UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

Berkshire Hathaway Energy Company,
Interstate Power & Light Company,
MidAmerican Energy Company,
PacifiCorp,
WEC Energy Group, Inc., and
Wisconsin Power & Light Company

Petitioners

v.

Birchtech Corp.

Patent Owner

Case Nos. IPR2025-00274 and IPR2025-00278
Patent No. 10,343,114

DECLARATION OF DR. STEPHEN NIKSA

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I. INTRODUCTION

1. My name is Stephen Niksa, and I declare as follows:

2. 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.

3. I have been asked to provide technical assistance in the *inter partes* review of U.S. Patent No. 10,343,114, which I may abbreviate as "the '114 Patent" or refer to as the "Challenged Patent." I understand that this patent was formerly owned by Midwest Energy Emissions Corp. ("ME2C"), but that ME2C changed its name to Birchtech Corp. I may refer to the Patent Owner simply as "ME2C." This declaration is a statement of my opinions on issues related to the unpatentability of claims of the Challenged Patent. I am being compensated at my normal rate of $365 per hour for my analysis, plus reimbursement for expenses. My compensation does not depend on the content of my opinions or the outcome of this proceeding.

4. This declaration contains statements of my opinions formed to date and the bases and reasons for those opinions. I may offer additional opinions based on further review of materials in this case, including opinions and/or testimony of other expert witnesses.

II. EDUCATION AND PROFESSIONAL EXPERIENCE

5. I have summarized in this section my educational background, career history, publications, and other relevant qualifications. My full curriculum vitae has been provided as Exhibit 1003 to this declaration.

6. I earned a Ph.D. in Chemical Engineering from Princeton University in 1982, and a B.S. in Chemical Engineering from Case Western Reserve University in 1975. I have nearly 50 years of experience researching coal combustion systems and associated pollution control systems. Since 1997, I have been the Founder and President of Niksa Energy Associates LLC, which provides consulting services to coal-utilization companies in the chemistry of solid fuel conversion and pollution control. Prior to Niksa Energy Associates LLC, I worked at SRI International, taught at Stanford University, and worked at Sandia National Laboratories. My research interests have included chemical reaction mechanisms for NO_X, mercury, selenium, arsenic, phosphorous, and other trace metals, SO_3, volatile organic compounds (VOCs), particulates, alkali vapors, and polynuclear aromatic hydrocarbons (PAH); fuel conversion kinetics; transformation of alkali compounds in fuel combustion; and catalysis, including catalyst deactivation during hydrothermal treatment of residual petroleum fractions, and during flue gas cleaning in utility SCRs; predictive mechanisms for multipollutant (NO_X, SO_2, Hg^0) conversion across SCR catalysts; the thermal and chemical behavior of catalytic converters; and thermal shock issues

in catalytic combustors for natural gas. I have authored hundreds of technical papers on the mechanisms of air pollutant formation and control. While at Stanford, I taught graduate courses in Radiation Heat Transfer; Combustion and Pollution; Physical Gas Dynamics; Introduction to Heat Transfer; Advanced Combustion; Analysis and Solution of Partial Differential Equations; and Spectroscopy Lab, FTIR Section.

7. Having this knowledge and experience, I am well-qualified to offer the opinions I express in this declaration.

III. THE CHALLENGED CLAIMS OF THE ’114 PATENT

8. The Challenged Claims of the ’114 Patent, which are claims 1-30, are set forth below. Some of the claim elements have been further sub-divided for ease of reference.

Claim Element	Claim Language from ’114 Patent
1(Preamble)	1. A method of separating mercury from a mercury-containing gas, the method comprising:
1(a)	combusting coal in a combustion chamber, to provide the mercury-containing gas, wherein
1(b)	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 coal upstream of the combustion chamber, or the combustion chamber comprises added Br_2, HBr, Br^-, or a combination thereof, or a combination thereof;

Claim Element	Claim Language from '114 Patent
1(c)	injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber; contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition;
1(d)	separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas;
1(e)	monitoring the mercury content of the cleaned gas; and
1(f)(1)	controlling, in response to the monitored mercury content of the cleaned gas, an injection rate of injecting the sorbent into the mercury-containing gas, the sorbent composition, or a combination thereof,
1(f)(2)	so that the mercury content of the cleaned gas is maintained at or below a desired level.
2	2. The method of claim 1, comprising removing greater than 70 wt % of the mercury in the mercury-containing gas.
3	3. The method of claim 1, comprising removing greater than 70 wt % of the mercury in the mercury-containing gas on the sorbent.
4	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.
5	5. The method of claim 1, wherein the combustion chamber comprises the halogen or halide promoter.
6	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.
7	7. The method of claim 1, wherein the promoter is contacted with the sorbent in vapor form, gaseous form, liquid form, or in an organic solvent.
8	8. The method of claim 1, further comprising injecting a secondary material into the mercury-containing gas downstream of the combustion chamber.
9	9. The method of claim 8, wherein the secondary material comprises a halogen, a compound derived from a halogen, a hydrohalide, a

Claim Element	Claim Language from ’114 Patent
	compound comprising a Group V or Group VI element and a molecular halogen, or a combination thereof.
10	10. The method of claim 1, wherein the sorbent material injected into the mercury-containing gas further comprises a non-carbon sorbent material.
11	11. The method of claim 10, wherein the non-carbon sorbent material comprises at least one of a porous felsic material, a vesicular felsic material, a porous basaltic material, a vesicular basaltic material, a clay-based compound, an alkaline compound, a calcium hydroxide compound, a sodium acetate compound, and a bicarbonate compound.
12	12. The method of claim 1, wherein the activated carbon comprises powdered activated carbon, granular activated carbon, or a combination thereof.
13	13. The method of claim 1, wherein the sorbent material injected into the mercury-containing gas is substantially free of halogen and halide promotion.
14	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.
15	15. The method of claim 1, wherein the combustion chamber comprises a boiler.
16	16. The method of claim 1, wherein the mercury-containing gas is a flue gas.
17	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.
18	18. The method of claim 1, wherein the injection of the sorbent material into the mercury-containing gas occurs upstream of a particulate separator or a scrubber.
19	19. The method of claim 1, wherein the coal comprises added halide sorbent enhancement additive.

Claim Element	Claim Language from ’114 Patent
20	20. The method of claim 1, wherein the combustion chamber comprises added Br_2, HBr, Br^-, or a combination thereof.
21	21. The method of claim 1, wherein the coal comprises added sorbent enhancement additive that comprises Br^-.
22	22. The method of claim 21, wherein the sorbent enhancement additive comprises a bromide compound.
23(Preamble)	23. A method of separating mercury from a mercury-containing gas, the method comprising:
23(a)	combusting coal in a combustion chamber, to provide the mercury-containing gas,
23(b)	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 coal upstream of the combustion chamber, or the combustion chamber comprises added Br_2, HBr, Br^-, or a combination thereof, or a combination thereof;
23(c)	injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber; contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition; and
23(d)	separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas.
24(Preamble)	24. A method of separating mercury from a mercury-containing gas, the method comprising:
24(a)	combusting coal in a combustion chamber, to provide the mercury-containing gas, wherein
24(b)	the mercury-containing gas comprises a halogen or halide promoter comprising HBr, Br^-, or a combination thereof,

Claim Element	Claim Language from ’114 Patent
	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;
24(c)	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; contacting mercury in the mercury-containing gas with the promoted sorbent, to form a mercury/sorbent composition;
24(d)	separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas;
24(e)	monitoring the mercury content of the cleaned gas; and
24(f)(1)	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 bromide compound, or a combination thereof, or a combination thereof,
24(f)(2)	so that the mercury content of the cleaned gas is maintained at or below a desired level.
25(Preamble)	25. A method of separating mercury from a mercury-containing gas, the method comprising:
25(a)	combusting coal in a combustion chamber, to provide the mercury-containing gas, wherein
25(b)	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

Claim Element	Claim Language from ’114 Patent
	compound, or a combination thereof, or a combination thereof,
25(c)	injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber; contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition; and
25(d)	separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas.
26	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.
27	27. The method of claim 25, wherein the combustion chamber comprises the added Br_2, HBr, the bromide compound, or a combination thereof.
28(a)	The method of claim 25, further comprising monitoring the mercury content of the cleaned gas; and 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 bromide compound, or a combination thereof, or a combination thereof,
28(b)	so that the mercury content of the cleaned gas is maintained at or below a desired level.
29	29. The method of claim 25, wherein the mercury-containing gas comprises about 1 g to about 30 g of the element bromine per 100 g of the sorbent.
30	30. The method of claim 25, wherein the mercury/sorbent composition comprises the element bromine, the sorbent material, and mercury.

IV. SCOPE OF WORK AND MATERIALS REVIEWED

9. I have been asked to review the Challenged Patent and its prosecution history, to provide an understanding of the technology relevant to the Challenged Patent, to review certain prior-art references, and to analyze whether or not those references disclose or teach limitations of claims from the Challenged Patent.

10. The opinions stated in this declaration are from the perspective of a Person of Skill in the Art (POSITA) as of August 30, 2004, whose qualifications and abilities are described below. I understand that Petitioners and Patent Owner may have a dispute as to whether the claims of the Challenged Patent are entitled to a priority date of August 2004 or May 2018. Unless otherwise noted, my opinions expressed in this report remain unchanged regardless of the date used.

11. In forming my opinions, I have reviewed the Challenged Patent, its prosecution history, the materials cited in the List of Exhibits, and the materials cited throughout my declaration. I have also relied on my academic and professional experience in reaching the opinions expressed in this declaration.

V. LIST OF EXHIBITS

12. In forming my opinions, I have reviewed the materials cited throughout my declaration, including the List of Exhibits below.

