reactor system at a temperature of 25°C. Preheated water was added to the simulated flue gas to supersaturate it. Enough water vapor was added to result in a simulated flue gas composition of 10% CO_2, 10.6% H_2O and 79.4% N_2 if all of the added water was considered to be in the gas phase. Water in excess of the saturation concentration (approximately 3.1%) was assumed to be absorbed by the sorbent. Therefore, the flue gas composition was assumed to be 11% CO_2, 3.1% water vapor, and a balance of N_2.

Sorbent flow was started after the flows of CO_2 and N_2 were established. The sorbent was collected in a bucket at the bottom of the reactor. The sorbent flow rate was calculated by weighing the collected sorbent at the end of each test. The temperature of the collected sorbent was monitored with a thermocouple. The gas exiting the reactor was passed through a condenser before entering a non-dispersive infrared CO_2 analyzer. The furnace surrounding the reactor was not used in these tests.

4.0 Results and Discussion

4.1 Heated Screw Conveyor Regeneration Testing

4.1.1 Heat Transfer from Screw to Sorbent

Temperature measurements from the regeneration tests are given in Table 3.

Table 3. System temperatures during seven decarbonation tests

Test number	1	2	3	4	5	6	7
Oil setpoint temperature (deg C)	149	149	149	149	149	149	166
Sorbent Inlet temperature (deg C)	20	20	20	49	50	50	55
Screw surface temperature (deg C)	120	120	120	120	120	120	NA
Sorbent exit temperature (deg C)	93	98	96.8	NA	NA	NA	NA
Temp at first vent (approx 1.5')	NA	NA	NA	90.2	90	93	95
Temp at second vent (approx 3')	NA	NA	NA	95	102	102	115
Temp at third vent (approx 4.5')	NA	NA	NA	115	117	115	123

NA = not measured

Table 3 demonstrates that heat transfer from the surface of the screw conveyor is adequate to heat the sorbent to the desired regeneration temperature of 120ºC. In Tests 4, 5, 6, and 7, the sorbent temperature was measured before it was introduced to the conveyor, at the first vent, at the second vent, and at the third vent. By the time the sorbent reached the third vent, its temperature was at least 115ºC in all four tests and as high as 123ºC in the 7th test. These results are very encouraging and show that a heated screw conveyor at 120ºC can transfer enough heat in roughly 3 minutes of sorbent residence time to heat the sorbent material to the desired regeneration temperature.

In addition to these promising results, there are several reasons to believe that the heated screw conveyor intended for the dry carbonate process will be even better at heating (and essentially regenerating) the sorbent than the test apparatus. The reasons are as follows:

1. The dry carbonate regeneration system will use a vertical screw conveyor instead of one that is horizontal. This will allow the sorbent to completely fill the empty spaces of the unit and will allow for better contact of the sorbent with all heated surfaces (i.e. the screw, other sorbent particles, and the entire surface of the jacket). In the horizontal configuration, heat transfer surfaces were limited to those of the screw flights.
2. The dry carbonate regeneration system does not require vent ports. The Therma-flite test unit had three vent ports which allowed some heat to escape to the atmosphere rather than being transferred to the sorbent particles.
3. The dry carbonate regeneration system will be insulated. This insulation will decrease heat losses.
4. The dry carbonate regeneration system will use steam as the heating source rather than heated oil. Condensing steam has a better heat transfer coefficient than heated oil, so this process will be more efficient in transferring heat than the test unit.

4.1.2 Mechanical Stability of Sorbent

The samples collected at Therma-flite were sent to RTI for particle size analysis using RTI’s Sympatec HELOS laser diffraction particle size analyzer. Particle size distributions are shown in Table 4. The samples were prescreened to eliminate particles > 355 µm to ensure proper operation of the HELOS system. The percentage by weight of sorbent >355 µm for each sample is listed in Table 4 [labeled as “>355µm (wt%)”]. Also listed in Table 4 are data from duplicate particle size analyses for each sample (columns labeled as "1" and "2"). Ten percent of the sample weight is made up of particles with diameters less than or equal to the “x10” value given. (For example, for sample 100705a-PreTF, 10 wt% of the particles are less than or equal to 44.9 µm diameter). Likewise, "x50" and "x90” represent the maximum particle size that includes 50% and 90% of the sample. Table 4 also lists the weight percentage of sorbent particles less than 21 µm and less than 42 µm in diameter.

