UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

NRG ENERGY, INC.
TALEN ENERGY CORPORATION, and
VISTRA ENERGY Corp.
Petitioners

v.

MIDWEST ENERGY EMISSIONS CORP.
Patent Owner

DECLARATION OF INVENTOR JOHN PAVLISH

Plaintiff's Exhibit
ME2C v. AJG
PTX-070
No. 1:19-cv-01334-CJB

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I, John Pavlish, declare and say as follows:

1. I am a citizen of the United States and am over 18 years of age. I have personal knowledge of the matters stated in this declaration.

2. I make this declaration to describe the conception and reduction to practice of invention of U.S. Patent No. 10,343,114 ("the '114 Patent,") and U.S. Patent No. 8,168,147 ("the '147 Patent").

3. Although I make this declaration on behalf of ME2C, my employer, other than the regular salary I receive from my employment duties, I am not being compensated for this declaration.

Personal Background

4. I have been the Chief Technology Officer and Senior Vice President of Midwest Energy Emissions Corporation since November 16, 2014. Prior to this, I served as an Executive Consultant Advisor to Midwest Energy Emissions Corporation. Prior to joining Midwest Energy Emissions Corporation, I was a Senior Research Advisor and the Director of the Center for Air Toxic Metals Program at the Energy & Environmental Research Center in Grand Forks, North Dakota.

5. I have over 25 years of mercury-related experience and am regarded as an international expert on the topic of mercury. My primary areas of interest and expertise include research, technical consultation and development of mercury control technologies, in particular, for coal combustion and gasification systems. I am an inventor of a number of patented mercury control technologies and have years of experience in development and testing of these technologies for commercial applications.

6. I have served on numerous professional and technical committees and am a U.S. Representative on the Mercury Emissions from Coal International Experts

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Working Group on Reducing Emissions from Coal and a member of the United Nations Environment Programme Global Mercury Partnership, Reduction of Mercury Releases from Coal Combustion. I have published over 200 papers, articles, and reports on various mercury-related topics and issues.

7. I also have years of power plant experience and have worked for an engineering/consulting company, Black & Veatch, where I served as Unit Leader/System Engineer. I am a professional engineer, a member of the American Society of Mechanical Engineers, and a member of the Air & Waste Management Association (A&WMA).

The EPA Calls For New Mercury Removal Technology in the 1990s

8. The background story for this technology begins with the Clean Air Act Amendments of 1990. That law required the U.S. Environmental Protection Agency (EPA) to study the impact of various hazardous air pollutants, including mercury.[1] To assist in the research, in 1992, the EPA established a National Center for Excellence at the Energy & Environmental Research Center (EERC) referred to as the Center for Air Toxic Metals (CATM). It is through the EERC that my fellow co-inventors and I would eventually discover the inventions claimed in the '114 and '147 patents. Our research focused heavily on developing new methods for detecting, measuring, and ultimately, removing mercury from coal-fired power plant exhaust gas.

9. In 1997 and 1998, the EPA issued two reports to Congress: *Mercury Study Report to Congress* (issued December 1997)[2] and *Study of Hazardous Air*

[1] Ex. 2002: https://www.epa.gov/clean-air-act-overview/1990-clean-air-act-amendment-summary-title-iii

[2] Ex. 2003, United States Environmental Protection Agency, "Mercury Study Report to Congress, Volume I: Executive Summary", EPA-452/R-97-003, December 1997, https://www.epa.gov/mercury/mercury-study-report-congress

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Pollutant Emissions from Electric Utility Steam (issued February 1998)[3]. As an outcome of these studies, the EPA found a pressing need for regulation of mercury pollution from power plants. Unfortunately, EPA also found that no existing technologies were up to the task of significantly reducing the mercury pollution from those plants.[4]

10. In the wake of these reports, various governmental and industry organizations injected millions of dollars into basic scientific research and experimental studies in search for new mercury removal technologies. The EERC was one of those groups.

The EERC's Pilot Test Combustor

11. By the early 2000s, my co-inventors (Edwin Olson and Michael Holmes) and I had already spent several years studying mercury emissions testing and capture technologies at the EERC. As part of this work, we conducted various tests at the EERC's Pilot Test Combustor ("PTC"). The PTC is a coal combustion chamber with emission control equipment similar to that used at coal plants through out the United States. This system is designed to simulate the flue gas and emissions controls of much larger commercial scale combustors, and allow for testing of new technologies without posing risks to private coal plants that are connected to the electrical grid. Test experience on the PTC has shown that it produces flue gas that is representative of larger full-scale coal-fired power plants.

[3] Ex. 2004, United States Environmental Protection Agency, "Study of Hazardous Air Pollutant Emissions from Electric Utility Steam Generating Units -- Final Report to Congress", United States Office of Air Quality EPA-453/R-98-004a, Environmental Protection Planning and Standards, February 1998, https://www.epa.gov/mats/study-hazardous-air-pollutant-emissions-electric-utility-steam-generating-units-final-report

[4] Ex. 2004, Footnote 3 reference at ES-19, "Regarding potential methods for reducing mercury emissions, the EPA has not identified any demonstrated add-on control technologies currently in use in the U.S. that effectively remove mercury from utility emissions."

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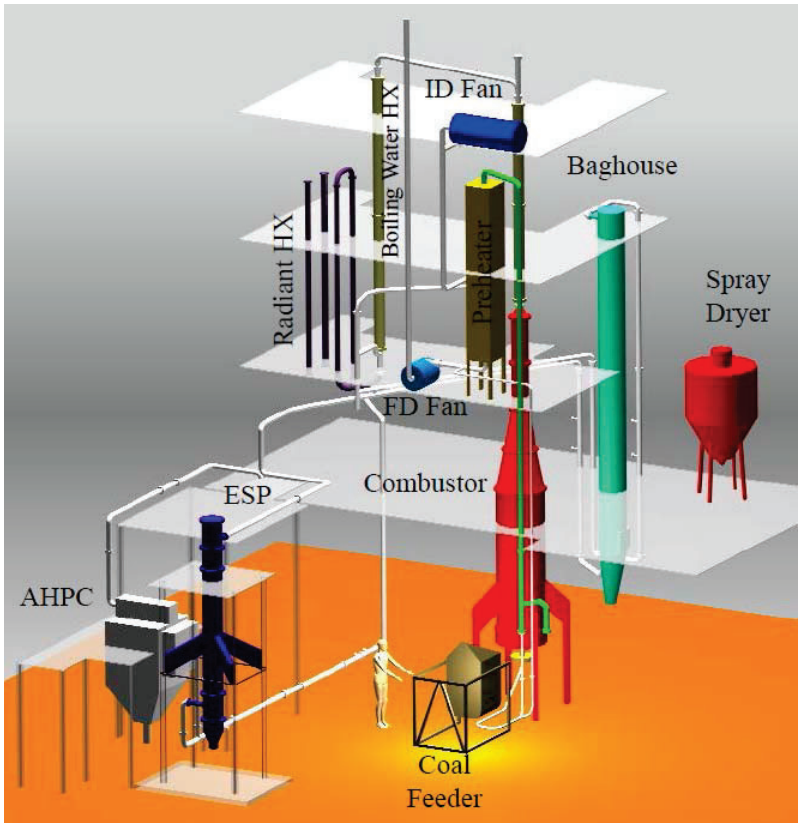
12. An image of the PTC is shown below. This is an accurate reflection of at least a portion of the system as it appeared in 2002:[5]



13. The diagram below reflects the PTC layout as of 2002.[7] A process flow diagram is shown below for the PTC, with additional equipment added such as a dry scrubber:

[5] Ex. 2005, EERC presentation, "Description of Test Facilities Particulate Test Combustor"

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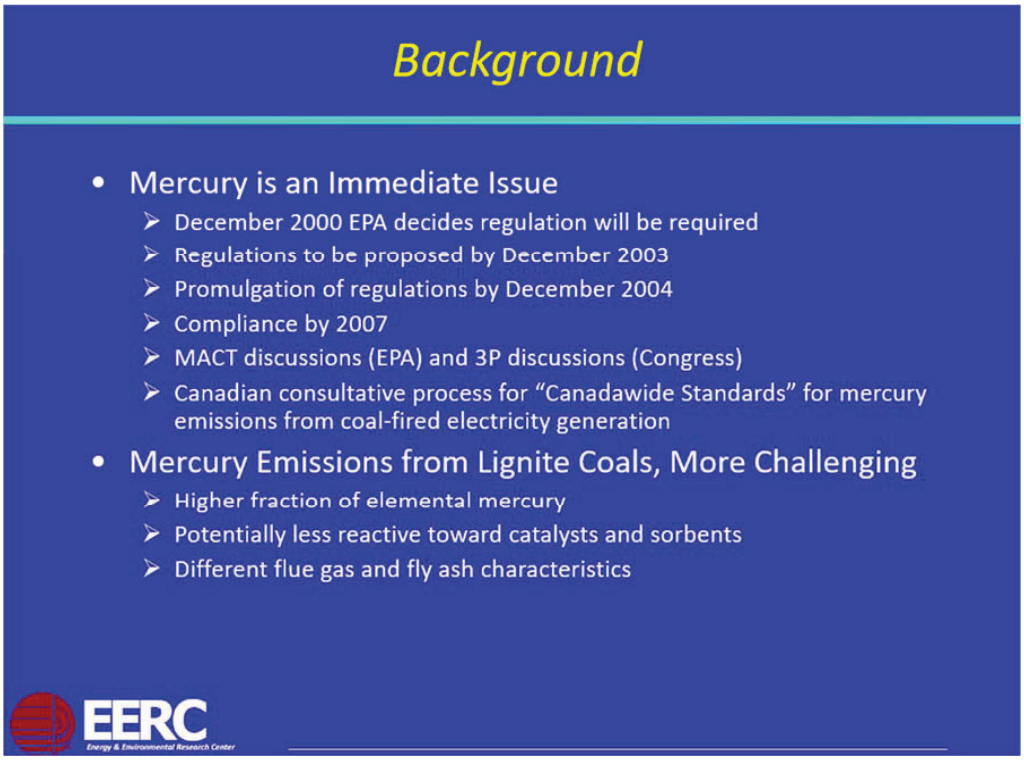
14. As shown above, the PTC included a coal feeder that could feed coal to the combustor. Emission gas from the combustor was channeled through various emission control equipment (e.g., electrostatic precipitator, baghouses, dry scrubber). Various sample ports were placed throughout the PTC to conduct gas measurements (including mercury measurements), and to provide an entry point for injecting materials such as activated carbon sorbent.

15. As described below, my co-inventors and I developed and tested the patented technology using the PTC.

The EERC Kicks Off DOE-Funded Research into Coal Additives and Sorbents

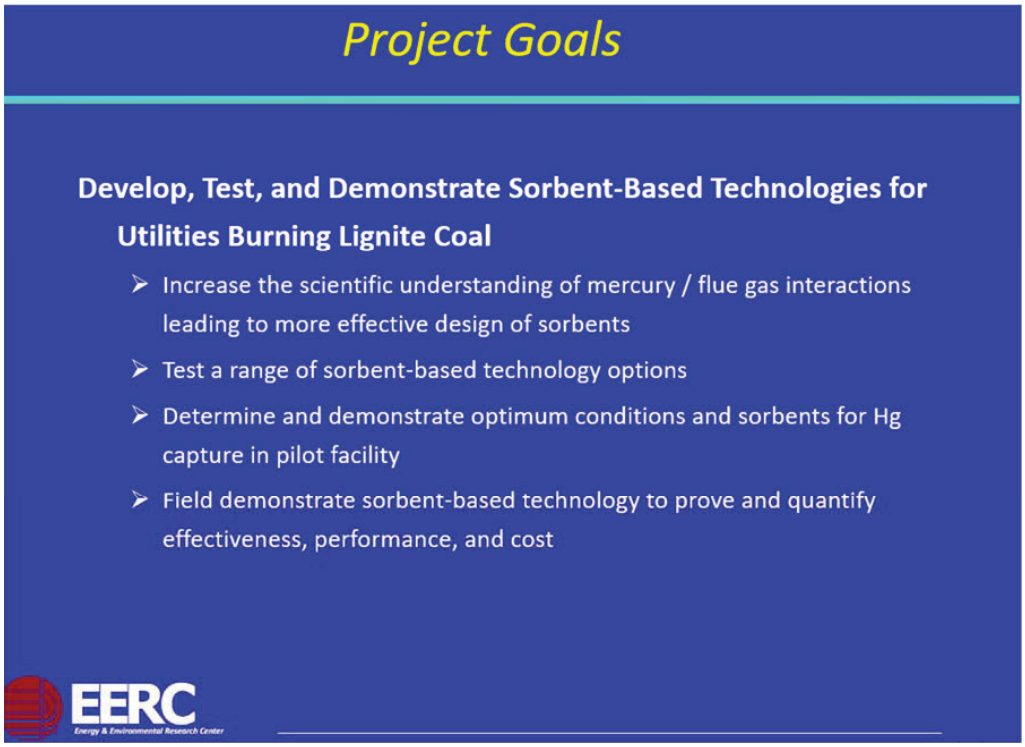
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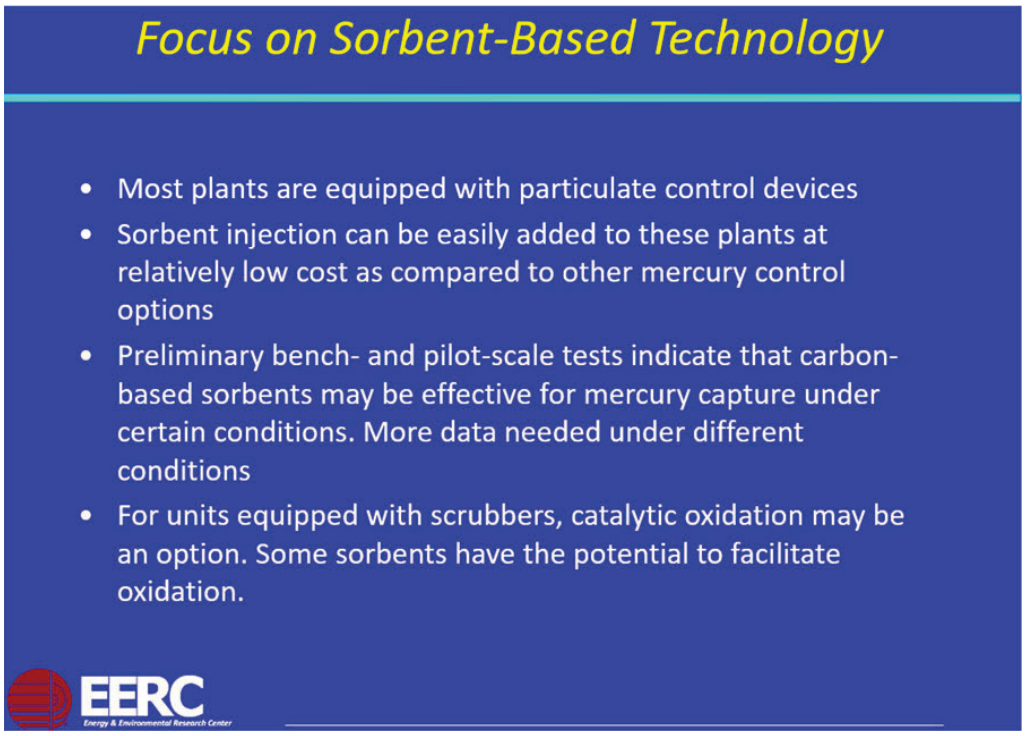
16. By 2001, we had decided to focus on testing and evaluating various sorbents for use in mercury capture. However, PTC testing was relatively expensive, and thus we needed to obtain funding to perform in depth testing. In December 2001, we held a project meeting at the EERC to discuss overall project strategy and funding. The overall project goals were memorialized in the slides below from that meeting:[6]



[6] These slides are attached as Exhibit 2006.

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17. As shown above, by December 2001, we had already determined to focus on sorbent-based technology, and in particular, carbon-based sorbents. Moreover, we had recognized that under certain conditions, a catalyst could be used so that the sorbent would both oxidize and capture mercury.