Exhibit	**Description of Exhibits Used in IPR2025-00274 and -00278 ['114 Patent]**
1001	U.S. Patent No. 10,343,114 to Olson et al. (filed May 14, 2018) **("'114 Patent" or "Challenged Patent")**
1002	Declaration of Dr. Stephen Niksa in Support of Petition for *Inter Partes* Review of U.S. Patent No. 10,343,114 **("'114 Niksa Decl.")**
1003	Curriculum Vitae of Dr. Stephen Niksa
1004	Family Tree of ME2C Patents
1005	U.S. Patent Publication No. 2004/0013589 to Vosteen et al. (filed July 24, 2002) **("Vosteen589")**
1006	U.S. Patent Pub. No. 2008/0107579 to Downs et al. (published May 8, 2008) **("Downs-Boiler")**
1007	U.S. Patent Prov. App. No. 60/555,353 (filed Mar. 22, 2004) **("Downs-Boiler-Provisional")**
1008	Travis Starns, "Full-Scale Test of Mercury Control with Sorbent Injection and an ESP at Wisconsin Electric's Pleasant Prairie Power Plant," Session AE1-C, Paper No. 43249, AIR & WASTE MANAGEMENT'S ASSOCIATION'S 95TH ANNUAL CONFERENCE (Baltimore, MD: June 23-27, 2002) (**"Starns"**)
1009	Massachusetts Dep. of Environmental Protection, Bureau of Waste Prevention, "Evaluation of the Technological and Economic Feasibility of Controlling and Eliminating Mercury Emissions from the Combustion of Solid Fossil Fuel" (Dec. 2002) **("Mass-EPA")**, available at: https://web.archive.org/web/20030411074158/http:/www.state.ma.us/dep/bwp/daqc/files/mercfeas.pdf

Exhibit	**Description of Exhibits Used in IPR2025-00274 and -00278 ['114 Patent]**
	and at https://www.mass.gov/doc/evaluation-of-technological-economic-feasibility-of-controlling-eliminating-mercury-emissions/download
1010	Sharon Sjostrom, "Full Scale Evaluations of Mercury Control Technologies with PRB Coals," Track A, Session A3 (Mercury – Control), Presentation A3b, EUEC: 8TH ELECTRIC UTILITIES ENVIRONMENTAL CONFERENCE (Tucson, Arizona: January 25, 2005) **("Sjostrom")**
1011	Craig Eckberg et al., "Mercury Control Evaluation of Halogen Injection into a Texas Lignite-Fired Boiler," Track A, Session A3 (Mercury – Control), Presentation A3c, EUEC: 8TH ELECTRIC UTILITIES ENVIRONMENTAL CONFERENCE (Tucson, Arizona: January 25, 2005) **("Eckberg")**
1012	U.S. Patent Pub. No. 2006/0048646 to Olson et al. (published Mar. 9, 2006) **("Olson-646")**
1013	U.S. Patent No. 6,953,494 to Nelson (filed May 6, 2003) **("Nelson")**
1014	U.S. Patent No. 7,514,052 to Lissianski et al. (filed Apr. 7, 2009) **("Lissianski")**
1015	RESERVED
1016	RESERVED
1017	RESERVED
1018	U.S. Patent No. 8,652,235 to Olson et al. (issued February 18, 2014) **("Olson-235")**

Exhibit	**Description of Exhibits Used in IPR2025-00274 and -00278 [’114 Patent]**
1019	U.S. Patent No. 9,468,886 to Olson et al. (issued from application no. 14/102,896) **(“’886 Patent”).** The file history for 14/102,896 is at Exhibit 1024.
1020	File History of U.S. Patent Prov. App. No. 60/605640 **(“Provisional”)**
1021	File History of U.S. Patent Application No. 11/209,163, which ultimately issued as U.S. Patent No. 7,435,286 **(“’163 Application File History”)**
1022	File History of U.S. Patent Application No. 12/201,595, which ultimately published as 2009/0062119 and was abandoned **(“’595 Application File History”)**
1023	Excerpts of File History of U.S. Patent Application No. 12/429,058, which ultimately issued as U.S. Patent No. 8,652,235 **(“’058 Application File History”)**. The excerpts are of the application as filed on April 23, 2009.
1024	File History of U.S. Patent Application No. 14/102,896, which ultimately issued as U.S. Patent No. 9,468,886 **(“’896 Application File History”)**.
1025	Excerpts of File History of U.S. Patent Application No. 15/295,594, which ultimately published as 2017-0128908 and was abandoned **(“’594 Application File History”).** The excerpts are of the application as filed on October 17, 2016.
1026	File History of U.S. Patent Application No. 15/978,760 (issued as U.S. Patent No. 10,343,114) **(“’114 Patent File History”)**

Exhibit	**Description of Exhibits Used in IPR2025-00274 and -00278 ['114 Patent]**
1027	Babcock & Wilcox, STEAM: ITS GENERATION AND USE, 40th ed. (The Babcock & Wilcox Company: 1992) **("B&W: Steam")**
1028	J. Bustard, S. Sjostrom, et al., "Full Scale Evaluation of Sorbent Injection for Mercury Control on Coal-Fired Power Plants," International Conference on Air Quality III, Paper No. A5-4 (Sept. 9-12, 2002: Arlington, VA) **("Bustard")**
1029	U.S. Patent No. 1,984,164 to Stock et al. (issued Dec. 11, 1934) **("Stock")**
1030	Electric Utilities Environment Conference 2005 Handout **("EUEC Handout")**
1031	Scan of jacket/cover of CD mailed to conference attendees from EUEC: 8th Electric Utilities Environmental Conference (Tucson, Arizona: January 23-26, 2005) **("EUEC CD Scan")**
1032	Redline comparison between U.S. Patent Pub. No. 2008/0107579 (Downs-Boiler, EX1006) and U.S. Patent Prov. Appl. No. 60/555,353 (Downs-Boiler-Provisional, EX1007), using Downs-Boiler-Provisional as the original version **("Downs-Boiler-Redline")**
1033	RESERVED
1034	RESERVED
1035	RESERVED
1036	CRC Handbook of Chemistry and Physics, 86th Ed.; Lide, D.R., ed. **("CRC Press: March 2005")**

Exhibit	**Description of Exhibits Used in IPR2025-00274 and -00278 [’114 Patent]**
1037	Paul Chu, “Power Plant Evaluation of the Effect of SCR Technology on Mercury,” Paper No. 106, COMBINED POWER PLANT AIR POLLUTANT CONTROL MEGA SYMPOSIUM (MEGA) (Washington, DC: May 19-22, 2003) **(“Power Plant Evaluation”)**
1038	Evan J. Granite et al., “Sorbents for Mercury Removal from Flue Gas,” DOE/FETC/TR–98-01, U.S. Department of Energy (Jan. 1998) **(“Granite”)**
1039	Thomas J. Feeley, et al., “A Review of DOE/NETL’s Mercury Control Technology R&D Program for Coal-Fired Power Plants,” *DOE/NETL Hg R&D Program Review* (April 2003) **(“Feeley”)**
1040	Oxtoby et al., PRINCIPLES OF MODERN CHEMISTRY, 4th ed (Saunders College Publishing: 1999) **(“Oxtoby”)**
1041	N.N. Greenwood and A. Earnshaw, CHEMISTRY OF THE ELEMENTS, 2nd ed. (Butterworth-Heinemann: 1997) **(“Greenwood”)**
1042	B.R. Puri, *Surface Complexes on Carbons*, *in* CHEMISTRY AND PHYSICS OF CARBON 191 (Philip L. Walker, ed.) (Marcel Dekker: 1970) **(“Puri”)**
1043	Frank E. Huggins et al., “XAFS Examination of Mercury Sorption on Three Activated Carbons,” *Energy & Fuels* 1999(13), p. 114-121 (1999) **(“XAFS”)**
1044	S. Niksa et al., *Predicting Complete Hg Speciation Along Coal-Fired Utility Exhaust Systems*, MEGA SYMPOSIUM, Paper # 45 (Washington, DC: Aug. 2004) **(“Hg Speciation”)**
1045	D.L. Laudal et al., *Evaluation of Mercury Speciation at Power Plants Using SCR and SNCR NOx Control Technologies*, Paper No. A5-01,

Exhibit	**Description of Exhibits Used in IPR2025-00274 and -00278 ['114 Patent]**
	INT'L CONF. ON AIR QUALITY III (Arlington, VA: Sept. 9-12, 2002) **("Laudal")**
1046	U.S. Patent No. 4,196,173 to DeJong **("DeJong")**
1047	U.S. Patent No. 5,695,726 to Lerner **("Lerner")**
1048	Carey, T. R., Jr., O. W. H., Richardson, C. F., Chang, R., & Meserole, F. B. (1998). Factors Affecting Mercury Control in Utility Flue Gas Using Activated Carbon. *Journal of the Air & Waste Management Association*, 48(12), 1166–1174. https://doi.org/10.1080/10473289.1998.10463753 **("Carey")**
1049	NETL - Mercury Emissions Control , February, 2003, available at: https://web.archive.org/web/20030315093905fw_/http://www.netl.doe.gov/coalpower/environment/mercury/control-tech/inactive.html **("U.S. DOE, Completed Mercury Projects, February, 2003")**
1050	Proposed National Emission Standards for Hazardous Air Pollutants; and, in the Alternative, Proposed Standards of Performance for New and Existing Stationary Sources: Electric Utility Steam Generating Units, 69 Fed. Reg. 4652-4752 [Volume 69, No. 20] (Jan. 30, 2004) **("EPA-Proposal")**
1051	U.S. EPA, "Study of Hazardous Air Pollutant Emissions from Electric Utility Steam Generation Units -- Final Report to Congress," (Vol. 1 1998), available at https://www3.epa.gov/ttn/utox/eurtc1.pdf **("U.S. EPA – Vol. 1 1998"**)
1052	U.S. EPA, "Mercury Study Report to Congress Volume 1: Executive Summary," EPA-452/R-97-003 (Dec. 1997), available at https://www.epa.gov/sites/production/files/2015-