Table 4. Particle size analysis for samples taken during Therma-flite tests

Sample Name	Pass #	>355 µm (wt %)	x10 (µm)		x50 (µm)		x90 (µm)		<21 µm (%)		<42 µm (%)	
			1	2	1	2	1	2	1	2	1	2
100705a-PreTF	NA	0.72%	44.9	45.0	71.7	72.5	112.0	114.4	0.45	0.38	6.83	6.74
101205a-TF	1	1.12%	45.5	45.6	73.7	75.1	118.6	125.3	0.27	0.15	6.35	6.20
101205b-TF	1	1.11%	46.1	49.7	77.2	81.0	129.1	131.9	0.49	0.37	6.18	4.44
101205c-TF	1	1.08%	46.5	46.6	75.8	76.8	120.1	124.3	0.39	0.37	5.76	5.73
101205d-TF	2	3.10%	51.4	51.1	85.2	84.3	142.5	135.4	0.26	0.14	3.72	3.80
101205e-TF	2	2.16%	49.4	49.8	81.5	81.2	134.5	132.9	0.36	0.35	4.61	4.37
101205f-TF	3	1.70%	47.6	48.8	77.7	79.2	121.1	121.3	0.26	0.16	5.18	4.71
101205g-TF	3	2.14%	51.2	51.7	83.7	87.5	135.0	147.6	0.35	0.26	3.84	3.71
101205h-TF	4	1.90%	47.6	48.1	77.7	80.8	125.2	133.4	0.27	1.13	5.15	5.37
101205i-TF	9	1.96%	47.9	49.4	78.5	81.0	129.6	133.8	0.27	0.26	5.02	4.50
101205j-TF	14	3.50%	50.1	49.8	83.7	82.6	140.0	135.7	0.27	1.13	4.39	4.81
101205k-TF	24	1.62%	51.3	49.4	84.0	80.6	136.9	130.2	0.26	0.25	3.75	4.42
Averages			48.6		79.7		129.6		0.37		4.99	

If attrition of the sorbent occurred during the Therma-flite tests, successive passes of the sorbent in the system would produce progressively smaller sorbent particles. It would be expected that particle sizes for x10, x50, and x90 would all decrease and the percentage of material below 21 µm and 42 µm would increase. The data in Table 4 indicate that this is not the case. In fact, the x10, x50, and x90 particles sizes slightly increase and the amount of material below 21 and 42 µm slightly decreases over successive passes of the sorbent. This is probably due to a slight agglomeration of the particles (due to the presence of water vapor after regeneration) as the sorbent is cycled multiple times. These data suggest that there is little to no degradation of the sorbent over 24 passes of the sorbent in the screw conveyor system.

4.1.3 Sorbent Regeneration Determinations by Thermogravimetric Analysis

Although it has been established that the sorbent can be heated to the desired regeneration temperature, it is important to actually confirm that CO_2 and H_2O were released during the Therma-flite tests. Thermogravimetric analysis (TGA) was used to measure the weight lost by collected samples. These samples were heated to 120ºC and 160ºC in an atmosphere of 100% N_2. The samples tested include: 100705a-PreTF (“fresh sample”), 101205a-TF (1st bucket, 1st pass), 101205c-TF (3rd bucket, 1st pass), and 101205k-TF (24th pass). Figure 3 is a comparison plot of the TGA results for these samples.