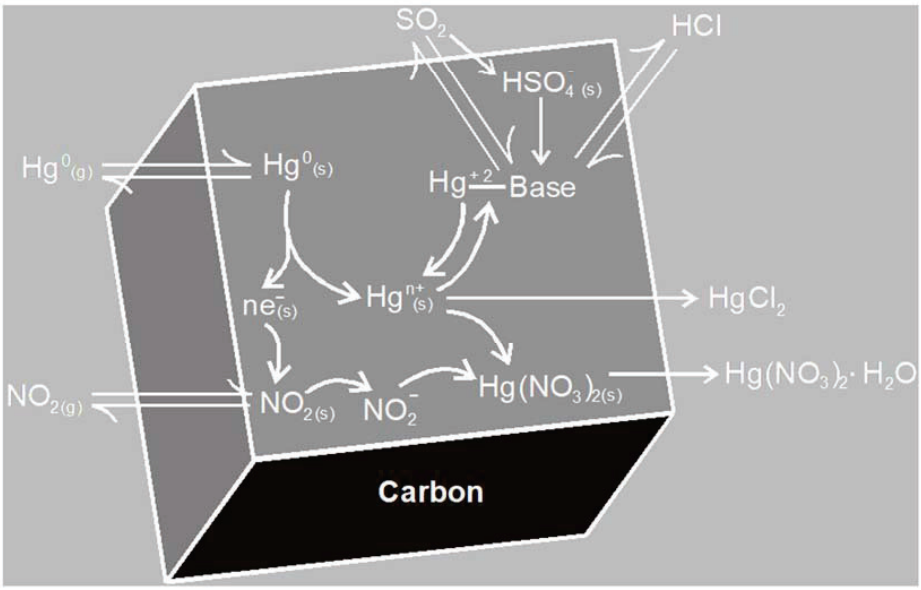
18. By February 2002, the EERC obtained a commitment from the Department of Energy ("DOE") to provide funding for the project. This funding was provided pursuant to a Cooperative Agreement with the EERC (No. DE-FC26-98FT40321), and designated for JV Task 45 – Mercury Control Technologies for Electric Utilities Burning Lignite Coal. Based on the success of this project, this work would later be referred to the Phase I bench- and pilot-scale testing. The results of the projected were later summarized in a report provided to the DOE.[7]

19. The EERC held a kickoff meeting to discuss the project on February 28, 2002. During this meeting we discussed the project timeline and overall strategy. As shown below,[8] part of the focus of the project was to identify sorbents and oxidation options. In particular, we had identified a reaction between chlorine[9] and activated carbon that we intended to study further.[10]

[7] Ex. 2010, "JV TASK 45 – MERCURY CONTROL TECHNOLOGIES FOR ELECTRIC UTILITIES BURNING LIGNITE COAL, PHASE I BENCH- AND PILOT-SCALE TESTING Final Report" (Oct. 2003) (the "October 2003 Report").
[8] These slides are attached as Exhibit 2007.
[9] For ease of reading, references in this declaration to "chlorine" and "bromine" generally use these terms to refer to chemical compounds that contain chlorine and bromine atoms.
[10] These slides are attached as Exhibit 2008.

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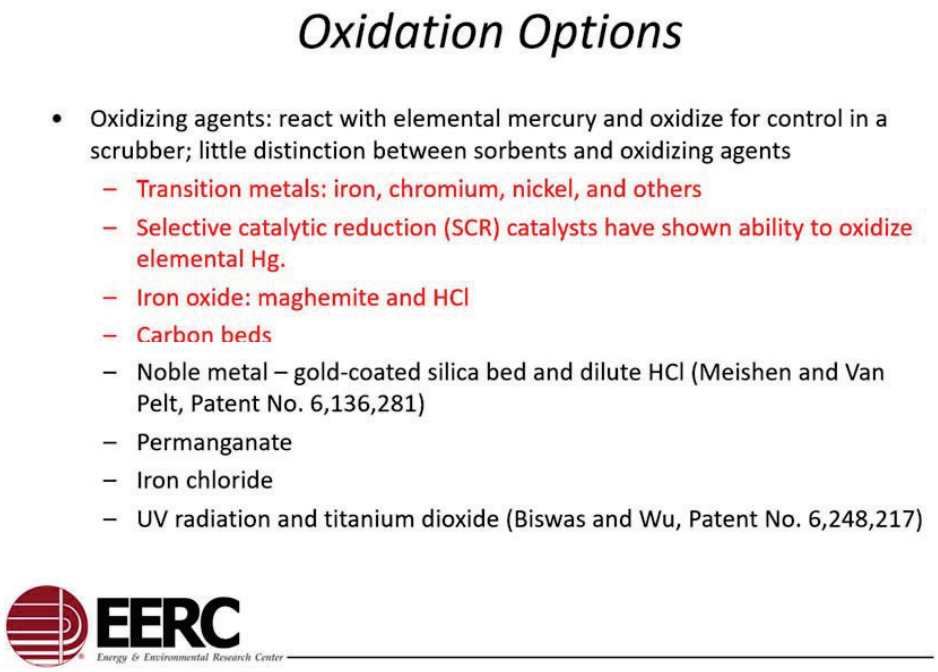
Mechanism of Mercury Capture with Carbon Sorbents



Sorbent Options

- Sorbents – injection and capture with particulate control
  - Carbons: activated carbons derived from coal, impregnated with iodine, sulfur, and other materials
  - Metal oxides: oxides of iron, manganese, and other metals
  - Calcium silicates – derived from fly ash or slag
  - Lime/activated carbon
  - Na_2S_4-impregnated activated carbon
  - Activated carbon derived from tires (Wojtowicz and Serio, Patent No. 6,322,613)
  - Iron chloride
  - Titania with added metals/oxides
  - Palladium chloride
  - Noble metals: gold, tin, zinc, copper, lead, cadmium, silver
  - Corn fibers
  - Fly ash reinjection (Knowles, Patent No. 5,787,823).

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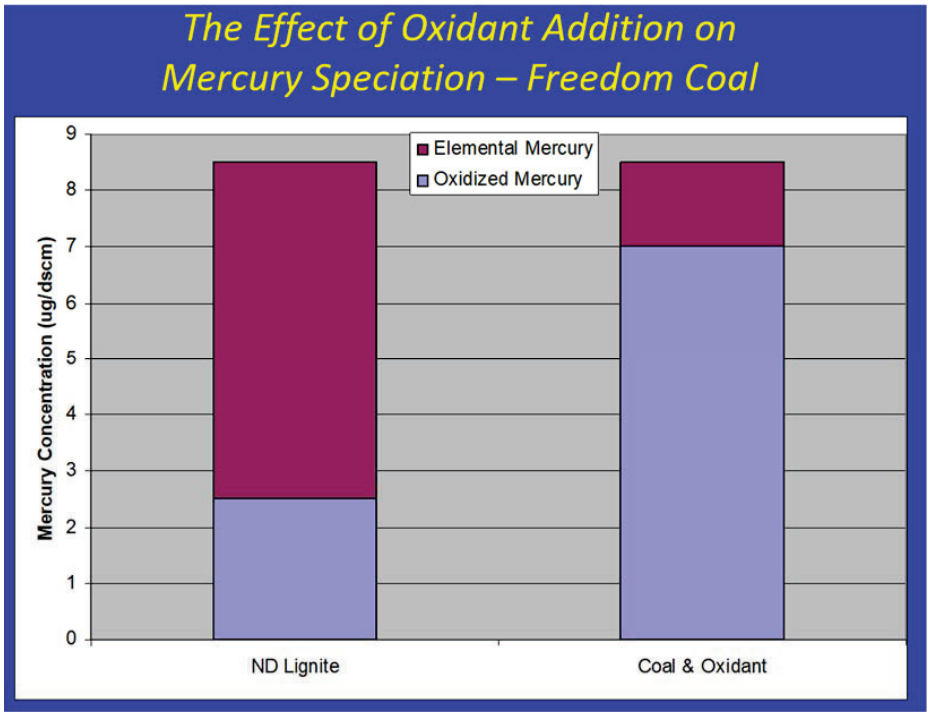


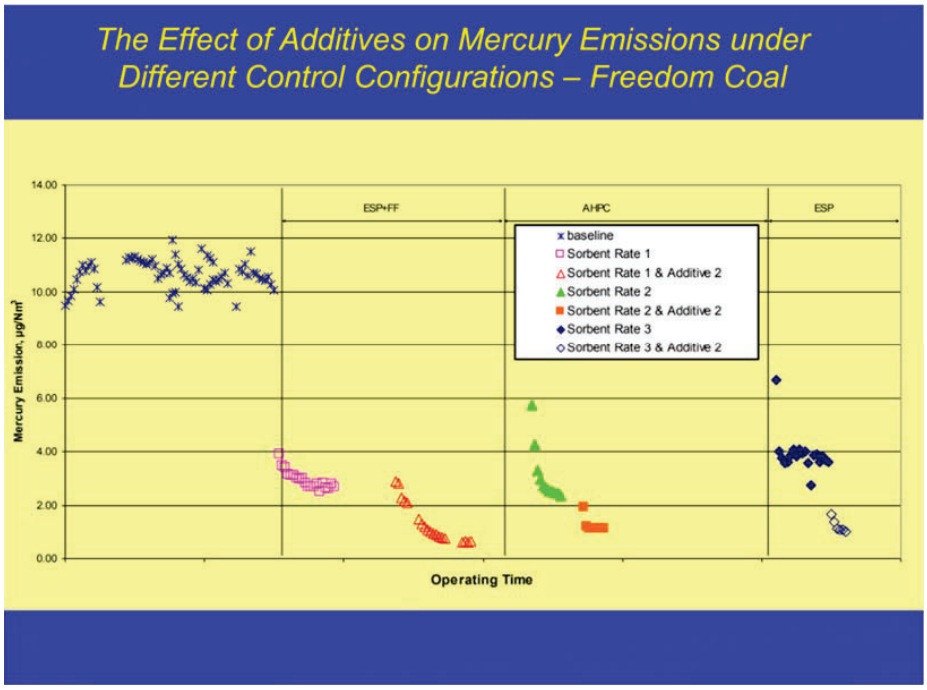
20. Following this kickoff meeting, we tested various sorbents, additives, and other variations at the PTC. Much of this initial work focused on the use of chlorine-based additives and activated carbon sorbents. One of the discoveries consistently demonstrated through that testing was the beneficial effect of combining a coal additive upstream of the combustor, and a sorbent used downstream of the combustor.

21. These results were memorialized, for example, in slides prepared for a post-testing review meeting held on February 3, 2003.[11] As shown in the slides below, comparative testing of sorbents and additives demonstrated an improvement over merely using sorbents, and a significant improvement over baseline testing:

[11] These slides are attached as Exhibit 2009.

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22. The testing described above was conducted during the summer and fall of 2002. I, along with others at the EERC, compiled and analyzed the results of this work into a report provided to the DOE—The October 2003 Report.[12]

23. By the end of the fall of 2002 funding for that PTC testing had been exhausted. Nonetheless, our work had demonstrated sufficiently promising results such that additional funding for PTC testing was procured.

24. Specifically, funding was sought under the CATM program (approval of research at the September 9, 2002 Research Advisory Council meeting for the Center for Air Toxic Metals) and a new round of funding through a North Dakota led initiative to test mercury control technologies. Through this effort a project entitled "Pilot- and Full-Scale Demonstration of Advanced Mercury Control Technologies for Lignite-Fired Power Plants" was funded through an EERC-DOE Cooperative Agreement No. DE-FC26-03NT41897.[13] This round of funding was used for PTC testing conducted in 2003.

Conception and Initial Reduction to Practice of Bromine as the Coal Additive

25. As described in the October 2003 report, by the time of the 2002 PTC testing, my co-inventors and I had conceived of using a pre-boiler additive to boost the performance of post-boiler, injected activated carbon sorbent.[14] Testing coal additives was just one portion of the work we (the EERC) were doing for the DOE project. At least initially, our work focused on the use of chlorine (chlorides, chlorine, chlorine compounds, chlorine salts, etc.) as the additive. This is because the role of chlorine (chlorides, chlorine, chlorine compounds, etc.) in combustion had already been studied to some degree. Thus, testing with chlorine was viewed

[12] Ex. 2010.
[13] Ex. 2011, "PILOT- AND FULL-SCALE DEMONSTRATION OF ADVANCED MERCURY CONTROL TECHNOLOGIES FOR LIGNITE-FIRED POWER PLANTS," (Feb. 2004) (the "February 2004 Report").
[14] Ex. 2010, October 2003 Report at 51.

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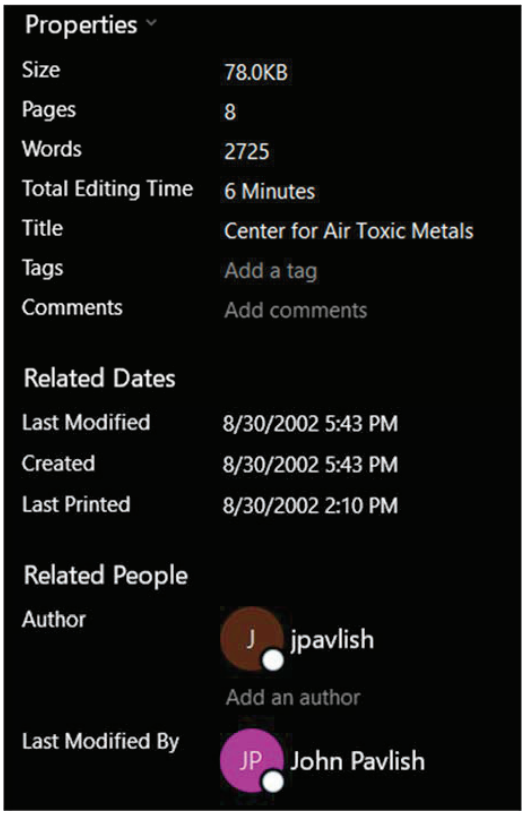
as a logical extension of chlorine-related research and a reasonable approach for a government-funded project.

26. However, on some occasions, after we had completed the required testing, we had some additional time with the PTC when we could experiment with more speculative approaches. It is during one of these "after hours" tests that we first tested the use of a bromine-based additive provided on the coal and injecting activated carbon downstream of the combustor. This decision was by no means obvious as I explained in my testimony submitted during prosecution of the '114 patent.[15] In fact, we were surprised and impressed with the results even if they were based on limited data at the time. However, because this testing was not a part of an officially funded project, we did not keep as detailed records of the testing.

27. I have attempted to locate documents to pinpoint when we conceived of using bromine as the additive, and when we conducted these after-hours tests with bromine. As part of that search, I located a list of potential research ideas that I had compiled in preparation for a September 9, 2002 Research Advisory Council meeting for the Center for Air Toxic Metals. This was an internal document that was used to keep track of potential research projects that I would oversee as Director of the CATM program.[16] The metadata for this document indicates that I last edited it on August 30, 2002:[17]

[15] Ex. 1026, '114 file history at 1775 – 1819.
[16] This document is attached at Ex. 2014.
[17] An image of this metadata is attached at Ex. 2015.

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28. This document notes our discovery that chlorine (chlorides, chlorine, chlorine compounds, chlorine salts, etc.) or other additives can enhance the effectiveness of sorbents:

> 1. Evaluate various chlorine (or other) additives for enhancement of sorbent reactivity/effectiveness. Recent pilot and field data suggest that introducing low-cost additives may significantly improve sorbent effectiveness, leading to better sorbent utilization. Additives to the fuel, sorbent, or directly to the flue gas should be considered.

29. It also identifies the need for studying the use of bromine (bromides, bromine, bromine compounds, bromine salts, etc.) to expedite mercury oxidation:

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4. Control of Hg Emissions Using Ultraviolet (UV) Light and Ionized Halogens. There is evidence that UV light and halogens (Cl and Br) from sea ice catalyze the oxidation of elemental Hg in the Arctic and Antarctic atmospheres, causing the oxidized form of mercury to deposit on the snow. An investigation of the fundamental mechanism of oxidation needs to be done to validate the hypothesis and to determine the fundamental reaction process and rates, the optimum level of Cl or Br radicals to expedite the reaction, synergisms between the two halogens, and to surmise whether SO_x and NO_x may have any detrimental effects on the oxidation reaction in real combustion flue gas. A novel control technology approach might evolve from this fundamental work.

30. Thus, at least by August 30, 2002, we had conceived of using bromine as the additive to coal combustion systems. Once we had received funding and were able to conduct the next round of testing at the PTC, we planned to perform at least some tests using a pre-boiler bromine-based additive with post-boiler activated carbon sorbent.

Testing Bromine Additive Combined with Activated Carbon Sorbent

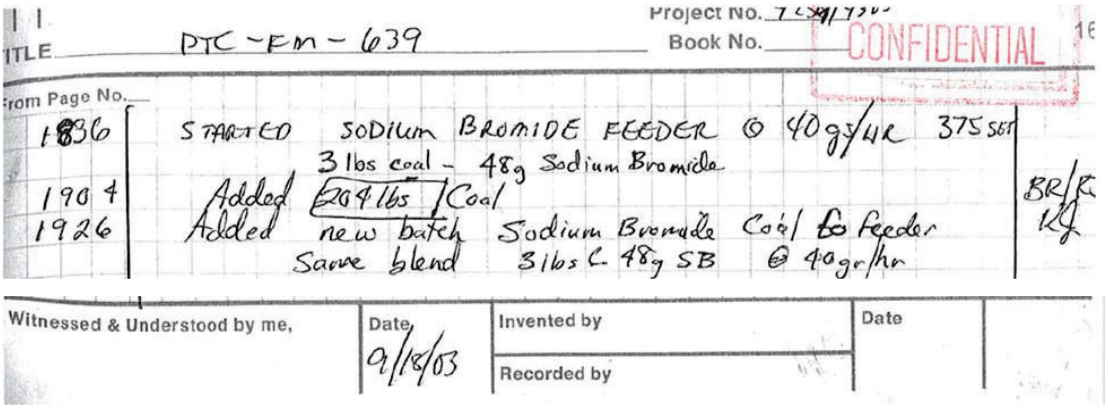
31. The next round of PTC testing began in 2003. Of particular relevance here, from September 8, 2003 to September 19, 2003, we tested various coal additives and sorbents, including the combined use of bromine additive and activated carbon sorbent. Those tests were recorded in PTC run logbooks that described and documented the conditions, activities, and procedural steps followed during each test.