Exhibit	**Description of Exhibits Used in IPR2025-00274 and -00278 ['114 Patent]**
	09/documents/volume1.pdf (**"U.S. EPA – Exec. Summary Vol. 1 Dec. 1997"**)
1053	U.S. EPA, AP-42: External Combustion Sources, Chapter 1: Fifth Edition, Volume I (Sep. 1998), available at https://www3.epa.gov/ttn/chief/ap42/ch01/index.html (last visited Nov. 20, 2024) **("Chapter 1 of AP-42")**
1054	U.S. DOE, Mercury Emissions Control - Regulatory Drivers (Jan. 24, 2003), available at https://web.archive.org/web/20030416142937/http:/www.netl.doe.gov/coalpower/environment/mercury/regs.html **("Mercury Emissions Control")**
1055	Clean Air Mercury Rule: Basic Information, available at https://web.archive.org/web/20050920005951/http:/www.epa.gov/mercuryrule/basic.htm **("Clean Air Mercury Rule")**
1056	EPA Newsroom, "EPA Announces First-Ever Rule to Reduce Mercury Emissions from Power Plants" (Mar. 15, 2005), available at: https://archive.epa.gov/epapages/newsroom_archive/newsreleases/91ab7266e65751b985256fc50067d9b0.html **("3/15/2005 EPA Press Release")**
1057	EPA Newsroom, "Public Comment Period Begins for Proposed Power Plant Regulations" (Jan. 29, 2004), available at: https://archive.epa.gov/epapages/newsroom_archive/newsreleases/4daf1d46e8dd755c85257036005511f9.html **("1/29/2004 EPA Press Release")**
1058	EPA Newsroom, "EPA Supplements Proposal to Reduce Power Plant Mercury Emissions," (Feb. 24, 2004), available at: https://archive.epa.gov/epapages/newsroom_archive/newsreleases/58

Exhibit	**Description of Exhibits Used in IPR2025-00274 and -00278 ['114 Patent]**
	10096dabfc9eba85256e440078905f.html **("2/24/2004 EPA Press Release")**
1059	Sharon Sjostrom et al., "Field Studies of Mercury Control Using Injected Sorbents," AWMA ANNUAL MEETING, Session Ae-1b (2002) **("Field Studies of Mercury Control")**
1060	EPA, "Mercury Study Report to Congress Volume VIII: An Evaluation of Mercury Control Technologies and Costs," EPA Report No. EPA-452/R-97-010 (Dec. 1997), available at https://www3.epa.gov/airtoxics/112nmerc/volume8.pdf **("EPA 1997 Mercury Study Report Vol. VIII")**
1061	EUEC 2005 home page, available at: https://web.archive.org/web/20050303090129/http:/www.euec.com/
1062	Charlene R. Crocker et al., "Mercury Control with the Advanced Hybrid Particulate Collector Technical Progress Report," U.S. DOE-NETL (Nov. 2003) **("Crocker")**
1063	Redline Comparison, showing changes to the specification in Patent Owner's first continuation-in-part filing: from 11/209,163 ('163 Application, as published at 2006/0048646) to 15/978,760 ('760 Application, as published at 2018/0257031)
1064	Redline Comparison, showing changes from 12/201,595 ('595 Application, as published at 2009/0062119) to 12/429,058 ('058 Application, as published at 2009/0297413)
1065	Redline Comparison, showing changes from 12/429,058 ('058 Application, as published at 2009/0297413) to 15/295,594 ('594 Application, as published at 2017/0128908)

Exhibit	**Description of Exhibits Used in IPR2025-00274 and -00278 [’114 Patent]**
1066	Redline Comparison, showing changes from 12/201,595 (’595 Application, as published at 2009/0062119) to 15/978,760 (’760 Application, as published at 2018/0257031)
1067	RESERVED
1068	Redline Comparison, showing changes to the specification in Patent Owner’s second continuation-in-part filing: from 15/295,594 (’594 Application, as published at 2017/0128908) to 15/978,760 (’760 Application, as published at 2018/0257031)
1069	Redline Comparison, showing changes from 12/429,058 (’058 Application, as published at 2009/0297413) to 15/978,760 (’760 Application, as published at 2018/0257031)
1070	Roop Chand Bansal, et al., ACTIVE CARBON (Marcel Dekker:1988). **(“Bansal”)**
1071	*Midwest Energy Emissions Corp., et al. v. Arthur J. Gallagher & Co., et al.*, No. 1:19-cv-01334-CJB, Dkt. No. 440 (D. Del. June 24, 2022). **(“Dkt No. 440”)**
1072	*Midwest Energy Emissions Corp., et al. V. Arthur J. Gallagher & Co., et al.*, No. 1:19-cv-01334-CJB, Dkt. No. 447 (D. Del. July 12, 2022). **(“Dkt No. 447”)**
1073	Welcome Page of CD mailed to conference attendees of the 2002 Air & Waste Management’s Association’s 95th Annual Conference & Exhibition (Baltimore, Maryland: June 23-27, 2002) **(“AWMA CD Scan”)**
1074	Main Menu of CD mailed to conference attendees of the 2002 Air & Waste Management’s Association’s 95th Annual Conference &

Exhibit	**Description of Exhibits Used in IPR2025-00274 and -00278 ['114 Patent]**
	Exhibition (Baltimore, Maryland: June 23-27, 2002) **("AWMA CD Scan, Main Menu")**
1075	Author Index of CD mailed to conference attendees of the 2002 Air & Waste Management's Association's 95th Annual Conference & Exhibition (Baltimore, Maryland: June 23-27, 2002) **("AWMA CD Scan, Author Index")**
1076	Papers by Session of CD mailed to conference attendees of the 2002 Air & Waste Management's Association's 95th Annual Conference & Exhibition (Baltimore, Maryland: June 23-27, 2002) **("AWMA CD Scan, Papers by Session")**
1077	Scan of jacket/cover of CD mailed to conference attendees of the 2002 Air & Waste Management's Association's 95th Annual Conference & Exhibition (Baltimore, Maryland: June 23-27, 2002) **("AWMA CD Photo")**
1078	AWMA Website (Internet Archive), available at https://web.archive.org/web/20020613041559/http://www.awma.org/about/overview.htm (AWMA Overview)
1079	AWMA Website (Internet Archive), available at https://web.archive.org/web/20020527005933/http://www.awma.org/ (AWMA Homepage, advertising AWMA 2002 Conference)
1080	AWMA Website (Internet Archive), available at https://web.archive.org/web/20020604012426/http://www.awma.org:80/about/ (AWMA About Page)
1081	AWMA Website (Internet Archive), available at https://web.archive.org/web/20020601173851/http://www.awma.org/

Exhibit	**Description of Exhibits Used in IPR2025-00274 and -00278 ['114 Patent]**
	ACE2002/tech-program/MondayPM.asp#AE-1c (AWMA Technical Program Schedule for Monday 24, 2002 for Session AE-1C)
1082	AWMA Website (Internet Archive), available at https://web.archive.org/web/20020616091740/http://www.awma.org/ACE2002/exhibition/list.asp (AWMA 2002 Conference list of exhibitors)
1083	AWMA Website (Internet Archive), available at https://web.archive.org/web/20020601121532/http://www.awma.org/ACE2002/top10list.asp (AWMA 2002 Conference Top Ten Reasons)
1084	AWMA Website (Internet Archive), available at https://web.archive.org/web/20020610093515/http://www.awma.org/ACE2002/welcome.asp (AWMA 95th Annual Conference and Exhibition Welcome Page)
1085	AWMA Website (Internet Archive), available at https://web.archive.org/web/20020806044928/http://www.awma.org:80/pubs/bookstore/ItemInfo.asp?OrderCode_s=VIP-110-CD (AWMA Bookstore Page, Order form for 2002 AWMA Conference CD)
1086	AWMA Website (Internet Archive), available at https://web.archive.org/web/20020806041256/http://www.awma.org:80/pubs/bookstore/ (AWMA Bookstore Homepage)
1087	State of Massachusetts Mass-EPA (Internet Archive) (dated Jan. 6, 2003), available at https://web.archive.org/web/20030106044457/http://www.state.ma.us/dep/bwp/about.htm (describing mission of Mass Department of Environmental Protection, Bureau of Waste Prevention)

Exhibit	**Description of Exhibits Used in IPR2025-00274 and -00278 ['114 Patent]**
1088	State of Massachusetts Mass-EPA (Internet Archive) (dated Dec. 21, 2002), available at https://web.archive.org/web/20021221040816/http://www.state.ma.us/dep/bwp/bwpprogs.htm (describing the divisions and programs of the Mass Bureau of Waste Prevention)
1089	State of Massachusetts Mass-EPA (Internet Archive) (dated Jan. 6, 2003), available at https://web.archive.org/web/20030106024342/http://www.state.ma.us/dep/bwp/bwppubs.htm (describing the publications by program of the Mass Bureau of Waste Prevention)
1090	State of Massachusetts Mass-EPA (Internet Archive) (dated Dec. 20, 2002), available at https://web.archive.org/web/20021220143210/http://www.state.ma.us/dep/bwp/daqc/daqcpubs.htm#ecp (describing the Air Program Planning Unit Publications of the Mass Bureau of Waste Prevention)
1091	Internet Archive Standard Affidavit, explaining how to interpret hyperlinks, available at: https://archive.org/legal/affidavit.php
1092	Expert Report of Philip J. O'Keefe, PE Regarding Infringement (Aug. 25, 2022) (excerpted), submitted by Patent Owner in *Midwest Energy Emissions Corp., et al. v. Arthur J. Gallagher & Co., et al.*, No. 1:19-cv-01334-CJB
1093	Deposition Transcript of Phillip O'Keefe Vol. 1 (Mar. 2, 2023), taken in *Midwest Energy Emissions Corp., et al. v. Arthur J. Gallagher & Co., et al.*, No. 1:19-cv-01334-CJB.
1094	Deposition Transcript of Phillip O'Keefe Vol. 2 (Mar. 3, 2023), taken in *Midwest Energy Emissions Corp., et al. v. Arthur J. Gallagher & Co., et al.*, No. 1:19-cv-01334-CJB.