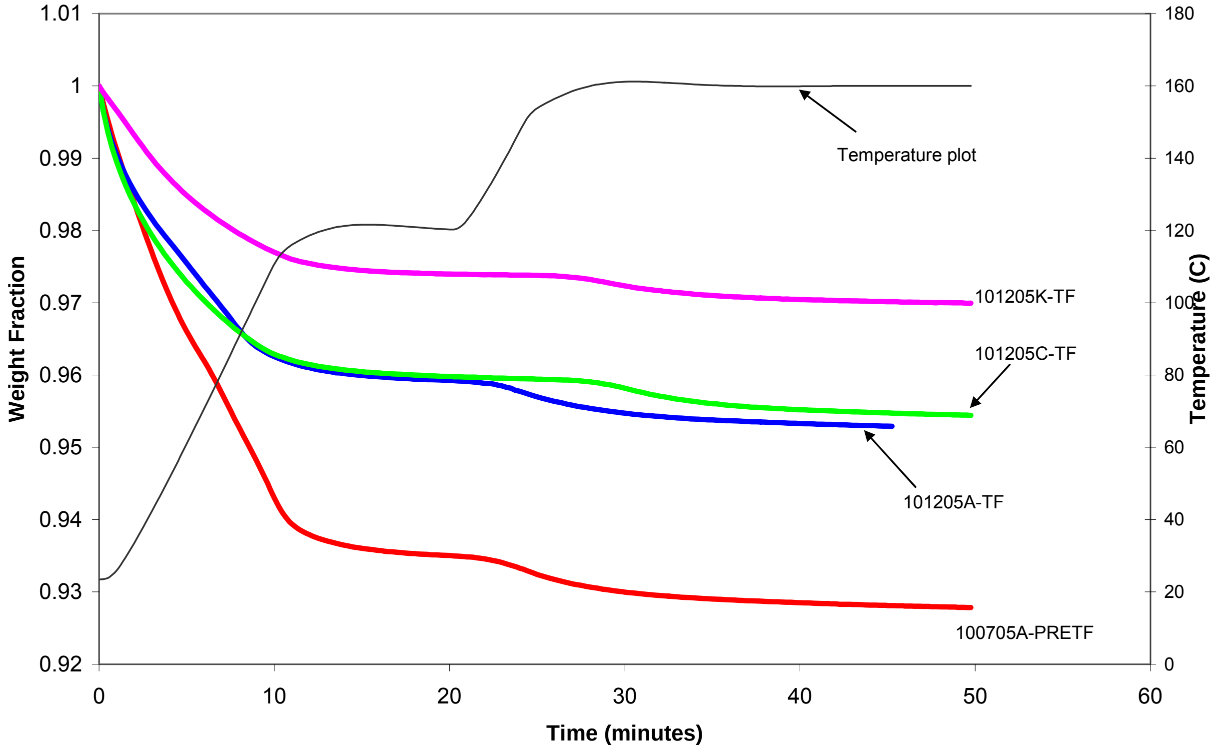

Figure 3. TGA results for samples taken during Therma-flite testing

Figure 3 shows that the "fresh" sample (100705a-PreTF) has the greatest weight loss on heating. This is expected since this sample did not go through the screw conveyor regeneration and thus has the full amount of CO_2 and H_2O to release. Samples 101205a-TF and 101205c-TF which represent the sorbent's first pass through the heated screw conveyor show a 2.5 wt% difference in weight loss as compared to the pretest sample. This suggests that CO_2 and H_2O were in fact released during the first pass through the system. However, comparative data for sample 101205k-TF (which represents the 24th pass through the system), proves that not all CO_2 and H_2O were removed in the first pass. The TGA plot for this sample shows a 4.1 wt% difference in weight loss as compared to the "fresh" sample. It would be expected that all CO_2 and H_2O would be removed by the 24th pass through the screw conveyor. However, the TGA plot for 101205k-TF shows a significant weight loss when heated to 120ºC. It is suspected that this weight loss is due to water that was absorbed by the sorbent after it was tested, and that this weight loss does not represent loss of CO_2 that was on the sorbent prior to Therma-flite testing. In order to confirm this assumption, evolved gas mass spectroscopy was used to determine if CO_2 was released upon heating of sample 101205k-TF.

4.1.4 Sorbent Regeneration Determinations by Mass Spectroscopy

Figure 4 shows mass spectroscopy plots for samples 100705a-PreTF and 101205k-TF. The samples were heated to 120ºC and 160ºC as in the TGA tests. The mass spectrometer was set to record CO_2 being emitted by the samples as they were heated.