32. The purpose of the logbook was to document that a test (or a series of tests) had been performed on the PTC on a specific date and time and to record real time events that accurately described: how the test (s) were conducted, the actual operating conditions of the test unit and any problems or upset that may have occurred as the test (s) proceeded, specific test parameters (such as injection rate of bromine, injection rate of sorbents, etc.), sample collection, data collection, and general observations. The date, operating conditions, test parameters, and events of testing are important for interpreting and understanding the data acquired from

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the testing. Access and input to the logbook was limited to the technicians and operators running the test on the PTC. For the September 2003 testing described here, those technicians and operators were working at the direction of myself and my co-inventors. These logbooks are provided at exhibits 2016 - 2018.

33. The logbook entry for September 18, 2003 at 18:36 records the addition of sodium bromide to the coal:



34. The logbook also records several additional times when a halide such as sodium bromide was added. In addition, the logbook records the use of activated carbon sorbent:

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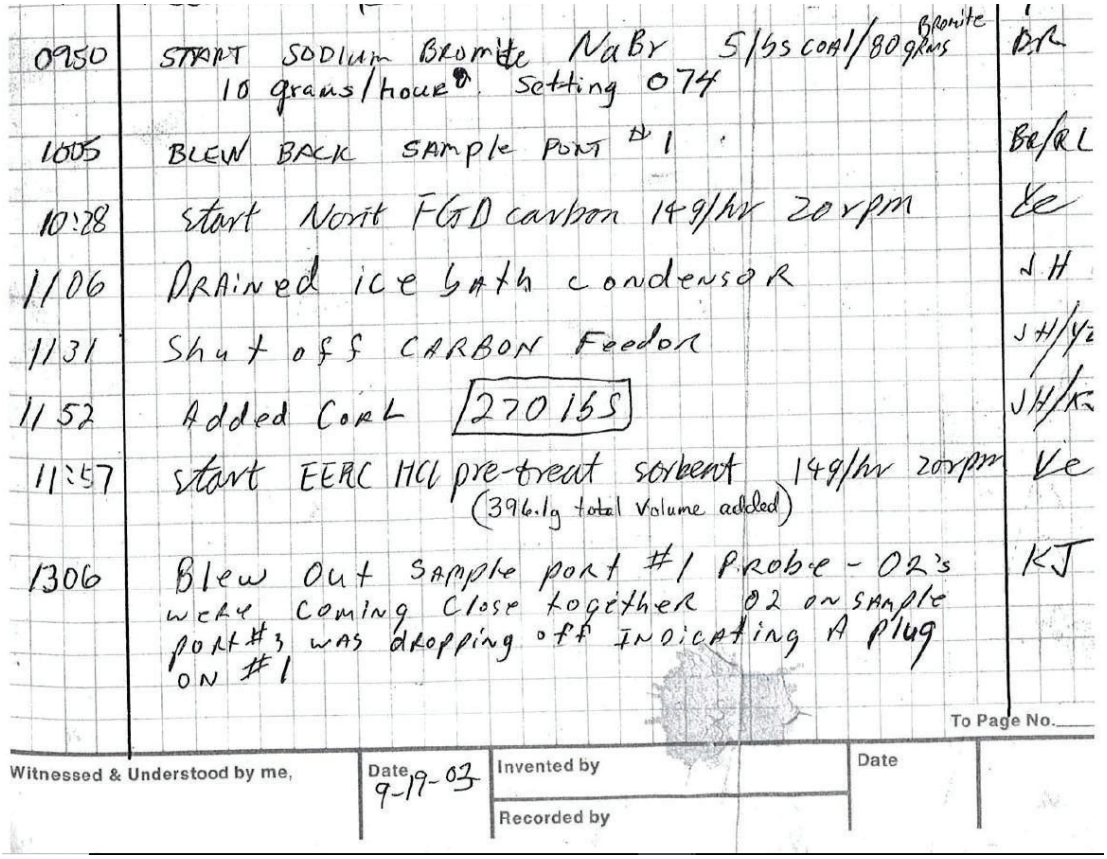
11:58	Added 1960.8 grams of Carbon to the k-tron feeder inlet ~~to the ESP~~	BR
12:25	Open port, installing Sampling Probe for M-26.	RL
12:26	Started M-26 sampling, ESP-inlet T1-9	GF
13:26	Done with M-26	
13:27	Port open to Remove Sampling ~~probe~~ probe M-26	RL

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Witnessed & Understood by me,	Date 9/18/03	Invented by	Date
		Recorded by	

1358	SHUT OFF CARBON + SALT FEEDERS - BYPASSED FLOW TO DROP ASH BOMB	BR
1408	FLOW BACK THROUGH ESP/ANPC - WHILE BYPASSED - DROPPED ASH BOMB - - PULSED/RAPPED ESP & ANPC - BLEW BACK HEAT TRACE LINE, FILTER AND PORT ON S.P. #1 - RESET DATA ADQUISITION	BR/RL
1414	FEEDERS BACK ON	BR

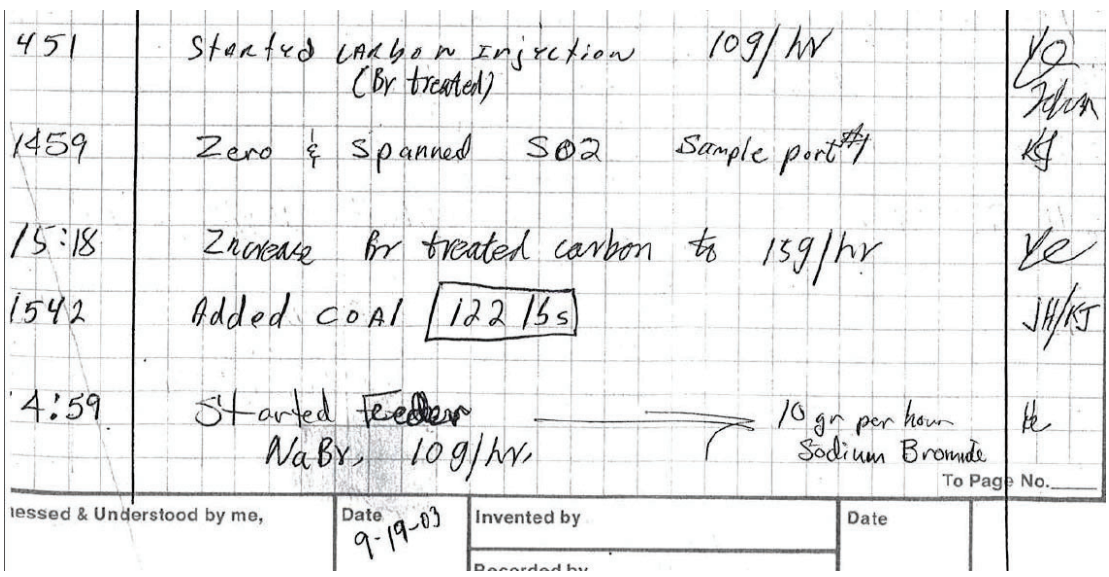
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0950	START SODIUM BROMIDE NaBr 5/55 coal/80 grams Bromite 10 grams/hour Setting 074	DR
1005	BLEW BACK SAMPLE PORT #1	BR/RL
10:28	start Norit FGD carbon 14g/hr 20rpm	Ve
1106	DRAined ice bath condensor	JH
1131	Shut off CARBON Feedor	JH/KJ
1152	Added Coal 270 lbs	JH/KJ
11:57	start EERC HCl pre-treat sorbent 14g/hr 20rpm (396.1g total Volume added)	Ve
1306	Blew Out SAMPLE port #1 PROBE - O2's were coming close together O2 on SAMPLE PORT #3 was dropping off INDICATING A PLUG ON #1	KJ

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Witnessed & Understood by me, Date 9-19-03 Invented by Recorded by Date

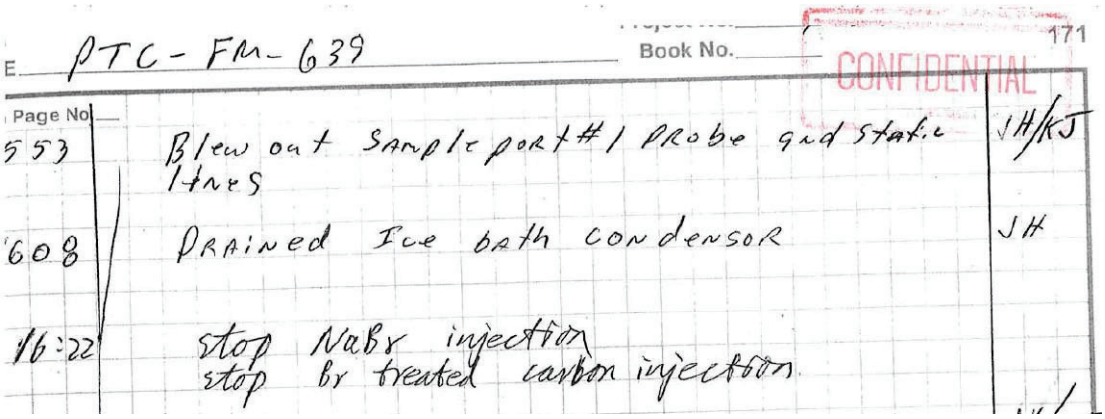


451	Started CARBON Injection 10g/hr (Br treated)	VO John
1459	Zero & Spanned SO2 Sample port #1	KJ
15:18	Increase Br treated carbon to 13g/hr	Ve
1542	Added COAL 122 lbs	JH/KJ
4:59	Started feeder NaBr, 10g/hr. 10 gm per hour Sodium Bromide	Ve

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E PTC-FM-639 Book No. 171
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553 Blew out Sample port #1 Probe and Static lines JH/KJ
608 Drained Ice bath condensor JH
16:22 stop NaBr injection
stop Br treated carbon injection

35. Note that the title in this logbook for this test is "PTC-FM-639." As explained below, the results of this testing were later reported to the DOE.

36. Below is an image of the additive apparatus used to supply additive to the coal feeder during these tests:



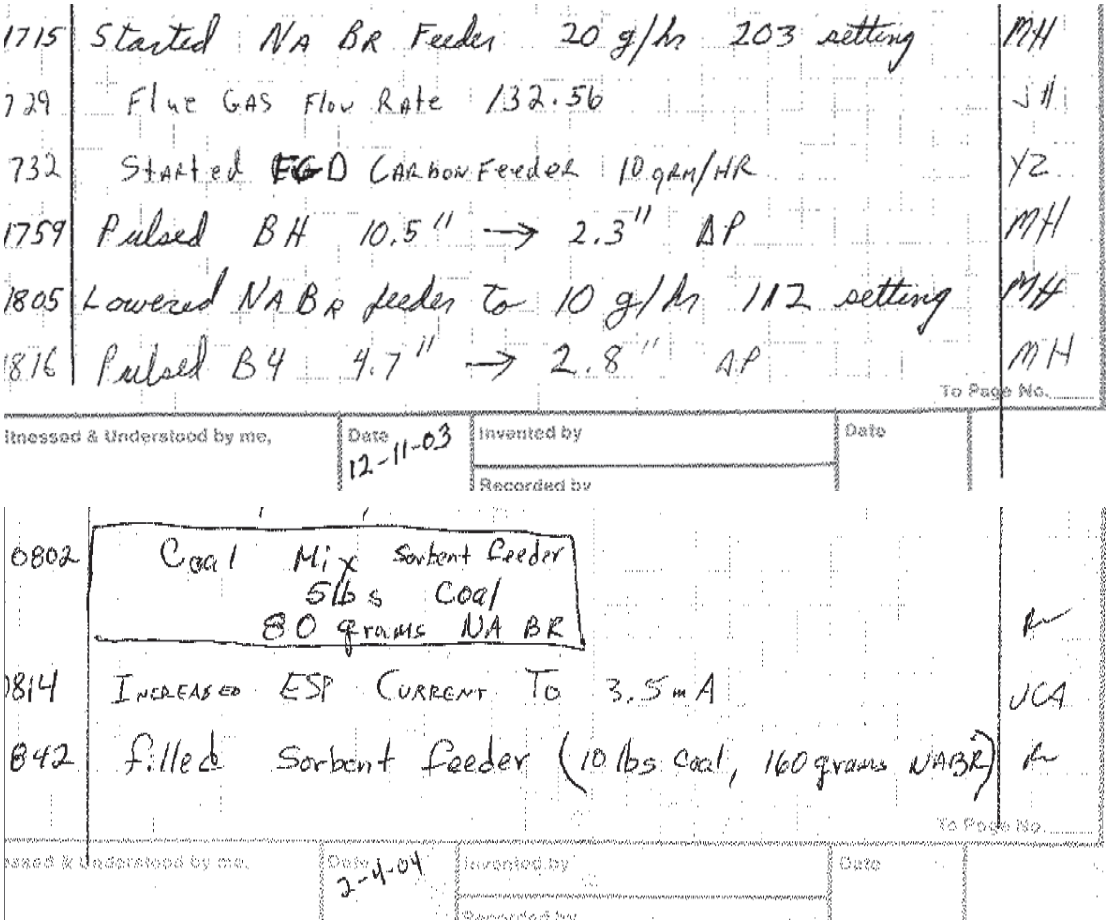
37. Below is an image of the activated carbon injection system used to inject sorbent during these tests:



38. The results from this September 2003 testing were significant. They confirmed that the use of bromine additive on the coal combined with activated carbon injection downstream from the combustion chamber provided significantly improved mercury capture as compared to methods employing chlorine additive or activated carbon without bromine addition. As a result, the EERC initially decided to maintain the use of bromine as an in-situ treatment as proprietary intellectual property.

39. The EERC also conducted additional follow up testing in late 2003, early 2004, and spring/summer of 2004. Some samples of log book entries from those tests are shown below:

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1715 Started NA BR Feeder 20 g/hr 203 setting MH
729 Flue GAS Flow Rate 132.56 JH
732 Started ~~EGD~~ CARBON Feeder 10 GRM/HR YZ
1759 Pulsed BH 10.5" → 2.3" ΔP MH
1805 Lowered NA BR feeder to 10 g/hr 112 setting MH
1816 Pulsed BH 4.7" → 2.8" ΔP MH

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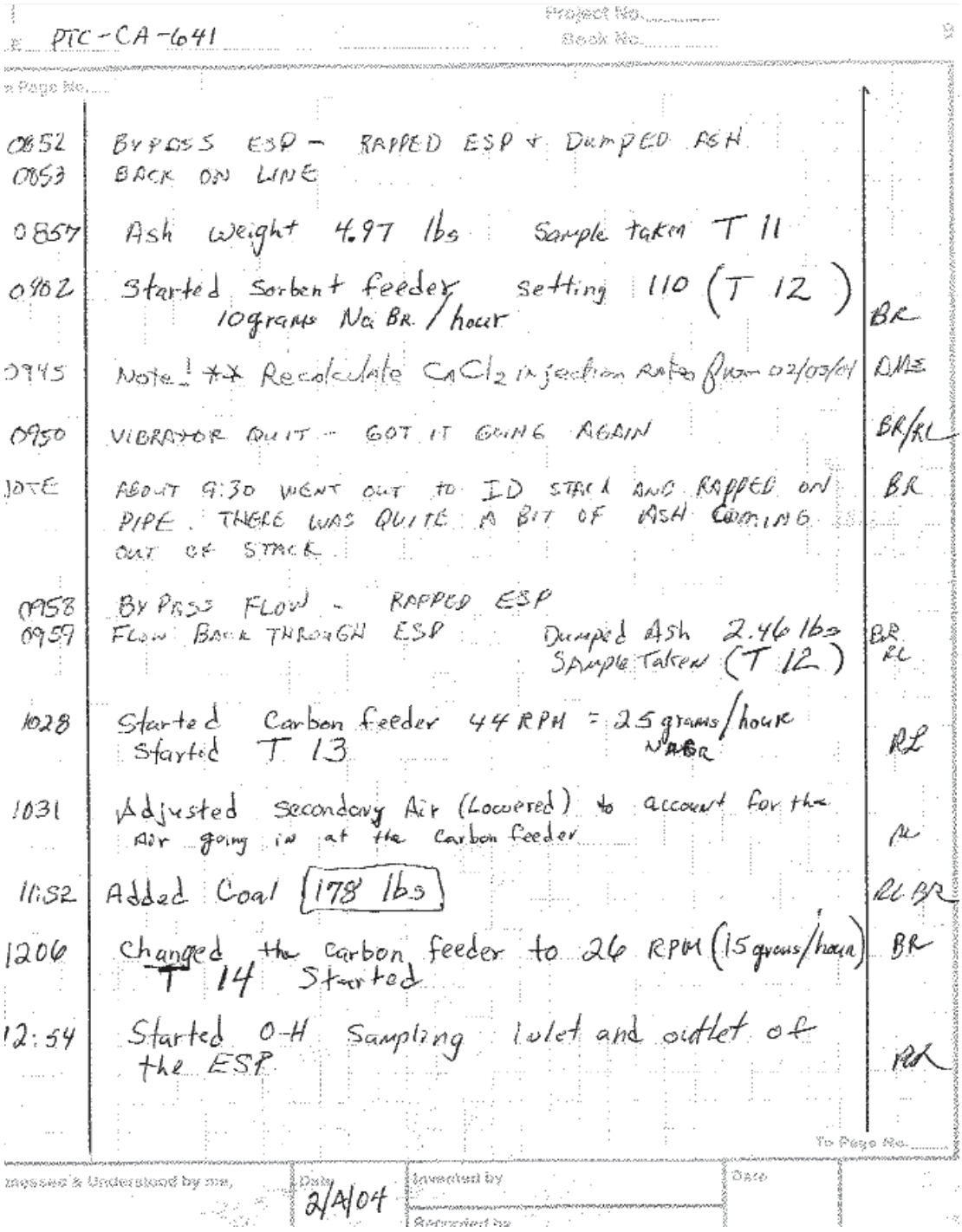
Witnessed & Understood by me, Date 12-11-03 Invented by Date Recorded by