Exhibit	**Description of Exhibits Used in IPR2025-00274 and -00278 [’114 Patent]**
1095	Deposition Transcript of Edwin Olson (Aug. 26, 2022) (excerpted), taken in *Midwest Energy Emissions Corp., et al. v. Arthur J. Gallagher & Co., et al.*, No. 1:19-cv-01334-CJB.
1096	Deposition Transcript of Michael Holmes (Aug. 24, 2022) (excerpted), taken in *Midwest Energy Emissions Corp., et al. v. Arthur J. Gallagher & Co., et al.*, No. 1:19-cv-01334-CJB.
1097	Deposition Transcript of John Pavlish (Aug. 25, 2022) (excerpted), taken in *Midwest Energy Emissions Corp., et al. v. Arthur J. Gallagher & Co., et al.*, No. 1:19-cv-01334-CJB.
1098	Affidavit of Tanya Zeif, Custodian of Records for Internet Archive (1/10/2025), sponsoring Exhibits 1078-1086
1099	Affidavit of Tanya Zeif, Custodian of Records for Internet Archive (1/13/2025), sponsoring Exhibits 1009, 1061, 1087-1090

Other than citations to prosecution histories, EX1020-EX1026, citations to exhibits reference the original page numbers found in the underlying document, and all emphases are added.

VI. SUMMARY OF CONCLUSIONS AND GROUNDS FOR CHALLENGE

13. After reviewing the materials identified in the List of Exhibits, I have concluded that each of the Challenged Claims of the Challenged Patent would have been anticipated or obvious to a person of ordinary skill in the art, based on the following grounds:

A. BASED ON REFERENCES THAT QUALIFY AS PRIOR ART BEFORE AUG. 30, 2004

Ground	Claims Challenged	Prior Art
A1	1-30	Obvious over Vosteen589 (EX1005) in view of Starns (EX1008)
A2	1-30	Obvious over Vosteen589 (EX1005) in view of Mass-EPA (EX1009)
A3	23, 25-27, 30	Anticipated by Downs-Boiler (EX1006)
A4	1-8, 12-30	Obvious over Downs-Boiler (EX1006) in view of Starns (EX1008)
A5	1-30	Obvious over Downs-Boiler (EX1006) in view Mass-EPA (EX1009)

B. BASED ON REFERENCES THAT QUALIFY AS PRIOR ART AFTER AUG. 30, 2004

Ground	Claims Challenged	Prior Art
B1	1-9, 12-30	Sjostrom (EX1010) in view of Eckberg (EX1011)
B2	1-30	Sjostrom (EX1010) in view of Olson-646 (EX1012)
B3	1-5, 7-12, 14-18, 20, 23-25, 27-30	Anticipated by Olson-235 (EX1018)

VII. LEGAL STANDARDS

14. I am not a legal expert. In presenting my opinions, I have been informed of, and applied, the legal standards provided to me by counsel in arriving at the opinions set forth in this declaration.

15. I understand that in this *inter partes* review proceeding, the Petitioners have the burden of proving that the claims of a Challenged Patent are unpatentable in light of the prior art by a preponderance of the evidence. I understand that a preponderance of the evidence is evidence sufficient to show that a fact is more likely true than not true.

A. LEVEL OF ORDINARY SKILL IN THE ART

16. When interpreting a patent, I understand that it is important to identify the relevant art pertaining to the patent-in-suit as well as the level of ordinary skill in that art at the time of the claimed invention. The "art" is the field of technology to which the patent is related.

17. I have been instructed by counsel that the person of ordinary skill in the art (**"POSITA"**) is a hypothetical person who is presumed to know the relevant prior art. I understand that the actual inventor's skill is not determinative of the level of ordinary skill. I further understand that the factors that may be considered in determining the level of skill include: the types of problems encountered in the art; prior art solutions to those problems; rapidity with which innovations are made; sophistication of the technology; and educational level of active workers in the field. I understand that not all such factors may be present in every case, and one or more of them may predominate.

B. LEGAL STANDARD FOR CLAIM CONSTRUCTION

18. I understand that the first step in determining whether a patent claim would have been anticipated or obvious is to ascertain how a POSITA would have understood the claim terms.

19. I have been instructed by counsel on the law regarding claim construction and patent claims, and I understand that a patent may include two types of claims: independent claims and dependent claims. An independent claim stands alone and includes only the limitations it recites. A dependent claim can depend from an independent claim, or it can further depend from another dependent claim. I understand that a dependent claim includes all the limitations that it recites, in addition to all the limitations recited in the claim(s) from which it depends.

20. It is my understanding that in proceedings before the USPTO, the claims of a patent are to be construed under what is referred to as the "*Phillips* standard." I understand that this means that claim terms of a patent are given the meaning the terms would have to a POSITA, in view of the description provided in the patent itself and the patent's file history.

21. I understand that to determine how a person of ordinary skill would understand a claim term, one should look to those sources available that show what a person of skill in the art would have understood the disputed claim language to mean. Such sources include the words of the claims themselves, the remainder of

the patent's description, the prosecution history of the patent (all considered "intrinsic" evidence), and "extrinsic" evidence concerning relevant scientific principles, the meaning of technical terms, the technical literature on established and emerging relevant technologies, and the state of the art at the time of the invention.

22. I understand that, in construing a claim term, one looks primarily to the intrinsic patent evidence, including the words of the claims themselves, the remainder of the patent, and the patent's prosecution history.

23. I understand that extrinsic evidence, which is evidence external to the patent and the prosecution history, may also be useful in interpreting patent claims when the intrinsic evidence itself is insufficient.

24. I understand that words or terms should be given their ordinary and accepted meaning unless it appears that the inventors were using them to mean something else. In making this determination, the claims, the remainder of the patent, and the prosecution history are of paramount importance. Additionally, the patent and its prosecution history must be consulted to confirm whether the patentee has acted as its own lexicographer (i.e., provided its own special meaning to any disputed terms), or intentionally disclaimed, disavowed, or surrendered any claim scope.

25. I understand that the claims of a patent define the scope of the rights conferred by the patent. The claims particularly point out and distinctly claim the

subject matter which the patentee regards as his invention. Because the patentee is required to define precisely what he claims his invention to be, it is not proper to construe claims in a manner different from the plain import of the terms as used in the patent. Accordingly, a claim construction analysis must begin and remain centered on the claim language itself. Additionally, the context in which a term is used in the asserted claim can be highly instructive. Likewise, other claims of the patent in question, both challenged and un-challenged, can inform the meaning of a claim term. For example, because claim terms are normally used consistently throughout the patent, the usage of a term in one claim can often illuminate the meaning of the same term in other claims. Differences among claims can also be a useful guide in understanding the meaning of particular claim terms.

26. I understand that a person of ordinary skill in the art is deemed to read a claim term not only in the context of the particular claim in which the disputed term appears, but in the context of the entire patent, including the remaining text and figures. For this reason, the words of the claim must be interpreted in view of the entirety of the patent specification (i.e., the claims, remaining text, and figures). The written description (figures and remaining text) is the primary basis for construing the claims and provides a safeguard such that correct constructions closely align with the patent.

27. In addition to consulting the patent itself, I understand that one should also consider the patent's prosecution history. The prosecution history provides evidence of how both the Patent Office and the inventors understood the terms of the patent, particularly in light of what was known in the prior art.

28. I understand that while intrinsic evidence is of primary importance, extrinsic evidence, e.g., all evidence external to the patent and prosecution history, including expert and inventor testimony, dictionaries, and learned treatises, can also be considered. Extrinsic evidence should not be considered, however, divorced from the context of the intrinsic evidence. Furthermore, while extrinsic evidence can shed useful light on the relevant art, it is less significant than the intrinsic record in determining the legally operative meaning of claim language.

C. LEGAL STANDARD FOR PRIOR ART

29. I understand that a patent or other publication must first qualify as prior art before it can be used to invalidate a patent claim. Specific for each prior art reference, I discuss the date of the prior art (e.g., when it was made publicly accessible for conference proceedings, or when it was filed and published for patents) and how that is earlier than the priority date of the Challenged Claims.

30. I understand that to qualify as prior art, a reference must contain an enabling disclosure that allows one of ordinary skill to practice the claims of the Challenged Patent without undue experimentation. I understand that a patent issued

by the United States Patent and Trademark Office is presumed to provide an enabling disclosure. Factors to consider in determining whether undue experimentation is needed are: (1) the quantity of experimentation necessary, (2) the amount of direction or guidance presented, (3) the presence or absence of working examples, (4) the nature of the invention, (5) the state of the prior art, (6) the relative skill of those in the art, (7) the predictability or unpredictability of the art, and (8) the breadth of the claims.

31. I understand that for a prior-art reference to be considered for obviousness, the reference must be "analogous." I understand that the comparison for purposes of determining "analogous" is between the asserted prior-art reference and the Challenged Patent. I have been further informed that for a prior-art reference to be considered "analogous" to the Challenged Patent and thus available as prior art for obviousness, at least one of the following conditions must be met: (1) the reference is from the same field of endeavor as the Challenged Patent, even if it addresses a different problem; or (2) the reference is reasonably pertinent to the particular problem the Challenged Patent is concerned with, even if it is not within the same field of endeavor.

D. LEGAL STANDARD FOR PATENTABILITY

32. I understand that for an invention claimed in a patent to be found patentable, it must be (among other things) new and not obvious based on what was known before the invention was made.

33. I understand that, once the claims of a patent have been properly construed, the second step in determining anticipation of a patent claim requires a comparison of the properly construed claim language to the prior art on a limitation-by-limitation basis.

34. I understand that for purposes of this declaration, there are two ways to demonstrate that a patent claim is invalid. A patent claim can be anticipated, or a patent claim can be obvious. I address each of these below.

1. Anticipation and Inherency

35. I understand that prior art can "anticipate" the claims of an asserted patent. It is my understanding that in order for a claim to be anticipated by the prior art, every element of that claim must be found, explicitly or inherently, in a single prior art reference. In other words, to determine whether a single prior art reference anticipates a patent claim, one should consider not only what is expressly disclosed in that reference, but also what inherently occurred as a natural result of the practice of the system or method disclosed in that prior art reference.