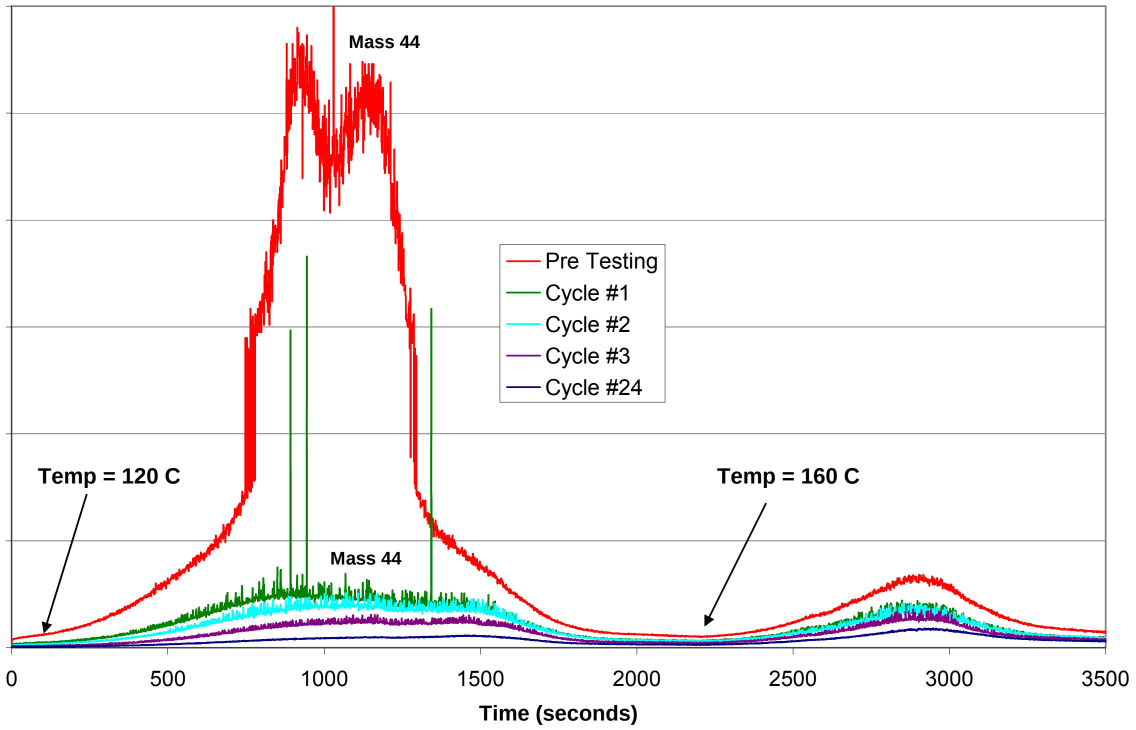

Figure 4. Mass spectroscopy results for 100705a-PreTF and 101205k-TF

As shown in Figure 4, a significant amount of CO_2 was released, as was expected, after heating sample 100705a-PreTF. Sample 101205k-TF, however, released little to no CO_2 when heated. This suggests that all of the CO_2 was released during the Therma-flite tests (the sorbent was fully regenerated) and that the weight loss indicated by TGA testing is probably attributable to H_2O that was adsorbed after the field test.

4.2 Downflow Reactor Tests Using Calcined Sodium Bicarbonate

Three tests were conducted in the downflow reactor this quarter. Calcined sodium bicarbonate (a mixture of Grade 3 and Grade 5) was used as the sorbent. Maximum CO_2 removals of between 57% and 91% were achieved. Test conditions and results are given in Table 5. Test data are given in Figures 5 through 7.