0802 Coal Mix Sorbent Feeder 5lbs Coal 80 grams NA BR
0814 INCREASED ESP CURRENT TO 3.5 mA JCA
0842 filled Sorbent feeder (10 lbs coal, 160 grams NABR)

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Witnessed & Understood by me, Date 2-4-04 Invented by Date Recorded by

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0852	BYPASS ESP - RAPPED ESP & DUMPED ASH	
0853	BACK ON LINE	
0857	Ash Weight 4.97 lbs Sample taken T 11	
0902	Started Sorbent feeder setting 110 (T 12) 10 grams Na Br / hour	BR
0945	Note! ** Recalculate $CaCl_2$ injection rate from 02/03/04	DME
0950	VIBRATOR QUIT - GOT IT GOING AGAIN	BR/RL
NOTE	ABOUT 9:30 WENT OUT TO ID STACK AND RAPPED ON PIPE. THERE WAS QUITE A BIT OF ASH COMING OUT OF STACK	BR
0958	BY PASS FLOW - RAPPED ESP	
0959	FLOW BACK THROUGH ESP Dumped Ash 2.46 lbs Sample Taken (T 12)	BR RL
1028	Started Carbon feeder 44 RPM = 25 grams/hour Started T 13 NaBr	RL
1031	Adjusted Secondary Air (Louvered) to account for the Air going in at the Carbon feeder	RL
11:52	Added Coal 178 lbs	RL BR
1206	Changed the Carbon feeder to 26 RPM (15 grams/hour) T 14 Started	BR
12:54	Started O-H Sampling Inlet and outlet of the ESP	RL

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Witnessed & Understood by me, Date 2/4/04 Corrected by Date

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Book No. TITLE PTC-CA-641

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1455	Sorbent feed turned off Done with O-H Sampling T-14	
1512	Bypassed flow, Power off Rapped	MH KJ
1515	ESP back on Line dumped Ash [10.75 lbs] Took sample	MH/KJ
534	Finished Adding coal [500 lbs]	KJ/MH
550	Started Sorbent feed NaBr 5 grams per hour [78 set pt]	KJ/DM
1640	Had problems with O2. Found that when Dirt was separated Thig had changed some of the Input signales Reading right now	DK MH JA
1646	Installed probe	GF
1647	Start of T-15 Method 29 inlet	GF MH
1747	E.O.T.-15 Method 29 inlet	GF MH
1749	Removed Sample probe	GF
1751	Reduced Sorbent feed NaBr To [60 set pt] 2.5 g/hr.	MH
1845	Shut off Sorbent feeder [NaBr]	KJ/DM
1857	Cleaned out Sorbent feeder Then put in 1.25 g of NaBR / $CaCl_2$ lbs/hr Setting on feeder of 110 ~ 285 g/hr of the mix 10 grams NaBR 13.24 g $CaCl_2 \cdot 2H_2O$ 5 lbs coal	MH KJ

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In particular, in February 2004 we performed additional testing with greater variation in the ratios of bromine (bromides, bromine, bromine compounds, bromine salts, etc.) to activated carbon. This additional testing demonstrated that even relatively small amounts of added bromine could significantly improve mercury capture, despite other theorized reactions that could potentially occur and consume bromine in coal combustion flue gas.

EERC Reports the Results to the DOE

40. Following the testing described above, the EERC prepared various reports to the DOE describing tests conducted by the EERC, and interpretation of the data obtained from these tests. My co-inventors and I received support from others at the EERC in preparing these reports. I do not believe that any of those individuals contributed to the actual inventions claimed in the applications that ultimately led to the ’114 and ’147 patents.

41. In February 2004, the EERC delivered a report to the DOE describing the results of our September 2003 testing (the “Feb. 2004 Report”).[18] This report explained that coal and additives were added to the PTC (i.e., upstream of the combustor) and sorbent was injected downstream of the combustor. Mercury levels were monitored both before and after the emission gas passed through an electrostatic precipitator (ESP) by using a continuous mercury monitor (CMM):

[18] See Ex. 2011, Feb. 2004 Report at 12 (providing coal analysis for “PTC-FM-639,” the PTC testing identifier from the logbooks described above); 17 (explaining that this testing occurred in September 2003).

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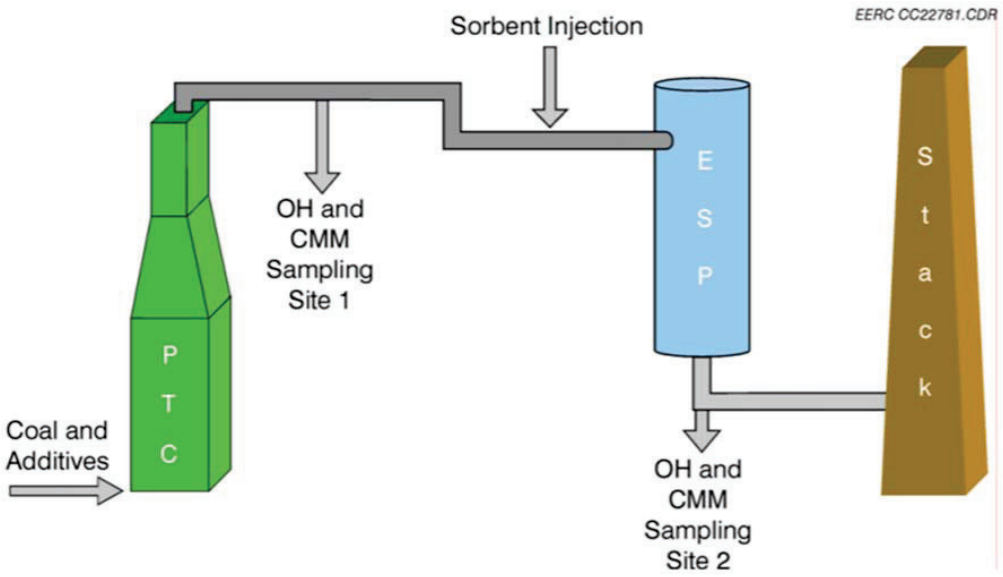


Figure 4. Injection and sampling schematic of the PTC with an ESP.

42. The report also described the 14 tests conducted during the September tests:

Table 1. Test Matrix for Unscrubbed Systems Equipped with ESPs

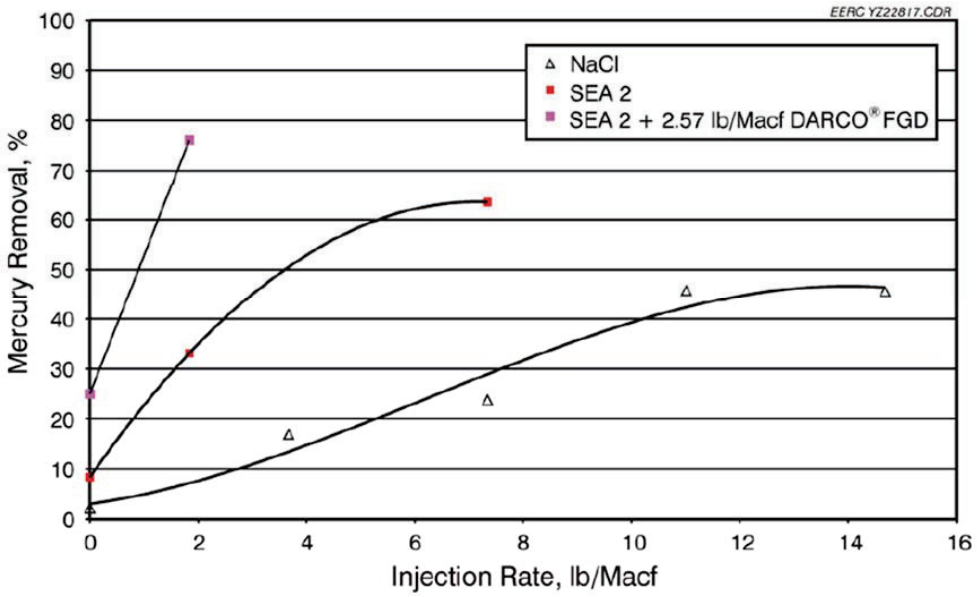
Test No.	Mercury Oxidant Additive		Sorbent	
	Category	Injection Rate, lb/Macf	Category	Injection Rate, lb/Macf
T1-1(Baseline)	None	NA	None	NA
T1-2	None	NA	DARCO® FGD	2.75–18.4
T1-3	NaCl	3.76–14.7	None	NA
T1-4	NaCl	3.76–14.7	DARCO® FGD	2.75–4.59
T1-5	SEA 2	1.84–7.34	None	NA
T1-6	SEA 2	1.84	DARCO® FGD	2.57
T1-7	NaCl	7.34–11.0	HCl-Treated FGD	2.57–4.59
T1-8	None	NA	EERC-Treated Carbon	1.84–2.75
T1-9	SEA 2	1.84	EERC-Treated Carbon	2.75
T1-10	Zn	7.34	None	NA
T1-11	Zn and NaCl	7.34–11.0	None	NA
T1-12	None	NA	Na_2S_4 (solution)	0.89–6.67
T1-13	$CaCl_2$	11	DARCO® FGD	0–4.59
T1-14	None	NA	ALSTOM Sorbent	1.1–3.1

43. This test matrix indicates that test T-6 employed the additive SEA2 and the sorbent DARCO FGD. DARCO FGD is the trade name for a powdered activated carbon product from Cabot (formerly Norit Americas). "SEA2" was a code name for the sodium bromide additive because, at the time, the EERC maintained the

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specific chemical composition of SEA2 as proprietary. Nonetheless, as noted above from the logbook, this additive was sodium bromide.

44. In February 2005, the EERC provided a further report to the DOE with additional analysis of this testing (the "Feb. 2005 Report").[19] It noted: "The significant improvement by DARCO® FGD–SEA2 is not merely an additive effect but more a synergistic response. The SEA2 addition in the combustion zone not only enhances gaseous mercury conversion to particulate-associated mercury, but also improves DARCO® FGD carbon reactivity with mercury species." It also reported that the combination of SEA2 and activated carbon performed significantly better than alternative approaches:



45. This report also described additional testing performed with SEA2 and activated carbon in December 2003, as noted in the PTC logbook shown below.

[19] See Ex. 2012, Feb. 2005 Report at 10 (providing coal analysis for "PTC-FM-639," the PTC testing identifier from the logbooks described above); 9 (explaining that this testing occurred in September 2003).

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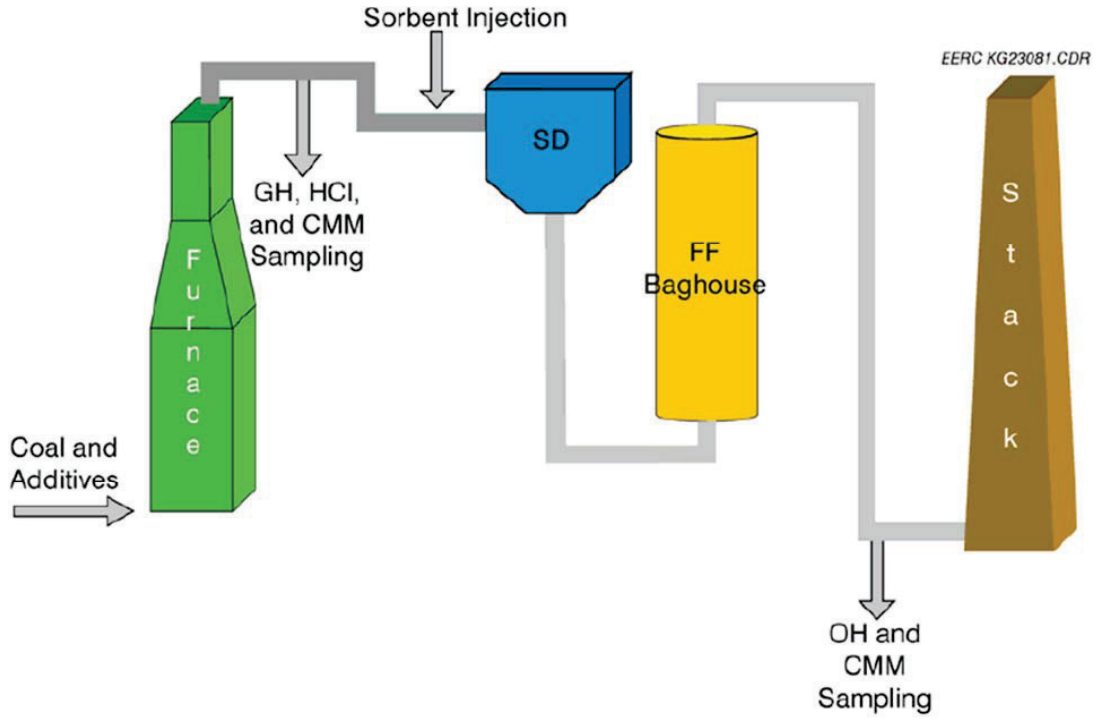
1715	Started NA BR Feeder 20 g/hr 203 setting	MH
729	Flue GAS Flow Rate 132.56	JH
732	Started EGD CARBON Feeder 10 GRM/HR	YZ
1759	Pulsed BH 10.5" → 2.3" ΔP	MH
1805	Lowered NABR feeder to 10 g/hr 112 setting	MH
816	Pulsed BH 4.7" → 2.8" ΔP	MH

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Witnessed & Understood by me, Date 12-11-03 Invented by Date

Recorded by

The results of the December 2003 tests are shown below (Feb. 2005 Report at 23, 25, 28):



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Table 10. Mercury Control Test Matrix

Coal Additive	Feed Rate, lb/Macf	Sorbent	Injection Rate, lb/Macf
None	NA	None	NA
None	NA	DARCO® FGD	1.84, 3.67, 7.35, and 11.0
None	NA	EERC-treated FGD	1.84, 3.67, and 7.35
None	NA	Amended Silicate™	7.35
NaCl	3.67, 7.35, and 11.0	None	NA
NaCl	3.67, 7.35, and 11.0	DARCO® FGD	3.67
SEA2	1.84 and 3.67	None	NA
SEA2	1.84 and 3.67	DARCO® FGD	1.84
$CaCl_2$	3.67, 7.35, and 11.0	None	NA
$CaCl_2$	3.67, 7.35, and 11.0	DARCO® FGD	3.67

46. The chart below provides an exemplary description of the effect of varying SEA2 and carbon addition rates on mercury capture:

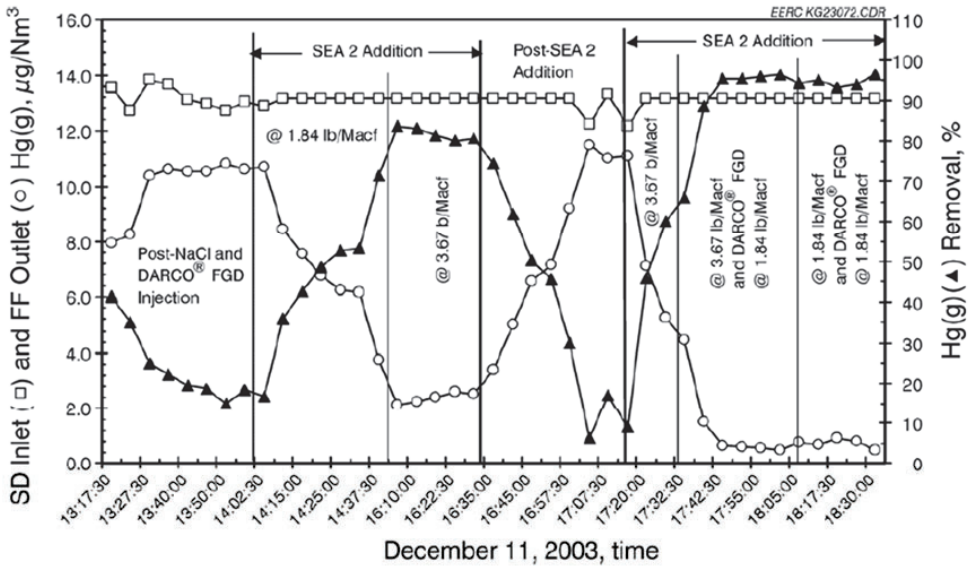


Figure 40. SDA inlet and FF outlet CMM results and SDA–FF Hg(g) removal efficiencies before, during, and after SEA2 additions and DARCO® FGD injection into the Center lignite coal and combustion flue gas, respectively.