36. It is further my understanding that to establish such inherency, the missing descriptive matter must be necessarily present in the item of prior art and that it would be so recognized by persons of ordinary skill in the art. It is also my understanding that such inherency may be shown through extrinsic evidence.

2. Obviousness

37. I understand that the prior art may render a patent claim "obvious." I understand that two or more prior art references (e.g., prior art articles, patents, or publications) that each disclose fewer than all elements of a patent claim may nevertheless be combined to render a patent claim obvious if the combination of the prior art collectively discloses all elements of the claim and one of ordinary skill in the art at the time would have been motivated to combine the prior art in such a way with a reasonable expectation of success.

38. I understand that this motivation to combine need not be explicit in any of the prior art, but it may be inferred from the knowledge of one of ordinary skill in the art at the time the patent was filed. I also understand that one of ordinary skill in the art is not an automaton but is a person having ordinary creativity. I further understand that an obviousness analysis recognizes that market demand often drives innovation, and that a motivation to combine references may be supplied by the direction of the marketplace. I further understand that one or more prior art references, articles, patents or publications that disclose fewer than all of the

elements of a patent claim may render a patent claim obvious if including the missing element would have been obvious to one of skill in the art (e.g., the missing element represents only an insubstantial difference over the prior art or a reconfiguration of a known system).

39. I understand that a person of ordinary skill in the art provides a reference point from which the prior art and claimed invention should be viewed. This reference point prevents a person of ordinary skill from using hindsight in deciding whether a claim is obvious.

40. I also understand that an obviousness determination includes the consideration of various factors such as (1) the scope and content of the prior art, (2) the differences between the prior art and the challenged claims, (3) the level of ordinary skill in the pertinent art, and (4) when in evidence, the existence of secondary considerations (such as commercial success, long-felt but unresolved needs, failure of others, etc.) to the extent they exist and have a nexus to the claimed invention.

41. I am informed that secondary indicia of non-obviousness (a.k.a. secondary considerations) may include (1) a long felt but unmet need in the prior art that was satisfied by the invention of the patent; (2) commercial success or lack of commercial success of processes covered by the patent; (3) unexpected results achieved by the invention; (4) praise of the invention by others skilled in the art;

(5) taking of licenses under the patent by others; and (6) deliberate copying of the invention. I also understand that there must be a relationship between any such secondary indicia and the invention. I further understand that contemporaneous and independent invention by others is a secondary consideration supporting an obviousness determination. I also understand that secondary considerations are given less weight when the alleged invention represents a relatively small advance in a crowded field with predictable results. I further understand that the patentee has the burden of coming forward with evidence of the relationship between any secondary consideration of non-obviousness and the claimed invention (also known as the "nexus").

42. It is also my understanding that there are additional considerations that may be used as further guidance as to when the above factors will result in a finding that a claim is obvious, including the following:

- the claimed subject matter is simply a combination of prior art elements according to known methods to yield predictable results;
- the claimed subject matter is a simple substitution of one known element for another to obtain predictable results;
- the claimed subject matter uses known techniques to improve similar devices or methods in the same way;
- the claimed subject matter applies a known technique to a known device or method that is ready for improvement to yield predictable results;

- there is known work in one field of endeavor that may prompt variations of it for use in either the same field or a different one based on design incentives or other market forces if the variations would have been predictable to a POSITA;
- there existed at the time of the invention a known problem for which there was an obvious solution encompassed by the patent's claims; and
- there is some teaching, suggestion, or motivation in the prior art that would have led a POSITA to modify the prior art reference or to combine prior art reference teachings to arrive at the claimed subject matter.

43. I understand that a particular combination may be proven obvious by showing that it was obvious to try the combination. For example, when there is a design need or market pressure to solve a problem and there are a finite number of identified, predictable solutions, a person of ordinary skill has good reason to pursue the known options within his or her technical grasp because the result is likely the product not of innovation but of ordinary skill and common sense.

44. I further understand that a claim may be deemed invalid for obviousness in light of a single prior art reference, without the need to combine references, if the elements of the claim that are not found in the reference can be supplied by the knowledge or common sense of one of ordinary skill in the relevant art.

45. I also understand that practical and common-sense considerations should guide a proper obviousness analysis, because familiar items may have obvious uses beyond their primary purposes. I further understand that a person of ordinary skill in the art looking to overcome a problem will often be able to fit the

teachings of multiple publications together like pieces of a puzzle, although the prior art need not be like two puzzle pieces that must fit perfectly together. I understand that an obviousness analysis therefore considers the inferences and creative steps that a person of ordinary skill in the art would employ under the circumstances.

46. I understand that a person of ordinary skill could have combined two pieces of prior art or substituted one prior art element for another if the substitution can be made with predictable results, even if the swapped-in element is different from the swapped-out element. I understand that the relevant question is whether prior art techniques are interoperable with respect to one another, such that a person of skill would view them as a design choice, or whether a person of skill could apply prior art techniques into a new combined system.

47. In sum, my understanding is that prior art teachings are properly combined where a person of ordinary skill in the art having the understanding and knowledge reflected in the prior art and motivated by the general problem facing the inventor, would have been led to make the combination of elements recited in the claims. Under this analysis, the prior art references themselves, or any need or problem known in the field of endeavor at the time of the invention, can provide a reason for combining the elements of multiple prior art references in the claimed manner.

VIII. LEVEL OF ORDINARY SKILL IN THE ART

48. As described in the Legal Standards section, I have been provided the legal standards for determining the qualifications of a Person of Ordinary Skill in the Art ("POSITA").

49. As of the Challenged Patent's earliest claimed priority date (August 2004), a POSITA would have had at least a bachelor's degree in chemical engineering, mechanical engineering, or a related field of study. A POSITA would also have at least two years' experience implementing pollution control in power generation plants for natural gas, coal, and/or industrial waste incineration. Among other areas, the POSITA would have been familiar with the topics discussed below in the Technology Background and State of the Art section.

50. I understand that Petitioners and Patent Owner may have a dispute as to whether the Challenged Claims are entitled to a priority date of August 2004. The qualifications of a POSITA, discussed above, remain unchanged.

51. I was at least a person of ordinary skill as of August 2004, and I remain so.[1]

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[1] In an earlier district-court litigation challenging patents from ME2C, I explained in a report that a person of skill in the art would have had a "Master's Degree in chemical engineering, chemistry, or a related field of study, as well as knowledge of mercury chemistry—including knowledge of gas phase and heterogeneous reactions of mercury and halogen species at the temperatures and under the

IX. TECHNOLOGY BACKGROUND AND STATE OF THE ART

52. In the subsections below, I describe some basic principles of chemistry and engineering relating to coal combustion and removing pollutants (such as mercury) from gas streams. The principles discussed in the subsections below would have been well-known to a POSITA by August 2004. The information below is still true, and would have been known to a POSITA, also in 2018.

A. FUNDAMENTAL PRINCIPLES OF CHEMISTRY

1. Periodic Table and Chemical Notation

53. The periodic table of elements (or "periodic table" for short) is a common way to display chemical elements in a tabular manner. Each box in the periodic table represents a chemical element. The periodic table typically displays the atomic number and atomic mass of a chemical element, and some periodic tables display other properties. The atomic number refers to the number of protons in the nucleus of an atom. The atomic mass of a chemical element is the number of protons

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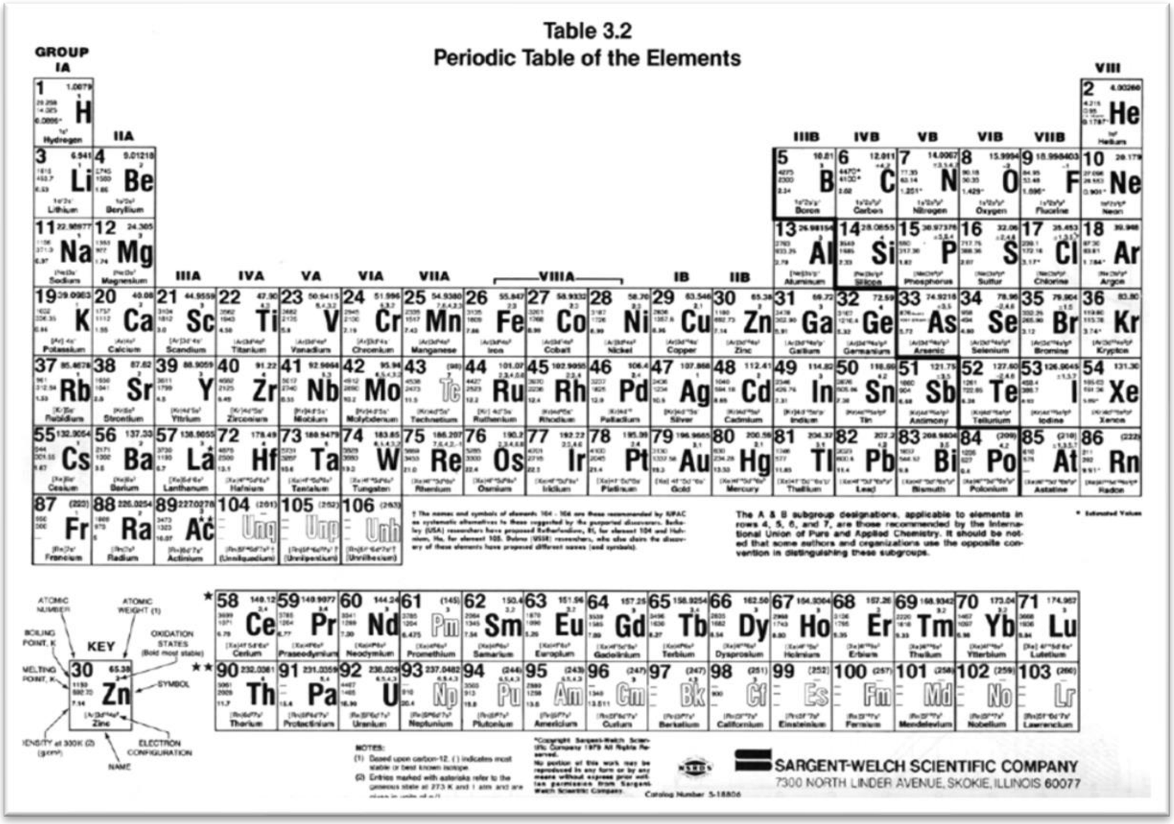
conditions found in coal-fired power plants." That litigation involved the alleged infringement of a patent (8,168,147) with claims directed more to the surface chemistry, with limitations such as: "activated carbon contains graphene sheets having carbene species edge sites" and "form a carbocation paired with a bromide anion." Those claim limitations are not present in the Challenged Claims in this declaration. Regardless of which definition is used for a POSITA—bachelor's degree or master's degree—my opinions are unaffected.

and neutrons in the nucleus of an atom, and is averaged to account for the occurrence of isotopes.