Table 5. Test conditions: Downflow reactor testing of calcined SBC

Test	110205	110305	120505
CO_2 Flow Rate (SLPM)	1.0	1.0	0.2
CO_2 Inlet Concentration (%)	10.7	10.7	10.8
H_2O Flow Rate (g/min)	0.79	0.79	0.15
Temperature (°C)	≈25	≈25	≈25
Average Sorbent Flow Rate (g/min)	299	160	250
Sorbent/CO_2 (g/g)	152	81	636
Maximum CO_2 Removal (%)	57	63	91

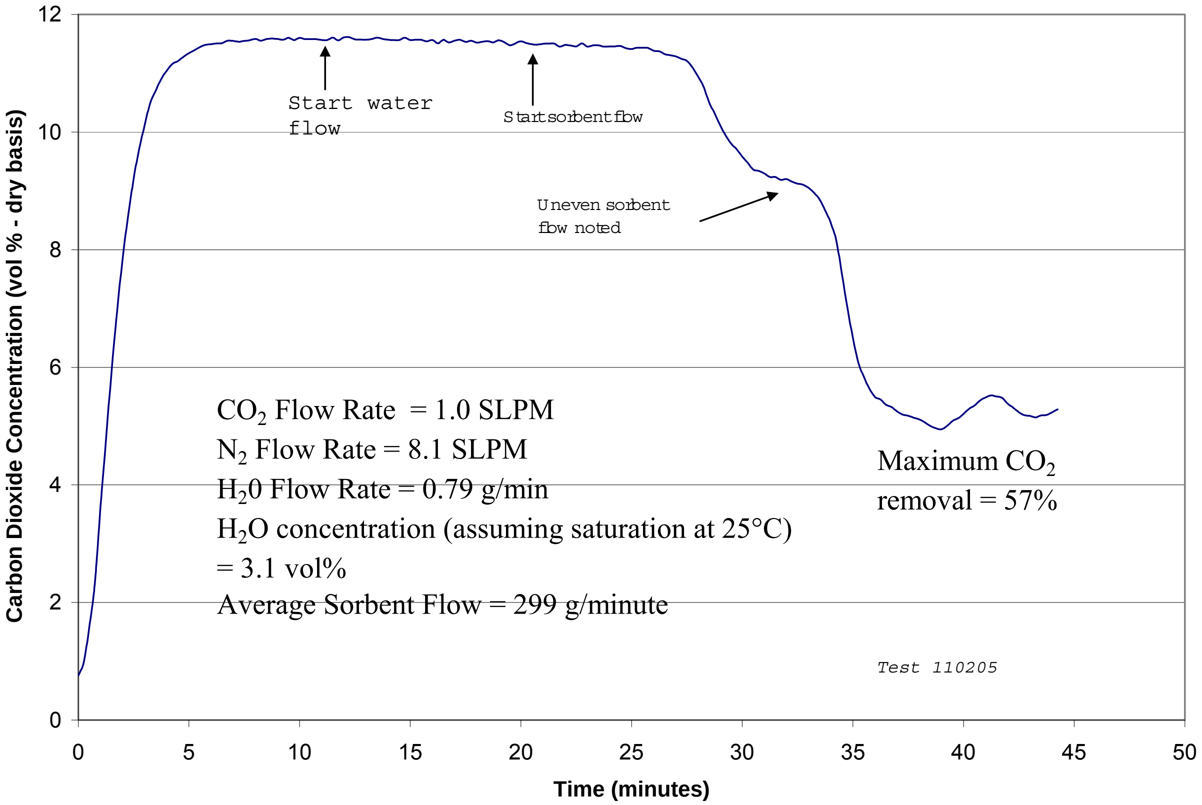

Figure 5. Downflow reactor test (110205) data: CO_2 removal from simulated water-saturated flue gas at 25°C with calcined SBC sorbent