47. An October 2005 Report described further testing conducted in February 2004 (the "Oct. 2005 Report"):[20]

Table 9-2. Week 1 – Test Matrix

Date	Sampling Inlet	Sampling Outlet	Sorbent	Rate, g/hr	Rate, lb/MMacf	Oxidant	Rate, g/hr	Rate, lb/MMacf
2/2/04	OH	OH	Baseline					
	M-29		Baseline					
			DARCO	25.0	7.03			
			DARCO	28.0	7.84			
			DARCO	32.0	8.96			
		OH	DARCO	45.0	12.60			
			DARCO	69.0	19.20			
2/3/04			Baseline					
						SEA1	15.2	4.28
						SEA1	29.8	8.38
			DARCO	25.0	7.03	SEA1	29.8	8.38
	OH	OH	DARCO	25.0	7.03	SEA1	45.5	12.80
	M-29		DARCO	25.0	7.03	SEA1	59.9	16.73
			DARCO	25.0	7.03	SEA1	15.2	4.28
2/4/04			Baseline					
						SEA2	9.8	2.73
			DARCO	25.0	6.96	SEA2	9.8	2.73
	OH	OH	DARCO	15.0	4.18	SEA2	9.8	2.73
			DARCO	15.0	4.18			
	M-29		DARCO	15.0	4.18	SEA2	6.9	1.92
			DARCO	15.0	4.18	SEA2	4.3	1.20
			DARCO	15.0	4.18			
			DARCO	15.0	4.18	SEA1–SEA2	2.6	0.72
2/5/2004			Baseline					
	OH	OH	EERC carbon	25.0	6.97			
			EERC carbon	35.0	9.76			
			Am. Silicate	25.0	6.91			
			Am. Silicate	50.0	13.82			

Notes:
M-29 = EPA Method 29
EERC carbon = EERC-treated DARCO carbon
Am. Silicate = Amended Silicate
SEA1–SEA2 = 50%–50% blend of SEA1 and SEA2. The total rate for both is given.

Conclusion

[20] Ex. 2013, Oct. 2005 Report at 20 ("EPA Method 29 was used for trace element sampling of the flue gas during Week 1 (February 2–4, 2004) testing of Caballo coal. Samples were collected at the ESP inlet upstream of the carbon injection location during three different conditions: baseline and SEA1 and SEA2 additions. The objective was to determine the effects of SEA additions on trace metal concentrations and particle–gas partitioning."); Oct. 2005 Report at 27

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48. As explained above, my co-inventors and I conceived of the inventions of the '114 and '147 patents at least as early as August 2002. We reduced those inventions to practice at least by September 2003 as documented in testing logbooks and EERC reports to the DOE.

49. A claim chart exhibit comparing these documents to the claims of the '114 and '147 patents is attached to this declaration.

50. I further declare that all statements made herein of my own knowledge are true, and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by a fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the patents at issue in these proceedings.

Dated: 7-27-2020

By: John Pavlish

John Pavlish

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UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

NRG ENERGY, INC.
TALEN ENERGY CORPORATION, and
VISTRA ENERGY Corp.
Petitioners

v.

MIDWEST ENERGY EMISSIONS CORP.
Patent Owner

DECLARATION OF INVENTOR EDWIN S. OLSON

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I, Edwin Olson, declare and say as follows:

1. I am a citizen of the United States and am over 18 years of age. I have personal knowledge of the matters stated in this declaration.
2. I am currently retired and am not being compensated for this testimony
3. I am one of the named inventors for the '114 and '147 patents.
4. I have reviewed the declaration of John Pavlish describing the conception and reduction to practice of those patents.
5. I agree with the testimony provided in that declaration and confirm that it is an accurate description of the work I and my co-inventors (John Pavlish and Mike Holmes) did to conceive and reduce to practe the inventions of the '114 and '147 patents.
6. I further declare that all statements made herein of my own knowledge are true, and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by a fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the patents at issue in these proceedings.

Dated: 7-26-2020 By: Edwin Olson

Edwin Olson

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UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

NRG ENERGY, INC.
TALEN ENERGY CORPORATION, and
VISTRA ENERGY Corp.
Petitioners

v.

MIDWEST ENERGY EMISSIONS CORP.
Patent Owner

DECLARATION OF INVENTOR MICHAEL J. HOLMES

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I, Michael Holmes, declare and say as follows:

1. I am a citizen of the United States and am over 18 years of age. I have personal knowledge of the matters stated in this declaration.

2. I am currently employed at the Lignite Energy Council and do not work for the EERC or Midwest Energy Emissions Corp.

3. I am not being compensated for this testimony.

4. I am one of the named inventors for the '114 and '147 patents.

5. I have reviewed the declaration of John Pavlish describing the conception and reduction to practice of those patents.

6. I agree with the testimony provided in that declaration and confirm that it is an accurate description of the work I and my co-inventors (John Pavlish and Edwin Olson) did to conceive and reduce to practe the inventions of the '114 and '147 patents.

7. I further declare that all statements made herein of my own knowledge are true, and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by a fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the patents at issue in these proceedings.

Dated: 7/27/2020

By: Michael E. Holmes

Michael Holmes

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'114 Claim Chart

No.	'114 Claim Element	Evidence of Reduction to Practice
1a	A method of separating mercury from a mercury-containing gas, the method comprising:	The Feb. 2004 Report describes the September 2003 testing (page 10): The pilot-scale test was started on September 8, 2003, and was completed on September 19, 2003. A 550,000-Btu/hr pulverized coal (pc)-fired unit, known as the PTC, was used to fire lignites and test mercury control options. The coal combustion flue gas exiting the PTC was cooled down to a nominal temperature of 149°C (300°F) and then was introduced into a single-wire tubular ESP unit. Figure 4 shows the schematic diagram of the system. Furnace additives were added to coal prior to introduction to the furnace. Mercury sorbents were fed with a K-Tron dual-screw feeder upstream of the ESP. CMMs were used to monitor mercury vapor concentrations at the ESP inlet (Site 1) and outlet (Site 2) 24 h per day for the entire testing period. Several OH method samples (ASTM D6784 Standard Test Method for Elemental, Oxidized, Particle-Bound and Total Mercury in Flue Gas Generated from Coal-Fired Stationary Sources) were collected at the ESP inlet and outlet throughout the testing period as verification of the CMM data. Fourteen tests were completed to evaluate various sorbent and mercury oxidant performance on mercury removal across the ESP as functions of feed rate. A detailed test matrix is listed in Table 1. Ten additional tests were performed to evaluate mercury control with the *Advanced Hybrid*™ filter and are summarized under Task 4 Results and Discussion. The Feb. 2004 Report also describes additional testing in December 2003 (page 14-15):

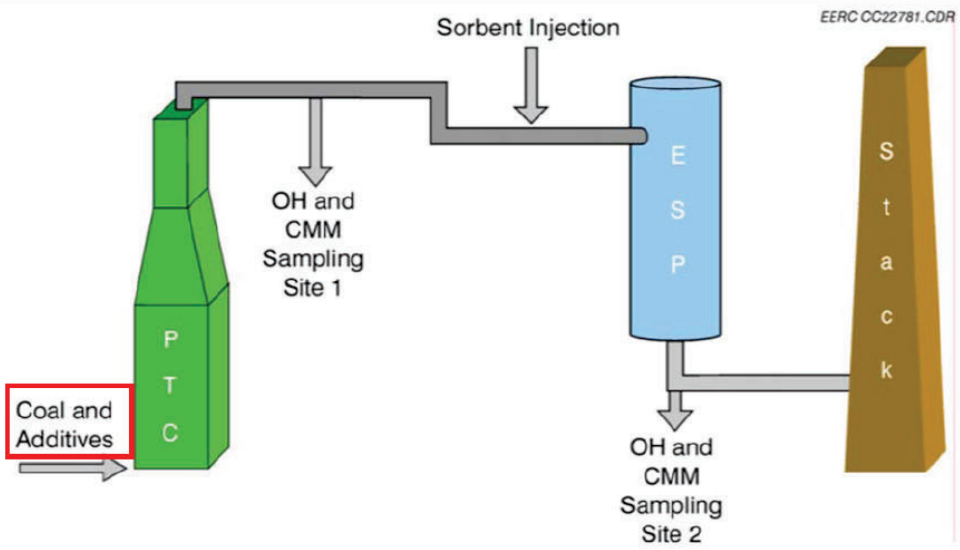
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No.	'114 Claim Element	Evidence of Reduction to Practice
		One week of short-term sorbent (Task 2.2) and furnace additive testing was accomplished in December 2003 to demonstrate mercury removal by sorbent injection combined with various oxidizing additives to simulate a scrubbed baghouse system. The 580 MJ/h (550,000 Btu/h) pulverized coal PTC unit was equipped with a Niro Inc. Produciton Minor Spray Dryer Model I and baghouse and fired with Center lignite coal. Table 4 summarizes the test matrix for the spray dryer–baghouse configuration. Based on previous pilot-scale testing results of ESP mercury removal effectiveness, three additives (NaCl, $CaCl_2$, and another for which the EERC is assessing the intellectual property issues) were evaluated. CMMs were set up at the inlet to the spray dryer upstream of the sorbent injection port at the outlet of the baghouse to monitor mercury vapor concentrations continuously throughout the 4-day test. Six OH method samples were collected at the same locations to verify CMM measurements and performance of the sorbents and additive injection. A Thermo Environmental Model 15C HCl analyzer was The October 2005 Report describes additional testing in February 2004 (page 20): sulfuric acid (H_2SO_4)–potassium permanganate ($KMnO_4$) solutions. EPA Method 29 was used for trace element sampling of the flue gas during Week 1 (February 2–4, 2004) testing of Caballo coal. Samples were collected at the ESP inlet upstream of the carbon injection location during three different conditions: baseline and SEA1 and SEA2 additions. The objective was to determine the effects of SEA additions on trace metal concentrations and particle–gas partitioning.
1b	combusting coal in a combustion chamber, to provide	The Feb. 2004 Report explains that coal was combusted in a 550,000-Btu/hr pc-fire combustor (known as the PTC) (page 10):

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No.	'114 Claim Element	Evidence of Reduction to Practice
	the mercury-containing gas,	The pilot-scale test was started on September 8, 2003, and was completed on September 19, 2003. A 550,000-Btu/hr pulverized coal (pc)-fired unit, known as the PTC, was used to fire lignites and test mercury control options. The coal combustion flue gas exiting the PTC was cooled down to a nominal temperature of 149°C (300°F) and then was introduced into a single-wire tubular ESP unit. Figure 4 shows the schematic diagram of the system. Furnace additives were added to coal prior to introduction to the furnace. Mercury sorbents were fed with a K-Tron dual-screw feeder upstream of the ESP.
1c	wherein the mercury-containing gas comprises a halogen or halide promoter comprising HBr, Br^-, or a combination thereof, wherein the coal comprises added Br_2, HBr, Br^-, or a combination thereof, added to	The Feb. 2004 Report describes adding coal and additives (including SEA 2) to the combustion chamber during the September 2003 testing (page 18): SEA 2 is noted as NaBr in the PTC logbooks, and when combusted with coal, produces a mercury-containing gas comprised of a bromine halogen or halide promoter.

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No.	'114 Claim Element	Evidence of Reduction to Practice
	the coal upstream of the combustion chamber, or the combustion chamber comprises added Br_2, HBr, Br^-, or a combination thereof, or a combination thereof;	 Figure 4. Injection and sampling schematic of the PTC with an ESP. *See also* Feb. 2004 Report at 17 ("mercury oxidants including NaCl, SEA 2, and zinc were examined for their impacts on mercury removal."); 15 ("Based on previous pilot-scale testing results of ESP mercury removal effectiveness, three additives (NaCl, CaCl2, and another for which the EERC is assessing the intellectual property

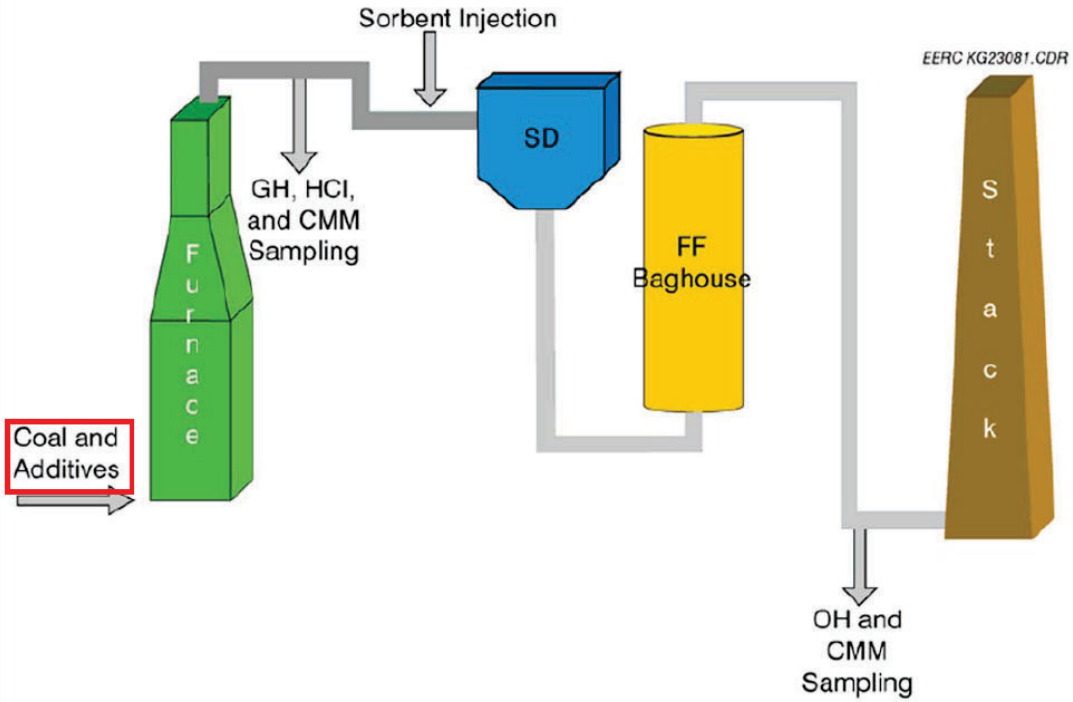
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No.	'114 Claim Element	Evidence of Reduction to Practice
		issues) were evaluated."); Final Report at 25 ("SEA2 is a proprietary Hg^0 oxidizing agent effective at addition rates on the order of 1/10 of those for SEA1.") The PTC Log Book identifies the SEA2 additive used as sodium bromide, which includes Br^-. Thus, the mercury-containing gas, the coal, and the combustion chamber comprised HBr, Br2, and Br^-. 1836 STARTED SODIUM BROMIDE FEEDER @ 40 gr/HR 375 SCF 3 lbs coal – 48g Sodium Bromide 1904 Added 20 lbs Coal 1926 Added new batch Sodium Bromide Coal to feeder Same blend 3 lbs C – 48g SB @ 40 gr/hr SEA2 and activated carbon were similarly used during the December 2003 testing. *See* Feb. 2004 Report at 15: One week of short-term sorbent (Task 2.2) and furnace additive testing was accomplished in December 2003 to demonstrate mercury removal by sorbent injection combined with various oxidizing additives to simulate a scrubbed baghouse system. The 580 MJ/h (550,000 Btu/h) pulverized coal PTC unit was equipped with a Niro Inc. Produciton Minor Spray Dryer Model I

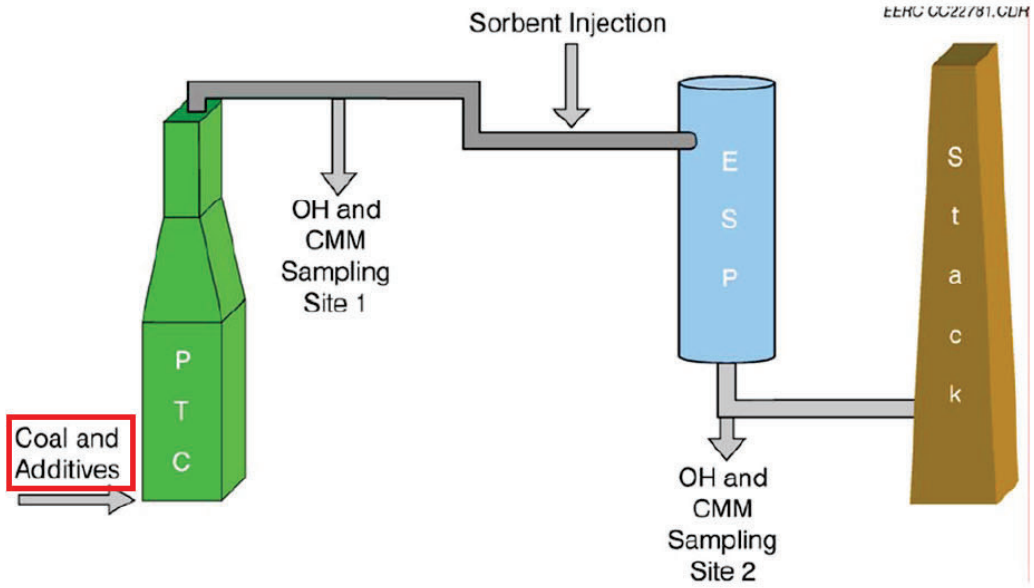
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No.	'114 Claim Element	Evidence of Reduction to Practice
		and baghouse and fired with Center lignite coal. Table 4 summarizes the test matrix for the spray dryer–baghouse configuration. Based on previous pilot-scale testing results of ESP mercury removal effectiveness, three additives (NaCl, $CaCl_2$, and another for which the EERC is assessing the intellectual property issues) were evaluated. CMMs were set up at the inlet to the spray dryer upstream of the sorbent injection port at the outlet of the baghouse to monitor mercury vapor concentrations continuously throughout the 4-day test. Six OH method samples were collected at the same locations to verify CMM measurements and performance of the sorbents and additive injection. A Thermo Environmental Model 15C HCl analyzer was *See* Feb. 2005 Report at 25 ("Pilot-scale Hg control testing was conducted December 8–11, 2003, using a 580-MJ/hr (550,000-Btu/hr) pc-fired unit equipped with a Niro Inc. Production Minor Spray Dryer Model I and baghouse."); at 27 ("Nine tests were completed to evaluate the effectiveness of potential Hg sorbents (DARCO® FGD, EERC-treated FGD, and Amended Silicate™) and Hg0 oxidation and sorbent enhancement additives (NaCl, SEA2, and CaCl2) to remove Hg using a SDA and FF."); at 25:

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No.	'114 Claim Element	Evidence of Reduction to Practice
		 SEA2 and activated carbon were also used in the February 2004 testing. Oct. 2005 Report at 20:

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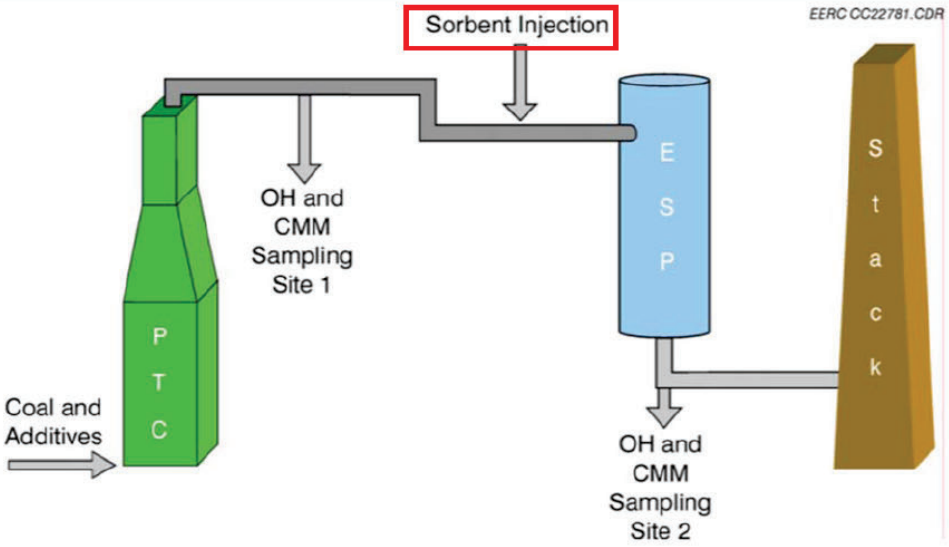
No.	'114 Claim Element	Evidence of Reduction to Practice
		sulfuric acid (H_2SO_4)–potassium permanganate ($KMnO_4$) solutions. EPA Method 29 was used for trace element sampling of the flue gas during Week 1 (February 2–4, 2004) testing of Caballo coal. Samples were collected at the ESP inlet upstream of the carbon injection location during three different conditions: baseline and SEA1 and SEA2 additions. The objective was to determine the effects of SEA additions on trace metal concentrations and particle–gas partitioning. Oct. 2005 Report at 26: 

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<table>
<tr><th>No.</th><th>'114 Claim Element</th><th>Evidence of Reduction to Practice</th></tr>
<tr><td>1d</td><td>injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber;</td><td>The Feb. 2004 Report describes injecting Darco FGD activated carbon into the mercury-containing gas downstream of the combustion chamber during the September 2003 testing (page 11):

Table 1. Test Matrix for Unscrubbed Systems Equipped with ESPs
<table>
<tr><th rowspan="2">Test No.</th><th colspan="2">Mercury Oxidant Additive</th><th colspan="2">Sorbent</th></tr>
<tr><th>Category</th><th>Injection Rate, lb/Macf</th><th>Category</th><th>Injection Rate, lb/Macf</th></tr>
<tr><td>T1-1(Baseline)</td><td>None</td><td>NA</td><td>None</td><td>NA</td></tr>
<tr><td>T1-2</td><td>None</td><td>NA</td><td>DARCO® FGD</td><td>2.75–18.4</td></tr>
<tr><td>T1-3</td><td>NaCl</td><td>3.76–14.7</td><td>None</td><td>NA</td></tr>
<tr><td>T1-4</td><td>NaCl</td><td>3.76–14.7</td><td>DARCO® FGD</td><td>2.75–4.59</td></tr>
<tr><td>T1-5</td><td>SEA 2</td><td>1.84–7.34</td><td>None</td><td>NA</td></tr>
<tr><td>T1-6</td><td>SEA 2</td><td>1.84</td><td>DARCO® FGD</td><td>2.57</td></tr>
<tr><td>T1-7</td><td>NaCl</td><td>7.34–11.0</td><td>HCl-Treated FGD</td><td>2.57–4.59</td></tr>
<tr><td>T1-8</td><td>None</td><td>NA</td><td>EERC-Treated Carbon</td><td>1.84–2.75</td></tr>
<tr><td>T1-9</td><td>SEA 2</td><td>1.84</td><td>EERC-Treated Carbon</td><td>2.75</td></tr>
<tr><td>T1-10</td><td>Zn</td><td>7.34</td><td>None</td><td>NA</td></tr>
<tr><td>T1-11</td><td>Zn and NaCl</td><td>7.34–11.0</td><td>None</td><td>NA</td></tr>
<tr><td>T1-12</td><td>None</td><td>NA</td><td>Na_2S_4 (solution)</td><td>0.89–6.67</td></tr>
<tr><td>T1-13</td><td>$CaCl_2$</td><td>11</td><td>DARCO® FGD</td><td>0–4.59</td></tr>
<tr><td>T1-14</td><td>None</td><td>NA</td><td>ALSTOM Sorbent</td><td>1.1–3.1</td></tr>
</table>
See also Feb. 2004 Report at 15 (describing "DARCO® FGD activated carbon, supplied by NORIT Americas, Inc.; an EERC-treated activated carbon")</td></tr>
</table>

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No.	'114 Claim Element	Evidence of Reduction to Practice
		 Figure 4. Injection and sampling schematic of the PTC with an ESP. The Feb. 2004 Report also describes injecting activated carbon sorbent during the December 2003 testing:[21]

[21] This table refers to a "December 2004 run," which is a typo. It should refer to a December 2003 run as noted in the preceding paragraph. Final Report at 14 ("One week of short-term sorbent (Task 2.2) and furnace additive testing was accomplished in

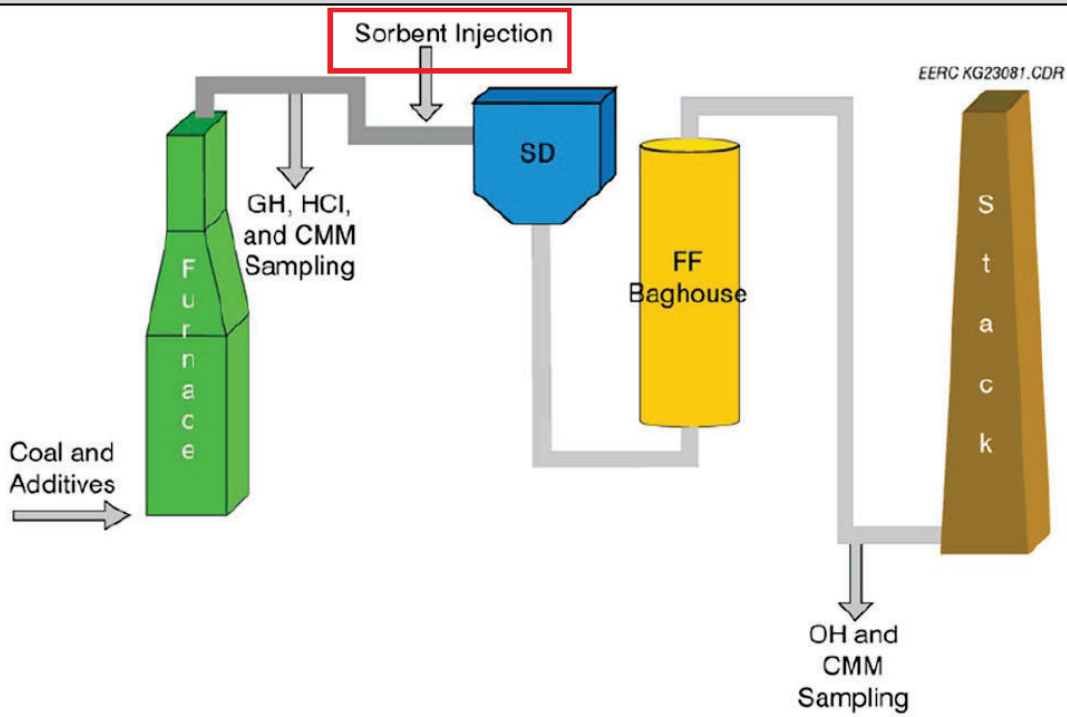
No.	'114 Claim Element	Evidence of Reduction to Practice
		Table 4. Spray Dryer Test Sample Matrix (December 2004 run)

Mercury Oxidation Additive		Sorbent	
Type	Feed Rate, lb/Macf	Type	Injection Rate, lb/Macf
None	NA	None	NA
None	NA	DARCO® FGD	1.84 – 11.02
None	NA	EERC-Treated FGD	1.84 – 7.35
None	NA	Amended Silicate™	7.35
NaCl	3.67 – 11.02	None	NA
NaCl	3.67 – 11.02	DARCO® FGD	3.67
SEA 2	1.84 – 3.67	None	NA
SEA 2	1.84 – 3.67	DARCO® FGD	1.84
$CaCl_2$	3.67 – 11.02	None	NA
$CaCl_2$	3.67 – 11.03	DARCO® FGD	3.67

See also Feb. 2005 Report at 25:

December 2003 to demonstrate mercury removal by sorbent injection combined with various oxidizing additives to simulate a scrubbed baghouse system."). This is also evidence based on the fact that the Final Report was prepared in February 2004.

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No.	'114 Claim Element	Evidence of Reduction to Practice
		 The Oct. 2005 Report describes injecting activated carbon sorbent during the February 2004 testing (pages 26-27):

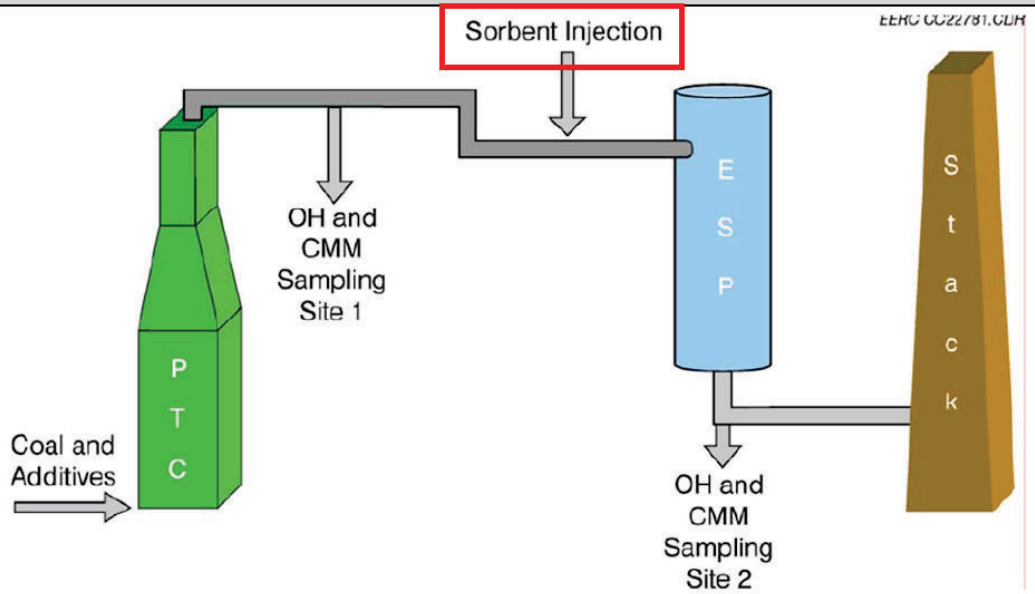
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Table 9-2. Week 1 – Test Matrix

Date	Sampling Inlet	Sampling Outlet	Sorbent	Rate, g/hr	Rate, lb/MMacf	Oxidant	Rate, g/hr	Rate, lb/MMacf
2/2/04	OH	OH	Baseline					
	M-29		Baseline					
			DARCO	25.0	7.03			
			DARCO	28.0	7.84			
			DARCO	32.0	8.96			
		OH	DARCO	45.0	12.60			
			DARCO	69.0	19.20			
2/3/04			Baseline					
						SEA1	15.2	4.28
						SEA1	29.8	8.38
			DARCO	25.0	7.03	SEA1	29.8	8.38
	OH	OH	DARCO	25.0	7.03	SEA1	45.5	12.80
	M-29		DARCO	25.0	7.03	SEA1	59.9	16.73
			DARCO	25.0	7.03	SEA1	15.2	4.28
2/4/04			Baseline					
						SEA2	9.8	2.73
			DARCO	25.0	6.96	SEA2	9.8	2.73
	OH	OH	DARCO	15.0	4.18	SEA2	9.8	2.73
			DARCO	15.0	4.18			
	M-29		DARCO	15.0	4.18	SEA2	6.9	1.92
			DARCO	15.0	4.18	SEA2	4.3	1.20
			DARCO	15.0	4.18			
			DARCO	15.0	4.18	SEA1–SEA2	2.6	0.72
2/5/2004			Baseline					
	OH	OH	EERC carbon	25.0	6.97			
			EERC carbon	35.0	9.76			
			Am. Silicate	25.0	6.91			
			Am. Silicate	50.0	13.82			

Notes:
M-29 = EPA Method 29
EERC carbon = EERC-treated DARCO carbon
Am. Silicate = Amended Silicate
SEA1–SEA2 = 50%–50% blend of SEA1 and SEA2. The total rate for both is given.

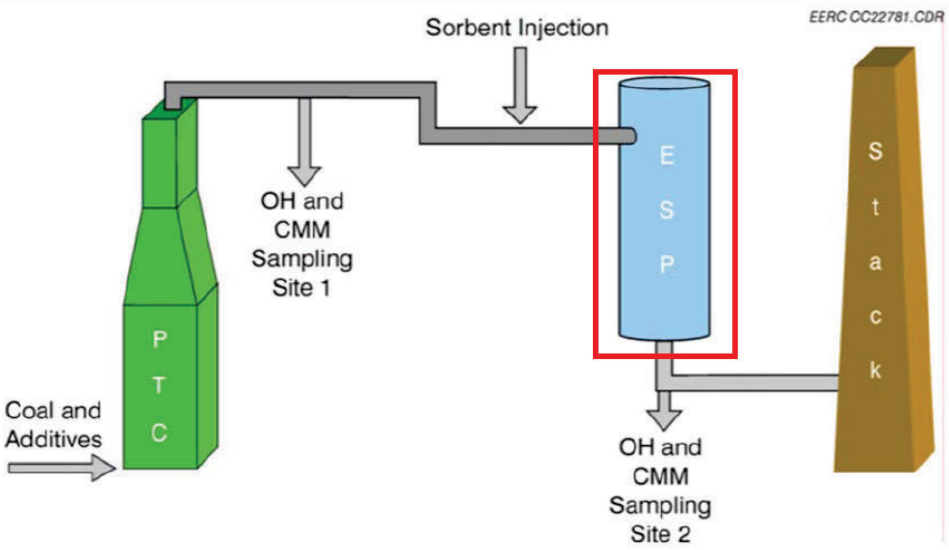
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No.	'114 Claim Element	Evidence of Reduction to Practice
		
1e	contacting mercury in the mercury-containing gas with the sorbent, to form	Because the coal and sodium bromide were combusted which formed the mercury containing gas, and activated carbon was injecting into the emission gas, the sorbent and mercury formed a mercury/sorbent composition. *See, e.g.,* Feb. 2004 Report at *** ("Sorbent injection for removing Hg involves adsorption of Hg species by a solid sorbent injected upstream of a particulate control device such as an FF (baghouse) or ESP."); *see also* Feb. 2005 Report at 18 ("The significant improvement by DARCO®