54. A sample periodic table from B&W: Steam is shown below:[2]



55. As can be seen above, the periodic table is arranged in periods (horizontal rows) and groups (vertical columns). It was well-known that chemical elements exhibit trends within a group.[3] Chemical elements within the same group tend to have similar chemical properties because they generally have the same

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[2] EX1027 (B&W: Steam) at exhibit page 239 (Table 3.2).

[3] EX1041 (Greenwood) at 27-29.

electron configuration in their valence (outermost electron) shell. For example, both sodium (Na) and potassium (K) have one electron in their valence shell, while chlorine (Cl), bromine (Br), and iodine (I) each have seven electrons.

2. Groups in the Periodic Table

56. As shown in the periodic table copied above, there are eighteen numbered columns (groups) of elements in the periodic table. Over the years, multiple conventions have developed in how the groups are numbered. The International Union of Pure and Applied Chemistry (IUPAC) labels the groups from Arabic numeral 1 through Arabic numeral 18. Group 1 is the left-most group, and Group 18 is the right-most group (noble gas elements). An earlier group number system was also developed by the IUPAC, and another system was developed by the Chemical Abstracts Service (CAS), a division of the American Chemical Society. In the CAS and older-IUPAC numbering scheme, the numbers of the periodic groups represent the highest oxidation state of elements in the group. In the CAS numbering, an “A” designates a main-group element, and a “B” designates a transition-metal element. In the old-IUPAC numbering, an “A” designates an element in the left portion of the periodic table, and a “B” designates an element in the right portion of the periodic table.

3. Oxidation and Oxidation Number

57. An oxidation state, or oxidation number, is a fictitious charge assigned to atoms in a molecule that represent the law of conservation of charge; the oxidation numbers of atoms in a neutral molecule add up to zero, and the oxidation numbers in an ion add up to the charge on the ion. The oxidation number symbolizes the transfer of electrons from one atom to another in a molecule—a positive number represents loss of electrons, and a negative number represents the gain of electrons.[4] By way of example, oxidation numbers for a calcium ion would be represented as Ca^{2+} (because the calcium lost two electrons), and for a bromide ion and iodine ion would be Br^{-} and I^{-} (because the bromine and iodine gained an electron). Oxidation refers to a chemical process by which an element is oxidized, or gives up electrons. Reduction refers to the chemical process by which an element is reduced, or accepts electrons. An oxidizing agent causes oxidation of another substance, while it itself is reduced.[5]

4. Group I (Alkali Elements), Group II (Alkaline Earth Elements), and Alkali Substances

58. Common alkali components include salts from: (i) an alkali metal (Group I, typically sodium or potassium) or an alkaline earth metal (Group II,

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[4] EX1040 (Oxtoby) at 85.

[5] EX1040 (Oxtoby) at 85, 87.

typically calcium or magnesium); and (ii) hydroxides (OH^-), carbonates (CO_3^{2-}), and phosphates (PO_4^{3-}). As such, common alkali components from hydroxides include: NaOH (sodium hydroxide, caustic soda, or lye); KOH (potassium hydroxide, potash or lye); $Ca(OH)_2$ (calcium hydroxide, hydrated or slaked lime); and $Mg(OH)_2$ (magnesium hydroxide). Common alkali components from carbonates include: $CaCO_3$ (calcium carbonate, limestone) and $MgCO_3$ (magnesium carbonate).

5. Group IV (Carbon)

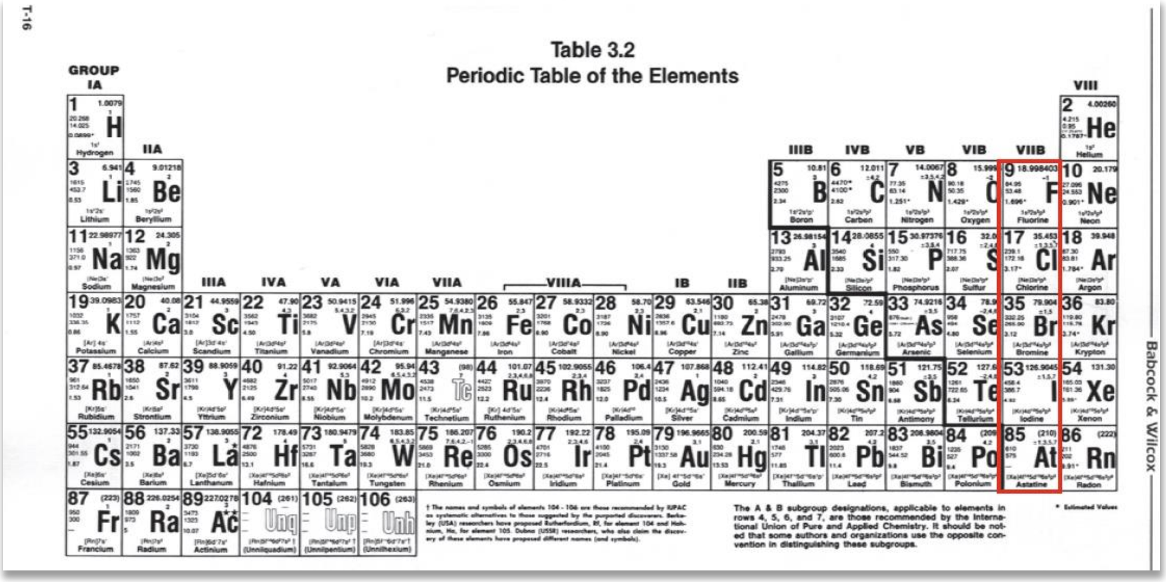
59. Elements in Group IV of the periodic table include carbon (C), silicon (Si), and germanium (Ge), among others.

6. Group V and Group VI Elements

60. As shown in the periodic table above ("Periodic Table and Chemical Notation" section), Group V of the periodic table contains nitrogen (N), phosphorus (P), and other less common elements. Group VI contains oxygen (O), sulfur (S), and other less common elements. Oxygen is present by definition in all coal combustion systems.

7. Group VII Elements (Halogens)

61. "Halogen" refers to those elements of the periodic table in Group VII and includes the chemically related elements fluorine (F), chlorine (Cl), bromine (Br), and iodine (I).[6] These are shown in the periodic table below.[7]



T-16

Table 3.2
Periodic Table of the Elements

Technically, astatine (At) with atomic number 85 is also a halogen, but it is radioactive and exceedingly rare in nature.

62. A summary of the four common halogens is provided below:

	Fluorine (F)	Chlorine (Cl)	Bromine (Br)	Iodine (I)
Atomic Number	9	17	35	53
Atomic Mass	18.998	35.453	79.904	126.904

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[6] EX1040 (Oxtoby) at 788, 791, A.44.

[7] EX1027 (B&W: Steam) at exhibit page 239 (Table 3.2).

Some known commonalities between the properties of the four above halogens are identified below:

- Each of the halogens exist as diatomic molecules in nature (e.g., F_2, Cl_2, Br_2, I_2).
- Each of the halogens are highly reactive due to their relatively high electronegativity. "Electronegativity is the power of an atom in a molecule to attract electrons to itself."[8]
- Each of the halogens has seven valence electrons in its outer electron shell.
- Each of the halogens acts as an oxidizing agent. They each raise the oxidation number of other elements that donate electrons.
- Each of the halogens form hydrogen halides (or hydrohalides in short) when combined with hydrogen. When in aqueous solution, the hydrohalides become hydrohalic acids (e.g., hydrofluoric acid, hydrochloric acid, hydrobromic acid, and hydroiodic acid).

63. A "halide" or "halide compound" (e.g., chloride, bromide, iodide) refers to the compound that results when a halogen combines with one or more other elements. For example, table salt (sodium chloride, NaCl) is a chloride compound. An example of a bromide compound is calcium bromide, or $CaBr_2$. An example of an iodide compound is sodium iodide (NaI).

64. A "hydrogen halide" or "hydrohalide" refers to "the molecular species HX and also the pure (anhydrous) compounds as hydrogen halides" and their

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[8] EX1041 (Greenwood) at 25 (quoting Linus Pauling).

aqueous solutions are called "hydrohalic acids."[9] It was known that "[a]nhydrous HX are versatile and vigorous reagents for the halogenation of metals."[10] Thus, hydrogen halides include hydrogen bromide (HBr), hydrogen chloride (HCl), and hydrogen iodide (HI).

8. Mercury

65. Elemental mercury (also referred to as metallic mercury) is a metal that may be found at ambient temperatures and atmospheric pressures as a heavy, silvery-white liquid.[11] The vapor pressure of mercury strongly depends on temperature, and mercury may readily vaporize at ambient conditions.[12] In general, atmospheric

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[9] EX1041 (Greenwood) at p. 809.

[10] EX1041 (Greenwood) at p. 813.

[11] EX1052, U.S. EPA, "Mercury Study Report to Congress Volume 1: Executive Summary," EPA-452/R-97-003 (Dec. 1997), available at https://www.epa.gov/sites/production/files/2015-09/documents/volume1.pdf, at 2-1.