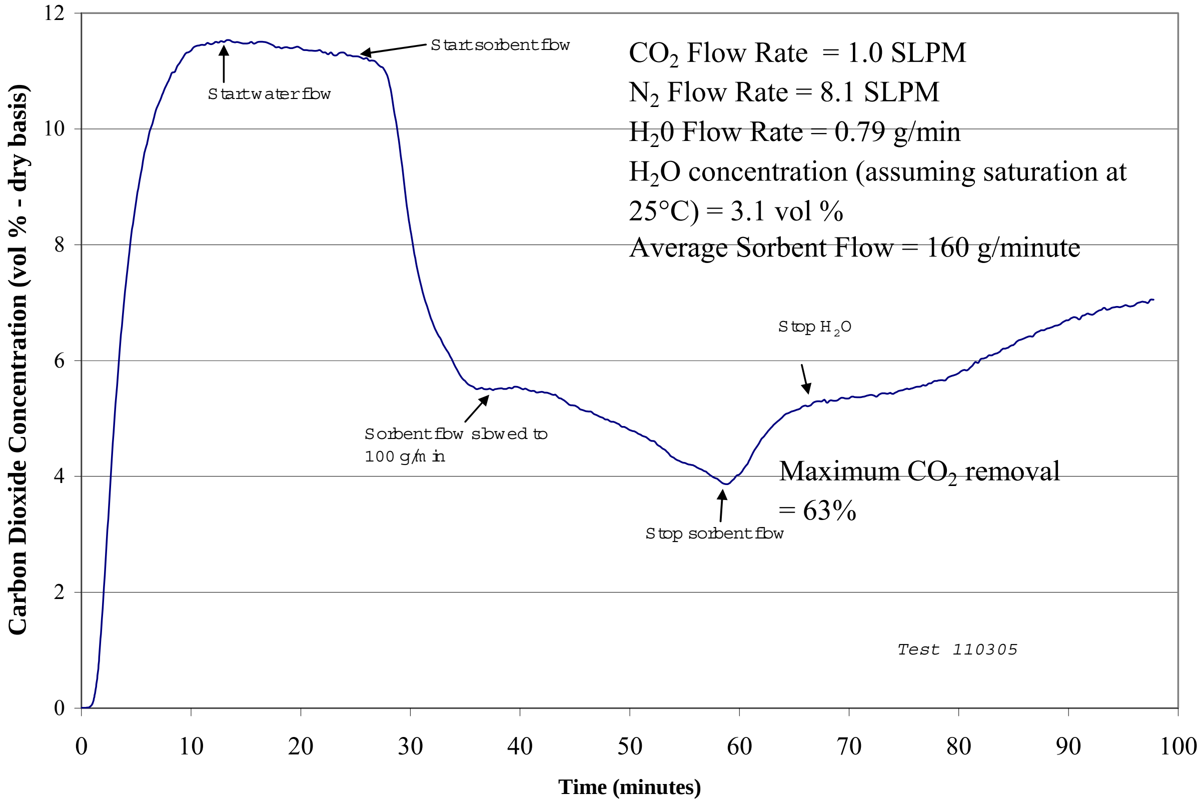

Figure 6. Downflow reactor test (110305) data: CO_2 removal from simulated water-saturated flue gas at 25°C with calcined SBC sorbent

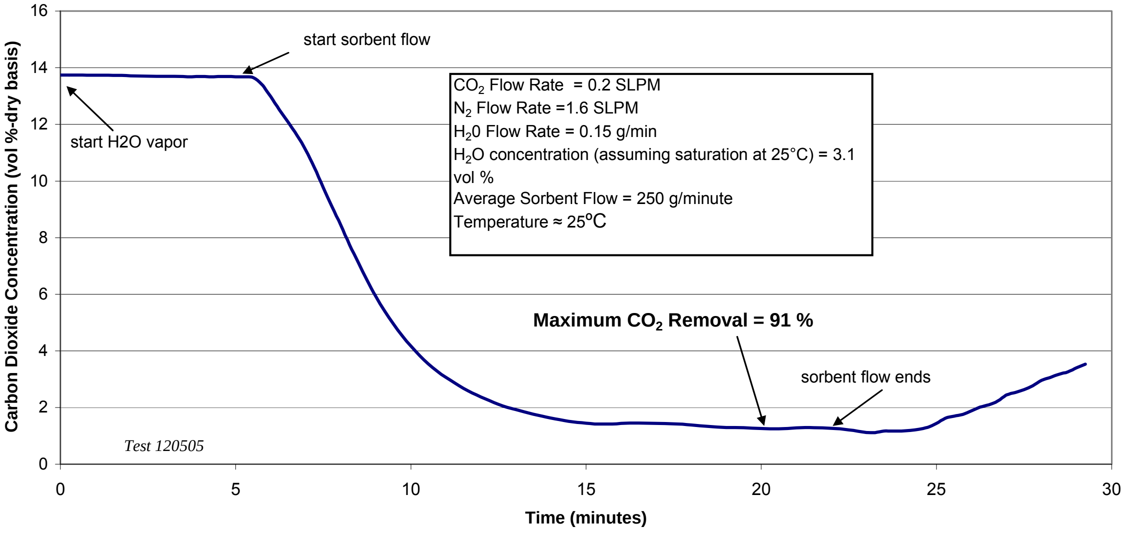

Figure 7. Downflow reactor test (120505) data: CO_2 removal from simulated water-saturated flue gas at 25°C with calcined SBC sorbent