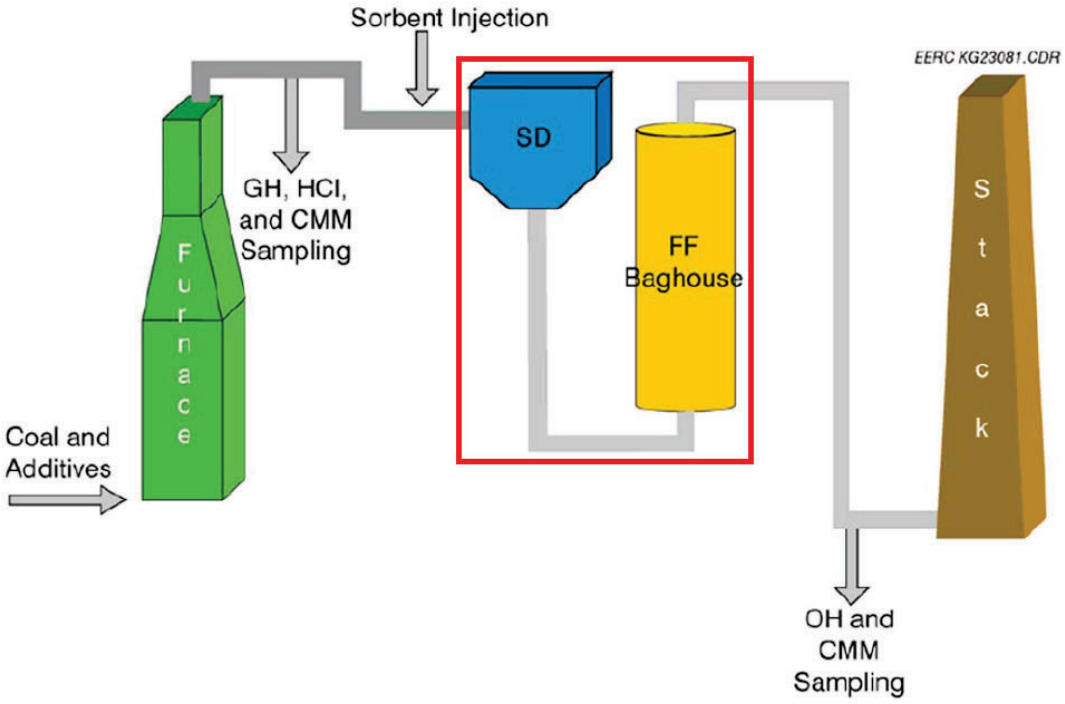
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No.	'114 Claim Element	Evidence of Reduction to Practice
	a mercury/sorbent composition;	FGD–SEA2 is not merely an additive effect but more a synergistic response. The SEA2 addition in the combustion zone not only enhances gaseous mercury conversion to particulate-associated mercury, but also improves DARCO® FGD carbon reactivity with mercury species.").
1f	separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas;	The mercury/sorbent composition was separated using an electrostatic precipitator during the September 2003 testing. Feb. 2004 Report at 10-11 ("Fourteen tests were completed to evaluate various sorbent and mercury oxidant performance on mercury removal across the ESP as functions of feed rate."):

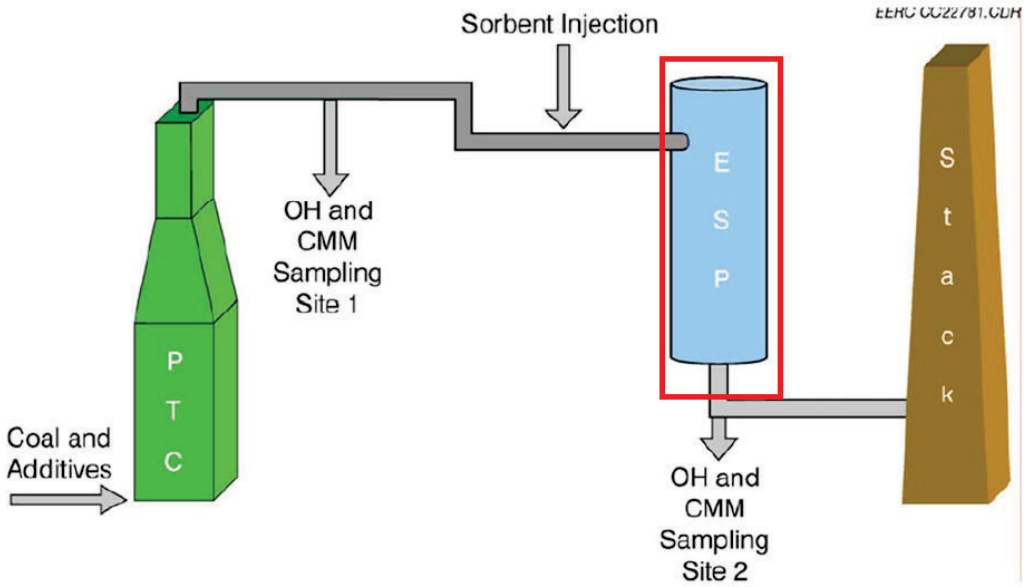
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No.	'114 Claim Element	Evidence of Reduction to Practice
		 Figure 4. Injection and sampling schematic of the PTC with an ESP. The mercury/sorbent composition was separated using a scrubbed baghouse system during the December 2003 testing. Feb. 2004 Report at 14 ("One week of short-term sorbent (Task 2.2) and furnace additive testing was accomplished in December 2003 to demonstrate mercury removal by sorbent injection combined with various

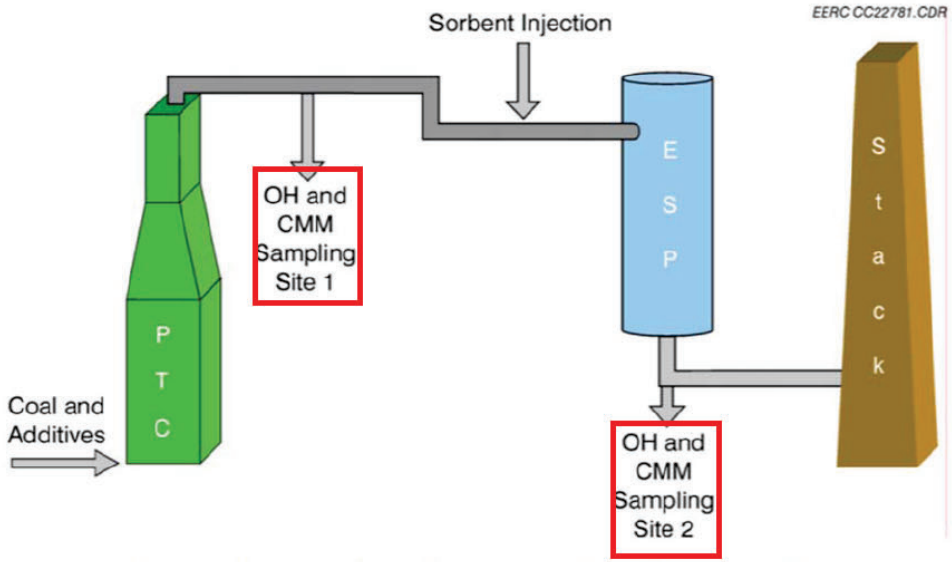
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No.	'114 Claim Element	Evidence of Reduction to Practice
		oxidizing additives to simulate a scrubbed baghouse system."); *see also* Feb. 2005 Report at 25: 

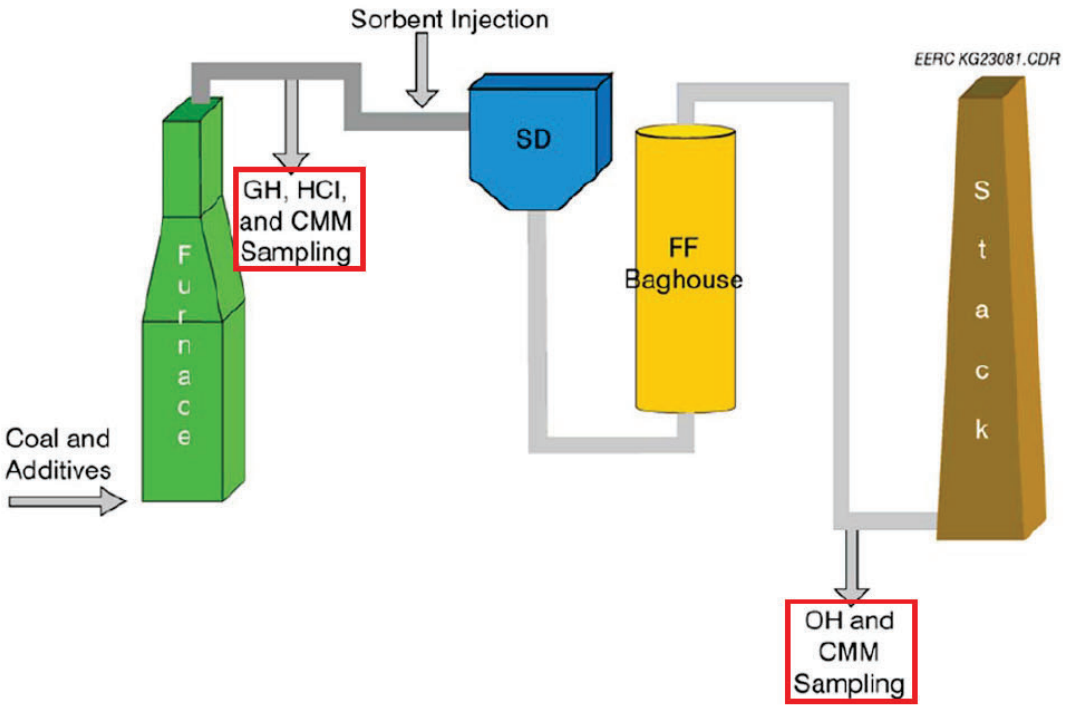
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No.	'114 Claim Element	Evidence of Reduction to Practice
		The mercury/sorbent composition was separated using an electrostatic precipitator during the February 2004 testing. Oct. 2005 Report at 26 ("ESP Hg removal testing was performed with the PTC firing Caballo subbituminous coal."): 
1g	monitoring the mercury content of	The Feb. 2004 Report describes the use of "Continuous Mercury Monitors" during the September 2003 testing and December 2003 testing. Feb. 2004 Report at 8 ("Hg^0

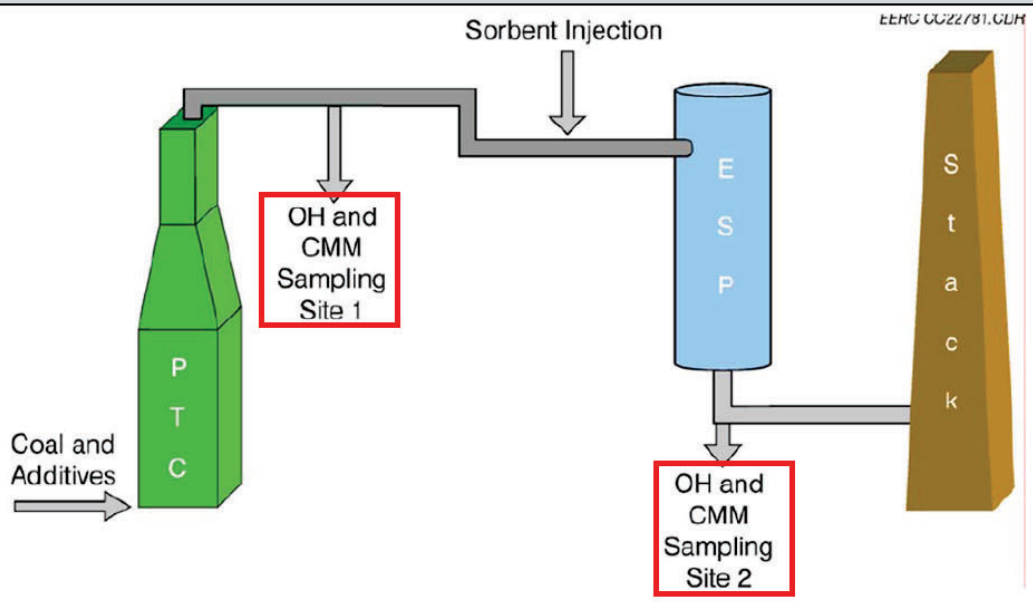
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No.	'114 Claim Element	Evidence of Reduction to Practice
	the cleaned gas; and	and total Hg levels will be measured on a nearly continuous basis using a continuous mercury monitor (CMM)"); at 10:  Figure 4. Injection and sampling schematic of the PTC with an ESP. *See also* Feb. 2005 Report at 25:

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No.	'114 Claim Element	Evidence of Reduction to Practice
		 *See also* Oct. 2005 Report at 26:

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No.	'114 Claim Element	Evidence of Reduction to Practice
		
1h	controlling, in response to the monitored mercury content of the cleaned gas, an	The Feb. 2004 Report describes adjusting the additive and sorbent injection rate. Both options result in changes to the sorbent composition. Feb. 2004 Report at 9("Specific sorbent injection rates will be determined based on the measured Hg concentration in the flue gas."). Feb. 2004 Report at 10 ("For continuous injection, the feed rate will be varied from 2500–12,000 lb sorbent/lb Hg"). Feb. 2004 Report

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<table>
<tr><th>No.</th><th>'114 Claim Element</th><th>Evidence of Reduction to Practice</th></tr>
<tr><td></td><td>injection rate of injecting the sorbent into the mercury-containing gas, the sorbent composition, or a combination thereof, so that the mercury content of the cleaned gas is maintained at or below a desired level.</td><td>at 10 ("Fourteen tests were completed to evaluate various sorbent and mercury oxidant performance on mercury removal across the ESP as functions of feed rate").

See also Feb. 2005 Report at 15:[22]

Table 4. Spray Dryer Test Sample Matrix (December 2004 run)
<table><tr><th colspan="2">Mercury Oxidation Additive</th><th colspan="2">Sorbent</th></tr><tr><th>Type</th><th>Feed Rate, lb/Macf</th><th>Type</th><th>Injection Rate, lb/Macf</th></tr><tr><td>None</td><td>NA</td><td>None</td><td>NA</td></tr><tr><td>None</td><td>NA</td><td>DARCO® FGD</td><td>1.84 – 11.02</td></tr><tr><td>None</td><td>NA</td><td>EERC-Treated FGD</td><td>1.84 – 7.35</td></tr><tr><td>None</td><td>NA</td><td>Amended Silicate™</td><td>7.35</td></tr><tr><td>NaCl</td><td>3.67 – 11.02</td><td>None</td><td>NA</td></tr><tr><td>NaCl</td><td>3.67 – 11.02</td><td>DARCO® FGD</td><td>3.67</td></tr><tr><td>SEA 2</td><td>1.84 – 3.67</td><td>None</td><td>NA</td></tr><tr><td>SEA 2</td><td>1.84 – 3.67</td><td>DARCO® FGD</td><td>1.84</td></tr><tr><td>$CaCl_2$</td><td>3.67 – 11.02</td><td>None</td><td>NA</td></tr><tr><td>$CaCl_2$</td><td>3.67 – 11.03</td><td>DARCO® FGD</td><td>3.67</td></tr></table></td></tr>
</table>

[22] This table refers to a "December 2004 run," which is a typo. It should refer to a December 2003 run as noted in the preceding paragraph. Final Report at 14 ("One week of short-term sorbent (Task 2.2) and furnace additive testing was accomplished in December 2003 to demonstrate mercury removal by sorbent injection combined with various oxidizing additives to simulate a scrubbed baghouse system."). This is also evidence based on the fact that the Final Report was prepared in February 2004.

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No.	'114 Claim Element	Evidence of Reduction to Practice
		See also Oct. 2005 Report at 27:
2	The method of claim 1, comprising removing greater than 70 wt % of the mercury in the mercury-containing gas.	This level of mercury capture was achieved during the September 2003, December 2003, and February 2004 testing. *See* Feb. 2005 Report at 73: – SEA2 and DARCO® FGD. The combination of DARCO® FGD injection at 1.84 lb/Macf and SEA2 addition provided exceptional SDA–FF Hg(g) capture, >90%, even at the lower addition rate of 1.84 lb/Macf. *See* Oct. 2005 Report at 49: The effectiveness of SEA2 addition, SEA2 additions combined with DARCO FGD injection, and a 50:50 wt% SEA1 and SEA2 mixture addition combined with ACI to remove Hg_{total} and Hg^0 from Caballo coal combustion flue gas is shown in Figures 11-15, 11-16, and 11-17. SEA2 addition at 1.9 lb/MMacf reduced the ESP outlet Hg_{total} concentration by 70%. When SEA2 was added during ACI, ESP Hg_{total} capture increased moderately to >80%. The Hg speciation results in Figure 11-16 suggest that in addition to Hg^0, some Hg^{2+} exited the ESP during the SEA2 and SEA2–SEA1 addition and ACI tests. The addition of the SEA1–SEA2 mixture at 0.5 lb/MMacf combined with ACI at 2.9 lb/MMacf resulted in a slightly lower ESP Hg_{total} removal as compared to the SEA2 addition and ACI tests.
3	The method of claim 1, comprising removing greater than 70 wt % of the	See claim 2.

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No.	'114 Claim Element	Evidence of Reduction to Practice
	mercury in the mercury-containing gas on the sorbent.	
4	The method of claim 1, wherein the sorbent in the mercury-containing gas comprises about 1 g to about 30 g of the halogen or halide promoter per 100 g of the sorbent material.	The February 2004 testing used bromine injection rates within this range. *See* Oct. 2005 Report at 27:

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Table 9-2. Week 1 – Test Matrix

Date	Sampling Inlet	Sampling Outlet	Sorbent	Rate, g/hr	Rate, lb/MMacf	Oxidant	Rate, g/hr	Rate, lb/MMacf
2/2/04	OH	OH	Baseline					
	M-29		Baseline					
			DARCO	25.0	7.03			
			DARCO	28.0	7.84			
			DARCO	32.0	8.96			
		OH	DARCO	45.0	12.60			
			DARCO	69.0	19.20			
2/3/04			Baseline					
						SEA1	15.2	4.28
						SEA1	29.8	8.38
			DARCO	25.0	7.03	SEA1	29.8	8.38
	OH	OH	DARCO	25.0	7.03	SEA1	45.5	12.80
	M-29		DARCO	25.0	7.03	SEA1	59.9	16.73
			DARCO	25.0	7.03	SEA1	15.2	4.28
2/4/04			Baseline					
						SEA2	9.8	2.73
			DARCO	25.0	6.96	SEA2	9.8	2.73
	OH	OH	DARCO	15.0	4.18	SEA2	9.8	2.73
			DARCO	15.0	4.18			
	M-29		DARCO	15.0	4.18	SEA2	6.9	1.92
			DARCO	15.0	4.18	SEA2	4.3	1.20
			DARCO	15.0	4.18			
			DARCO	15.0	4.18	SEA1–SEA2	2.6	0.72
2/5/2004			Baseline					
	OH	OH	EERC carbon	25.0	6.97			
			EERC carbon	35.0	9.76			
			Am. Silicate	25.0	6.91			
			Am. Silicate	50.0	13.82			

Notes:
M-29 = EPA Method 29
EERC carbon = EERC-treated DARCO carbon
Am. Silicate = Amended Silicate
SEA1–SEA2 = 50%–50% blend of SEA1 and SEA2. The total rate for both is given.