[12] EX1052, U.S. EPA, "Mercury Study Report to Congress Volume 1: Executive Summary," EPA-452/R-97-003 (Dec. 1997), available at https://www.epa.gov/sites/production/files/2015-09/documents/volume1.pdf, at 2-1.

mercury is elemental mercury vapor.[13] Mercury generally exists in three oxidation states: Hg^0 (metallic/elemental), Hg_2^{2+} (mercurous), and Hg^{2+} (mercuric).[14]

9. Common Units of Measurements

66. **Moles:** A "mole" is a unit in chemistry that relates the mass of chemical elements to macroscopic terms. A mole (abbreviated "mol") of a chemical substance is equal to 6.022×10^{23} atoms (or molecules) of that substance. So, for example, 1 mol of elemental bromine equals 6.022×10^{23} bromine atoms. The number of grams of an element is provided by the atomic mass of a substance. Accordingly, 1 mol of bromine atoms equals 79.9 grams, and 1 mol of bromine molecules (Br_2) equals 159.8 grams. Similarly, 1 mol of iodine atoms equals 126.9 grams, and 1 mole of iodine molecules (I_2) equals 253.8 grams.

67. **PPM and PPB:** The parts-per notation is used by engineers to describe small quantities, such as a mole fraction or a mass fraction. Common units in coal combustion are parts-per-million (ppm) and parts-per-billion (ppb) of the moles in

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[13] EX1052, U.S. EPA, "Mercury Study Report to Congress Volume 1: Executive Summary," EPA-452/R-97-003 (Dec. 1997), available at https://www.epa.gov/sites/production/files/2015-09/documents/volume1.pdf, at 2-1.

[14] EX1052, U.S. EPA, "Mercury Study Report to Congress Volume 1: Executive Summary," EPA-452/R-97-003 (Dec. 1997), available at https://www.epa.gov/sites/production/files/2015-09/documents/volume1.pdf, at 2-1.

the system, which are the same as elements of volume. PPMW and PPBW are the corresponding levels on a mass basis, though sometimes people use PPM units to report fractions on a mass basis (such as when tracking halogen addition to coal).

68. **ACF and SCF:** ACF refers to "actual cubic feet," and is a measurement of the volume of a quantity (e.g., flue gas). SCF refers to "standard cubic feet," and is a measure of the volume of a quantity at a standardized pressure (typically 1 atm, which is also 101.325 kPa) and a standardized temperature (typically either 0ºC or 25ºC). MACF or MMACF refer to 1 million actual cubic feet, and MSCF and MMSCF refer to 1 million standard cubic feet. The two quantities can readily be converted from one to another as follows:

$SCF = ACF \times (P_{actual}/P_{standard}) \times (T_{standard}/T_{actual})$ [where T is represented in Kelvin]

Absolute Hg concentrations can be expressed in μg/Normal-m^3 @ 3%O_2, where "normal" is the European equivalent of "standard" and the actual O_2 concentration in flue gas is adjusted to 3%.

B. COAL POWER PLANTS AND ASSOCIATED UNITS

1. Types of Coal

69. As of 1992, coal was the most common fossil fuel in use globally for utility and industrial power generation.[15] It was known that coal tends to be a

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[15] EX1027 (B&W: Steam) at 8-1.

heterogenous fuel source, meaning that its chemical composition may vary by location and even within a coal seam.[16] Thus, a system of classification of coal was standardized by the American Society of Testing and Materials (ASTM) that organizes the broad characteristics of coal by rank.[17] This classification system uses a given coal's heating value and quantities of volatile matter and fixed carbon content as ranking criteria based on proximate analysis.[18] The four broad classifications are organized from highest to lowest rank as: (I) Anthracitic (also called "anthracite"); (II) Bituminous; (III) Subbituminous; and (IV) Lignitic (also called "lignite").[19] It was known that a common source of subbituminous coal in the United States was the Powder River Basin, which spans Montana and Wyoming. In general, bituminous coals (and anthracites) have the highest native halogen levels whereas lignites (and subbituminous coals) tend to have much lower values.

70. It was known that, as a byproduct of combustion, some unburned carbon is present in the combustion and flue gases. The amount of unburned carbon,

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[16] EX1027 (B&W: Steam) at 8-3.

[17] EX1027 (B&W: Steam) at 8-4.

[18] EX1027 (B&W: Steam) at 8-4.

[19] EX1027 (B&W: Steam) at 8-5. These ranks are also disclosed by the Massachusetts Department of EPA. EX1009 (Mass-EPA) at 23 (section 2.1, entitled "Coal Types and Coal Preparation").

often referred to as loss on ignition (LOI), was generally proportionally related to the rank of the coal being fired due to the higher volatility of the lower rank coals. Therefore, there were typically proportionately lower amounts of unburned carbon in the flue gases of low-rank coals such as lignite and subbituminous coal.

71. The major organic components of coal include carbon, hydrogen, and oxygen.[20] Impurities in coal typically include sulfur, nitrogen, and minerals or ash. Such impurities, and others, can give rise to hazardous air pollutants (HAP), such as the pollutants of sulfur oxides (SO_x) and nitrogen oxides (NO_x) discussed below.[21] In 1998, the EPA published its final report to Congress based on a study of HAPs from electric utility steam generation in analyzing thirteen "priority HAPs."[22] Among the priority HAPs, the EPA report concluded that "[b]ased on available information and current analyses, the EPA believes that mercury from coal-fired utilities is the HAP of greatest potential concern."[23]

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[20] EX1027 (B&W: Steam) at 8-3.

[21] EX1027 (B&W: Steam) at 8-3.

[22] EX1051, U.S. EPA, "Study of Hazardous Air Pollutant Emissions from Electric Utility Steam Generation Units -- Final Report to Congress," (Vol. 1 1998), available at https://www3.epa.gov/ttn/utox/eurtc1.pdf, at ES-5.

[23] EX1051 U.S. EPA, "Study of Hazardous Air Pollutant Emissions from Electric Utility Steam Generation Units -- Final Report to Congress," (Vol. 1 1998), available at https://www3.epa.gov/ttn/utox/eurtc1.pdf, at ES-27, 7-45.

2. **Combustion Chamber and Boiler**

72. It was known that the main method in use by the electric utility steam generation industry for the combustion of coal as a fuel source was pulverized coal firing.[24] Pulverized coal firing is performed by feeding small particle sized coal—around 50 micron mean diameter—to a combustion chamber or furnace for combustion of the pulverized coal.[25] Illustrated below is a typical pulverized coal-fired power plant, known since at least 1992, with a Carolina-type design boiler shaded in orange and labeled as the "steam generator" to show where the combustion chamber is situated with respect to the other major systems in use by electric utilities.[26]

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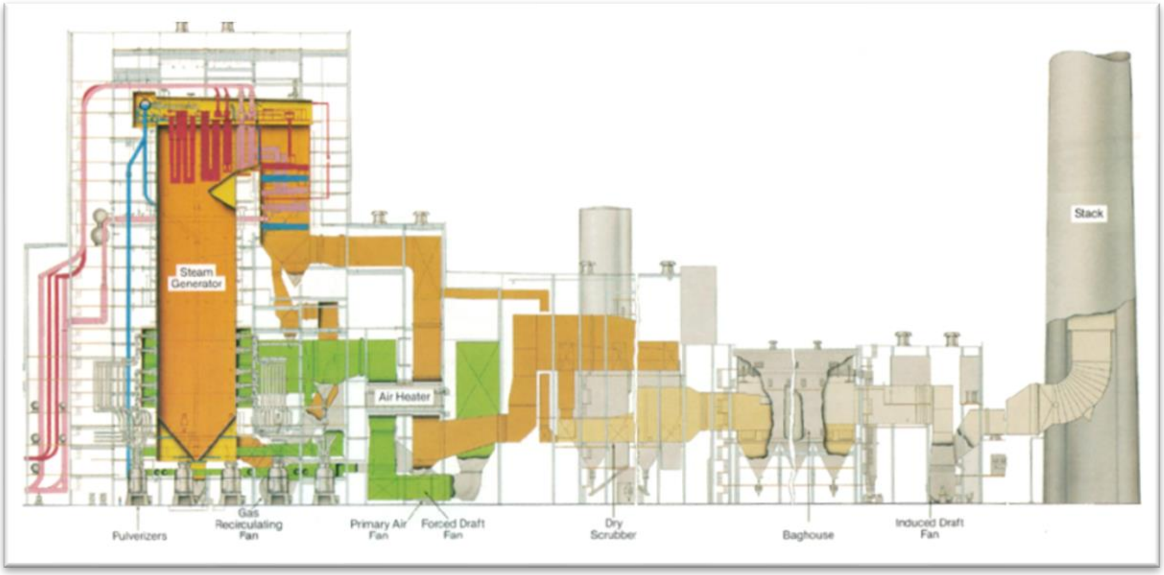
[24] EX1027 (B&W: Steam) at 13-1 (noting also use of cyclone, stoker, and fluidized bed firing methods).

[25] EX1027 (B&W: Steam) at 13-1.

[26] EX1027 (B&W: Steam) at Plate 8.



73. Regardless of the configuration of the combustion chamber, the components within these systems generally included a number of burners that fired the pulverized coal as it was carried from the pulverizers by a stream of primary air supplied by a large forced-draft fan. It was known that the combustion chamber may also include a supply of secondary air and over-fire air ports for the control of NOx formation. At the base of the combustion chamber would typically be a bottom ash handling system to collect and remove the portion of heavier ash that was discharged from the furnace and settled at the bottom of the combustion chamber.