These low temperature tests demonstrate that CO_2 can be readily removed from flue gas using low cost (relative to engineered supported sorbents) calcined SBC. Water addition in these tests greatly exceeded the amount which could be vaporized at saturation. It is assumed that the excess water was absorbed by the sorbent and used in the reaction as needed, either in the condensed phase or by vaporization to replace water vapor used in the reaction. Moreover, it has been proven that CO_2 capture can exceed 90% at a high enough sorbent to CO_2 ratio (and with sufficient gas-solid contact time). This result is shown in test 120505.

These tests were conducted at approximately 25°C. At this temperature the reaction end point is sodium bicarbonate (as opposed to Wegscheider's salt, which is expected at higher temperatures).

4.3 Construction of Heated Hollow-Screw Conveyor Sorbent Regeneration Apparatus

A detailed design of a double, hollow screw regeneration system was given in the previous quarterly report (Green, et al. 2005a). During this quarter all equipment necessary for construction of the heated hollow screw conveyor regeneration system was specified and ordered. Construction of the system was started and the support frame and mounting brackets were assembled. The delivery of the two screw conveyors was postponed until January, 2006, therefore the assembly of the system could not be completed this quarter. The assembly will be completed early in the next quarter and moved into the laboratory. Following connection of the steam generator and the cooling water lines, the system will undergo shakedown testing with a new batch of sorbent.

4.4 Design of Baffled Absorber System

As expected, CO_2 removals improve with greater sorbent-to-gas ratios and longer sorbent residence times. This has been demonstrated with calcined SBC, as described in Section 4.2 and with supported sorbents as previously reported (Green, et al., 2005b). Increased sorbent residence time is also expected to have a positive effect on CO_2 removal efficiency. An increase in residence time can be achieved, in a downflow reactor system, with the addition of baffles. A conceptual design which can be adapted to the current laboratory downflow reactor, and can be added to larger scale equipment, has been developed. This design, shown schematically in Figure 8, is based on a smaller-scale cascade impactor design by Brink (1958).

5.0 Other Project Activities

A project review briefing was prepared and presented at DOE/NETL in Pittsburgh on December 7, 2005. Arrangements were made to obtain additional supplies of supported sorbent and SBC.