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No.	'114 Claim Element	Evidence of Reduction to Practice
		Oct. 2005 Report at 30:

Table 9-4. Week 2 – Test Matrix

Date	Sampling Inlet	Sampling Outlet	Sorbent	Rate, g/hr	Rate, lb/MMacf	Oxidant	Rate, g/hr	Rate, lb/MMacf
SDA–ESP								
2/17/04	OH	OH	Baseline					
			DARCO	25	5.82			
				35	8.14			
				45	10.47			
		OH		55	12.8			
			Baseline					
						SEA1	25	5.82
SDA–ESP								
2/18/04			Baseline					
						SEA1	25	5.82
	OH	OH	DARCO	25	5.82	SEA1	25	5.82
			DARCO	25	5.82	SEA1	35	8.14
			Baseline					
						SEA2	1	0.23
						SEA2	2.5	0.58
		OH	DARCO	10	2.33	SEA2	2.5	0.58
			DARCO	10	2.33	SEA2	5	1.16
SDA–FF								
2/19/04		OH	Baseline					
			DARCO	10	2.33			
	OH	OH	DARCO	25	5.82			
			DARCO	55	12.8			
			Baseline					
						SEA1	10	2.33
		OH	DARCO	10	2.33	SEA1	15	3.49
			DARCO	10	2.33	SEA1	25	5.82
SDA–FF								
2/20/2004			Baseline					
						SEA2	1	0.23
						SEA2	1.5	0.35
		OH	DARCO	10	2.33	SEA2	1.5	0.35
			DARCO	10	2.33	SEA2	0.5	0.12
			Baseline					
			Am. Silicate	15	3.49			
			Am. Silicate	30	6.98			

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No.	'114 Claim Element	Evidence of Reduction to Practice
5	The method of claim 1, wherein the combustion chamber comprises the halogen or halide promoter.	See 1c.
6	The method of claim 1, wherein the coal comprises added Br_2, HBr, Br^-, or a combination thereof, added to the coal upstream of the combustion chamber.	See 1c.
7	The method of claim 1, wherein the promoter is	Given the temperatures of coal combustion, the halide additive (NaBr) provides the promoter (Br^2, HBr, Br^-)) in gaseous form.

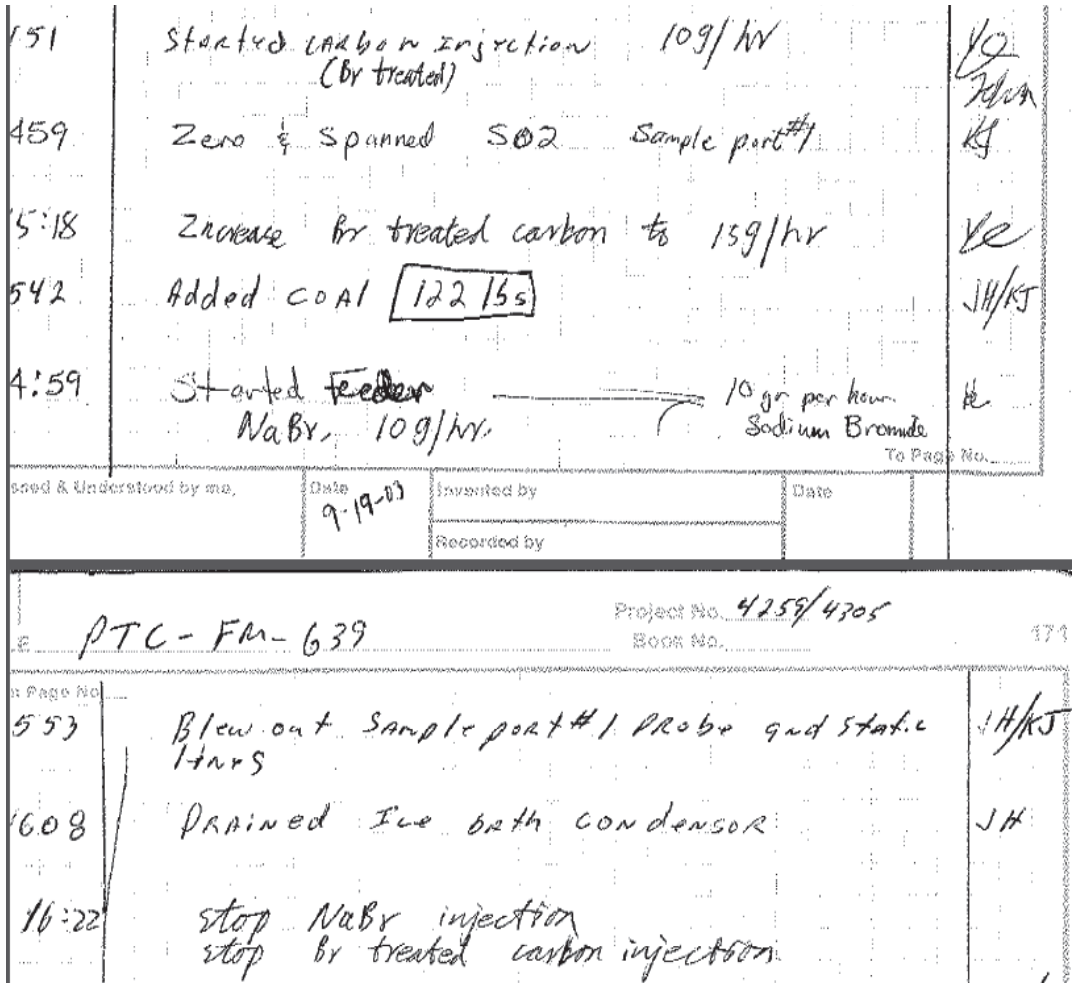
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No.	'114 Claim Element	Evidence of Reduction to Practice
	contacted with the sorbent in vapor form, gaseous form, liquid form, or in an organic solvent.	
12	The method of claim 1, wherein the activated carbon comprises powdered activated carbon, granular activated carbon, or a combination thereof.	See 1d.
13	The method of claim 1, wherein the sorbent material injected into the	See 1d.

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No.	'114 Claim Element	Evidence of Reduction to Practice
	mercury-containing gas is substantially free of halogen and halide promotion.	
14	The method of claim 1, wherein the sorbent material injected into the mercury-containing gas is a promoted sorbent obtained by contacting a base sorbent with another halogen or halide promoter.	The PTC logbook on September 19, 2003 shows the injection of a bromine treated activated carbon and addition of NaBr to the coal.

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1551 Started carbon injection 10g/hr (Br treated) VO
1459 Zero & Spanned SO2 Sample port #4 KJ
15:18 Increase Br treated carbon to 15g/hr VE
1542 Added coal 12215s JH/KJ
14:59 Started feeder NaBr, 10g/hr. 10 gr per hour Sodium Bromide VE

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Read & Understood by me. Date 9-19-03 Invented by Date Recorded by

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1553 Blew out Sample port #1 probe and static lines JH/KJ
1608 Drained ice bath condensor JH
16:22 stop NaBr injection stop Br treated carbon injection

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No.	'114 Claim Element	Evidence of Reduction to Practice
		See 1d. The Feb. 2004 Report, Feb. 2005 Report, and Oct. 2005 Report describe the combined use of SEA2 with EERC-treated carbon. *See* Feb. 2005 Report at 24: *EERC-Treated FGD.* The EERC has developed a more effective activated carbon for capturing Hg using a proprietary chemical pretreatment process. Previous testing of the EERC-treated FGD on North Dakota lignite combustion flue gases has demonstrated that it is a much more effective Hg sorbent than DARCO® FGD (23). EERC-treated carbon is Norit FGD activated carbon treated with bromine, as indicated in the PTC log book as "Br treated carbon."
15	The method of claim 1, wherein the combustion chamber comprises a boiler	See 1a.
16	The method of claim 1, wherein the mercury-	The combustion gases exiting the combustion chamber is a flue gas. Thus mercury-containing gas is a flue gas.

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No.	'114 Claim Element	Evidence of Reduction to Practice
	containing gas is a flue gas.	
17	The method of claim 1, wherein the injection of the sorbent material into the mercury-containing gas occurs upstream of an air pre-heater.	See 1d.
18	The method of claim 1, wherein the injection of the sorbent material into the mercury-containing gas occurs upstream of a particulate	See 1d.

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No.	'114 Claim Element	Evidence of Reduction to Practice
	separator or a scrubber.	
19	The method of claim 1, wherein the coal comprises added halide sorbent enhancement additive.	See 1c.
20	The method of claim 1, wherein the combustion chamber comprises added Br_2, HBr, Br^-, or a combination thereof.	See 1c.
21	The method of claim 1, wherein	See 1c.

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No.	'114 Claim Element	Evidence of Reduction to Practice
	the coal comprises added sorbent enhancement additive that comprises Br^-.	
22	The method of claim 21, wherein the sorbent enhancement additive comprises a bromide compound.	See 1c.
23a	A method of separating mercury from a mercury-containing gas, the method comprising:	See 1a.
23b	combusting coal in a combustion	See 1b.

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No.	'114 Claim Element	Evidence of Reduction to Practice
	chamber, to provide the mercury-containing gas, wherein the mercury-containing gas comprises a halogen or halide promoter comprising HBr, Br^-, or a combination thereof, wherein	
23c	wherein the mercury-containing gas comprises a halogen or halide promoter comprising HBr, Br^-, or a combination	See 1c.

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No.	'114 Claim Element	Evidence of Reduction to Practice
	thereof, wherein the coal comprises added Br_2, HBr, Br^-, or a combination thereof, added to the coal upstream of the combustion chamber, or the combustion chamber comprises added Br_2, HBr, Br^-, or a combination thereof, or a combination thereof;	
23d	injecting a sorbent material comprising activated carbon	See 1d.

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No.	'114 Claim Element	Evidence of Reduction to Practice
	into the mercury-containing gas downstream of the combustion chamber;	
23e	contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition; and	See 1e.
23f	separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas.	See 1f.
24a	A method of separating mercury	See 1a.

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No.	'114 Claim Element	Evidence of Reduction to Practice
	from a mercury-containing gas, the method comprising:	
24b	combusting coal in a combustion chamber, to provide the mercury-containing gas, wherein the mercury-containing gas comprises a halogen or halide promoter comprising HBr, Br^-, or a combination thereof, wherein	See 1b.
24c	wherein the mercury-containing	See 1c.

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No.	'114 Claim Element	Evidence of Reduction to Practice
	gas comprises a halogen or halide promoter comprising HBr, Br^-, or a combination thereof, wherein the coal comprises added Br_2, HBr, Br^-, or a combination thereof, added to the coal upstream of the combustion chamber, or the combustion chamber comprises added Br_2, HBr, Br^-, or a combination	

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No.	'114 Claim Element	Evidence of Reduction to Practice
	thereof, or a combination thereof;	
24d	injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber such that the activated carbon reacts with the halogen or halide promoter in the mercury-containing gas to form a promoted sorbent;	See 1d.

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No.	'114 Claim Element	Evidence of Reduction to Practice
24e	such that the activated carbon reacts with the halogen or halide promoter in the mercury-containing gas to form a promoted sorbent;	The Feb. 2004 Report and Final Report both explain that the tests performed with sorbent and SEA2 demonstrated higher levels of mercury capture as compared to tests performed only with sorbent, and that the reactivity of the sorbent was enhanced when a halide additive (NaBr) was added to the coal. This confirms that the activated carbon sorbent and halogen/halide promoter reacted to form a promoted sorbent that enhanced (improved) its performance to capture mercury.
24f	contacting mercury in the mercury-containing gas with the promoted sorbent, to form a mercury/sorbent composition;	See 1e.
24g	separating the mercury/sorbent composition from the mercury-	See 1f.

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No.	'114 Claim Element	Evidence of Reduction to Practice
	containing gas, to form a cleaned gas;	
24h	monitoring the mercury content of the cleaned gas; and	See 1g.
24i	controlling, in response to the mercury content of the cleaned gas, an injection rate of injecting the sorbent into the mercury-containing gas, a rate of addition to the coal or the combustion chamber of the added Br_2, HBr, the	See 1h.

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No.	'114 Claim Element	Evidence of Reduction to Practice
	bromide compound, or a combination thereof, or a combination thereof, so that the mercury content of the cleaned gas is maintained at or below a desired level.	
25a	A method of separating mercury from a mercury-containing gas, the method comprising:	See 1a.
25b	combusting coal in a combustion chamber, to provide	See 1b.

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No.	'114 Claim Element	Evidence of Reduction to Practice
	the mercury-containing gas, wherein	
25c	the coal comprises added Br_2, HBr, a bromide compound, or a combination thereof, added to the coal upstream of the combustion chamber, or the combustion chamber comprises added Br_2, HBr, a bromide compound, or a combination thereof, or a	See 1c.

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No.	'114 Claim Element	Evidence of Reduction to Practice
	combination thereof,	
25d	injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber;	See 1d.
25e	contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition; and	See 1e.
25f	separating the mercury/sorbent composition from	See 1f.

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No.	'114 Claim Element	Evidence of Reduction to Practice
	the mercury-containing gas, to form a cleaned gas.	
26	The method of claim 25, wherein the coal comprises the added Br_2, HBr, the bromide compound, or a combination thereof, added to the coal upstream of the combustion chamber.	See 1c.
27	The method of claim 25, wherein the combustion chamber comprises the added Br_2, HBr,	See 1c.

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No.	'114 Claim Element	Evidence of Reduction to Practice
	the bromide compound, or a combination thereof.	
28a	The method of claim 25, further comprising monitoring the mercury content of the cleaned gas; and	See 1g.
28b	controlling, in response to the mercury content of the cleaned gas, an injection rate of injecting the sorbent into the mercury-containing	See 1h.

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No.	'114 Claim Element	Evidence of Reduction to Practice
	gas, a rate of addition to the coal or the combustion chamber of the added Br_2, HBr, the bromide compound, or a combination thereof, or a combination thereof, so that the mercury content of the cleaned gas is maintained at or below a desired level.	
29	The method of claim 25, wherein the mercury-containing gas	See claim 4.

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No.	'114 Claim Element	Evidence of Reduction to Practice
	comprises about 1 g to about 30 g of the element bromine per 100 g of the sorbent.	
30	The method of claim 25, wherein the mercury/sorbent composition comprises the element bromine, the sorbent material, and mercury.	See 24e.

'147 Claim Chart

No.	'147 Claim Element	Evidence of Reduction to Practice
1a	1. A method for separating mercury from a mercury containing gas comprising:	See '114 claim 1a.

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No.	'147 Claim Element	Evidence of Reduction to Practice
1b	promoting at least a portion of a particulate sorbent material comprising activated carbon by chemically reacting the sorbent material with a bromine containing promoter to form a promoted brominated sorbent, wherein the bromine containing promoter is in gaseous form, vapor form, or non-aqueous liquid form, and wherein the activated carbon contains graphene sheets having carbene species edge sites which react with the bromine containing promoter to form a carbocation paired with a bromide anion in the promoted brominated sorbent for oxidation of the mercury;	See '114 claim 1e and 24e.
1c	chemically reacting elemental mercury in the mercury containing gas with the promoted brominated sorbent to form a mercury/sorbent chemical composition; and	See '114 claim 1e and 24e.
1d	separating particulates from the mercury containing gas, the particulates including ash and the mercury/sorbent chemical composition.	See '114 claim 1f.
17	A method according to claim 1, further comprising injecting the particulate sorbent material at a sorbent material injection rate and injecting separately the bromine containing promoter into a gas stream whereby in-flight reaction produces the promoted	See '114 claim 1 (describing separate addition of NaBr and injection of activated carbon) and 4 (describing the ratio of 1 to about 30 grams).

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No.	'147 Claim Element	Evidence of Reduction to Practice
	brominated sorbent, wherein the promoter is reacted in the gas phase or as a vapor, wherein the promoter is added at from about 1 to about 30 grams per 100 grams of the sorbent material.	
18	A method according to claim 17, wherein the gas stream is a mercury containing gas.	See '114 claim 1
19	A method according to claim 18, wherein the gas stream is a transport gas.	Because the sorbent is injected into the gas as it is being transported, it is a transport gas. Because the halide additive is added (injected) into the combustor with the coal that provides the mercury containing gas, the mercury-containing gas with the Br^2, HBr, and Br^- promoters is a transport gas.
20	A method according to claim 17, wherein the promoter injection rate and the sorbent injection rate into the gas are determined at least in part on the monitored mercury content of the cleaned gas.	See '114 claim 1h.

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