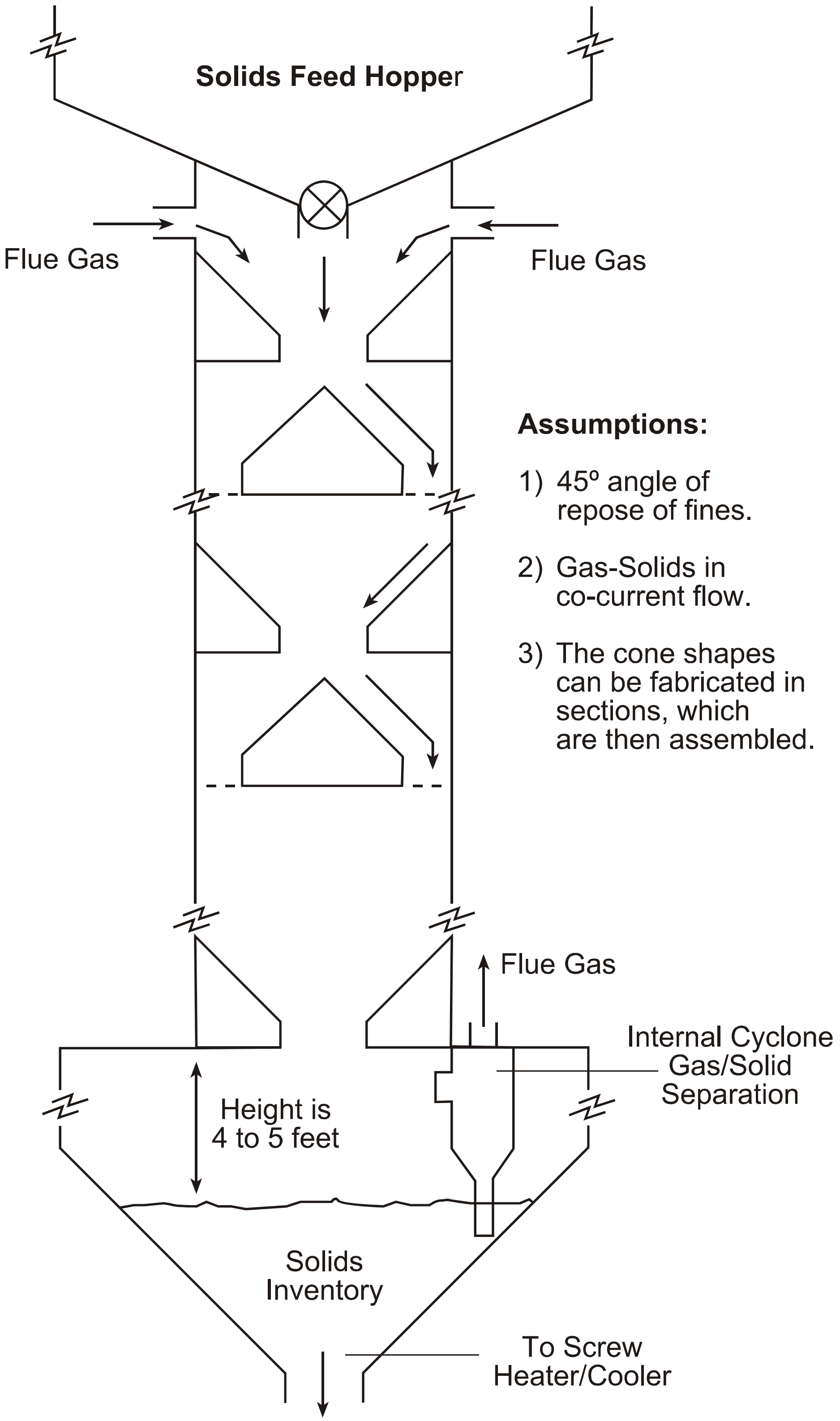

Figure 8. Conceptual design of baffled downflow contractor

6.0 Conclusions

Field testing confirmed that a supported sorbent (SCI-090905-1) could be heated to regeneration temperature while being conveyed in a heated hollow screw conveyor and that essentially complete regeneration could be achieved. Screw conveyor processing resulted in no appreciable attrition of RTI's supported sorbent as indicated by comparable particle size distributions of fresh sorbent and sorbent that had undergone 24 passes in the field test equipment.

Calcined SBC (a mixture of grade 3 and grade 5) was used in a downflow contactor system to remove 91% of the CO_2 from a simulated water-saturated flue gas containing 10.8% CO_2. At a much lower sorbent to CO_2 ratio, 61% CO_2 removal was achieved.

Construction of a laboratory-scale, double-screw sorbent regenerator/cooler system was started. This will be completed in January, 2006 following receipt of the screws from Therma-flite, Inc.

7.0 Future Work

The draft annual report will be delivered in final form following receipt of comments from the DOE Project Manager.

The laboratory-scale, double hollow screw conveyor regenerator/cooler system will be completely assembled and moved from RTI's machine shop to the laboratory. Shakedown testing will be started.

An abstract will be submitted for presentation at the Fifth Annual Conference on Carbon Capture and Sequestration to be held in Alexandria, Virginia.

8.0 References

Brink, J. A. 1958. "*Cascade Impactor for Adiabatic Measurements*", Ind. Eng. Chem., Vol. 50, p.645.

Green, D.A., Nelson, T.O., Turk, B.S., Box, P., and Gupta, R.P. 2005a. *Carbon Dioxide Capture From Flue Gas Using Dry Regenerable Sorbents*. Quarterly Technical Progress Report, RTI International. October.

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