74. The term "boiler" has been colloquially used to refer to an overall combustion chamber and related equipment, including the tubes of the steam-water circulation system that were in contact with the hot gases from the combustion of

the pulverized coal.[27] These tubes carried liquid water through them which, when in contact with the hot gases of the furnace, boiled the water to generate the steam necessary to drive the turbines and produce electricity. The boiler tubes were generally grouped in banks of steam and water tubes hung on stringers that were located in the top regions of the furnace and within the backpass of the furnace before the air preheater. The various stages of the steam tube banks were generally referred to as superheaters—these may be primary superheaters, secondary superheaters, and reheat superheaters.[28] The steam from the various boiler banks typically would be directed to different pressure stages of the turbine and then returned to another bank of water tubes before making a complete loop. Beyond the superheater banks of the boiler ordinarily would be a bank of water tubes called an "economizer," for the purpose of recovering extra thermal energy from the flue gases to be provided to the boiler feedwater before it entered superheater banks.[29] It was known that the point within the furnace after the last bank of the superheater section, and before the entrance to the economizer, was commonly referred to as the "furnace exit" and was

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[27] EX1027 (B&W: Steam) at 18-1.

[28] EX1027 (B&W: Steam) at 18-2, 3.

[29] EX1027 (B&W: Steam) at 19-1.

understood as the transition point after which the combustion gases were referred to as flue gases from there forward.

75. It was known that downstream of the boiler-tube section of the furnace, the flue gases pass through the economizer and another heat exchanger called an "air heater" or an "air preheater." The function of this air preheater was to reclaim some of the thermal energy from the combustion gases, by transferring this waste heat to the primary and secondary air before it enters the combustion chamber, thus enhancing the combustion efficiency of the pulverized coal.[30] After exiting the air preheater, the cooler flue gases continue along the flue-gas cleaning system that removes fly ash and SO_2, prior to exhausting these gases to the environment.

3. Components Typically Upstream of the Combustion Chamber

76. It was known in the art, and a POSITA would have expected, that several components would be upstream of the combustion chamber. These components included the air supply for the primary air and secondary air and the coal handling systems and are shown in the diagram below.[31]

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[30] EX1027 (B&W: steam) at 19-6.

[31] EX1027 (B&W: Steam) at 13-3 to 13-5.

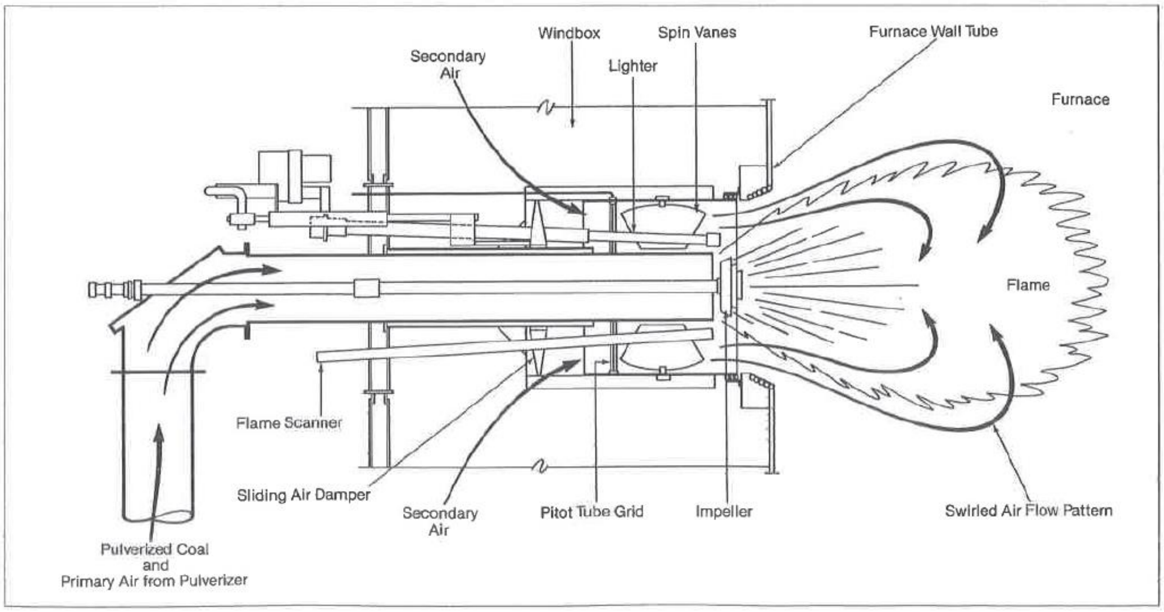

Fig. 5 S-type burner and components.

Steam 40 / *Burners and Combustion Systems for Pulverized Coal* **13-5**

As can be seen in the above figure, the secondary air is conveyed to the furnace using a separate pipe as compared to the pulverized coal and primary air.

77. It was known that coal handling systems transport coal from the coal storage pile, typically on a conveyor system, to a coal bunker for temporary storage ahead of the pulverizers. These coal bunkers were typically situated vertically above a number of pulverizers so that the coal can be gravity fed to the feeder below.[32] These feeders meter the rate of coal provided to the pulverizers which, as the name implies, were responsible for crushing the coal with a series of rollers that grind the

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[32] EX1027 (B&W: Steam) at 11-13, 13-3 to 13-5.

coal into a powder.[33] It was known that a stream of primary air from the air preheater serves a dual purpose of drying out the coal and transporting the pulverized coal to the burners in the furnace.[34]

4. Flue Gas Constituents

78. In 1972, the EPA first published AP-42, *Compilation of Air Pollutant Emissions Factors*. The Fifth Edition of AP-42 was published in January 1995 with various supplements and updates periodically provided.[35] Chapter 1 of the AP-42 is titled "External Combustion Sources." Chapter 1 of the AP-42 has a first section titled "Bituminous and Subbituminous Coal Combustion."[36] The Bituminous and Subbituminous Coal Combustion section was last supplemented in September 1998.[37] Thus, in 2003, the AP-42 demonstrated that much was already known in the art about flue gas constituents.

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[33] EX1027 (B&W: Steam) at 12-8.

[34] EX1027 (B&W: Steam) at 12-2.

[35] EX1053 (U.S. EPA, AP-42: External Combustion Sources, Chapter 1: Fifth Edition) at 1.1-10.

[36] EX1053 (U.S. EPA, AP-42: External Combustion Sources, Chapter 1: Fifth Edition).

[37] EX1053 (U.S. EPA, AP-42: External Combustion Sources, Chapter 1: Fifth Edition) at 1.1-11.

79. The AP-42 explained that "[e]missions from coal combustion depend on the rank and composition of the fuel, the proportions of fuel and air, the type and size of the boiler, firing conditions, load, type of control technologies, and the level of equipment maintenance."[38] It was known that potential emissions included particulate matter, sulfur oxides (SOx), nitrogen oxides (NOx), carbon monoxide (CO), organic compounds, trace metals, acid gases, and greenhouse gases.[39]

80. Particulate matter emitted from coal combustion processes "include[d] the ash from combustion of the fuel as well as unburned carbon resulting from incomplete combustion."[40] It was also known that in typical pulverized coal operations, combustion resulted in a particulate matter that "is primarily composed of inorganic ash residues."[41] In particular, the ash that is entrained in the flue gas was commonly referred to as "fly ash."[42] Unburned carbon in fly ash was estimated as the loss-on-ignition (LOI), which is the mass fraction of combustibles lost during incineration of a fly ash sample in air. In general, LOI is greater when in-furnace

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[38] EX1053 (Chapter 1 of AP-42) at 1.1-3.

[39] EX1053 (Chapter 1 of AP-42) at 1.1-3 to 1.1-6.

[40] EX1053 (Chapter 1 of AP-42) at 1.1-3.

[41] EX1053 (Chapter 1 of AP-42) at 1.1-3.

[42] EX1053 (Chapter 1 of AP-42) at 1.1-3.

technologies are implemented to reduce NO_X emissions. LOI was also greater with coals of progressively higher rank.

81. It was known that sulfur oxides ("SO_x") that were emitted from coal combustion "form[ed] as the organic and pyritic sulfur in the coal [were] oxidized during the combustion process."[43] It was known that nitrogen oxide ("NO_x") emissions "result[ed] from thermal fixation of atmospheric nitrogen in the combustion flame and from oxidation of nitrogen bound in the coal."[44] NO_x emissions were known to be "primarily nitric oxide (NO)" with trace amounts of nitrogen dioxide (NO_2) and nitrous oxide (N_2O).[45]

82. It was known that organic compound emissions from coal combustion "include volatile, semi volatile, and condensable organic compounds either present in the coal or formed as a product of incomplete combustion" such as "alkanes, alkenes, aldehydes, alcohols, and substituted benzenes (e.g., benzene, toluene, xylene, and ethyl benzene)."[46] It was also known that the rate at which these

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[43] EX1053 (Chapter 1 of AP-42) at 1.1-3.

[44] EX1053 (Chapter 1 of AP-42) at 1.1-3.

[45] EX1053 (Chapter 1 of AP-42) at 1.1-3.

[46] EX1053 (Chapter 1 of AP-42) at 1.1-4.

emissions are generated also "depends on the combustion efficiency of the boiler."[47] It was also known that similar to CO emissions, "combustion modifications that change combustion residence time, temperature, or turbulence may increase or decrease concentrations of organic compounds in the flue gas."[48]

83. It was known that the amount of trace metals (including mercury) emitted during coal combustion generally depends on "the physical and chemical properties of the metal itself; the concentration of the metal in the coal; the combustion conditions; and the type of particulate control device used, and its collection efficiency as a function of particle size."[49] In 2003, the types of trace metals were generally categorized into three classes:[50]

> Class 1: Elements that are approximately equally concentrated in the fly ash and bottom ash, or show little or no small particle enrichment. Examples include manganese, beryllium, cobalt, and chromium.
>
> Class 2: Elements that are enriched in fly ash relative to bottom ash, or show increasing enrichment with decreasing particle size. Examples include arsenic, cadmium, lead, and antimony.

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[47] EX1053 (Chapter 1 of AP-42) at 1.1-4.

[48] EX1053 (Chapter 1 of AP-42) at 1.1-4.

[49] EX1053 (Chapter 1 of AP-42) at 1.1-4 – 1.1-5.

[50] EX1053 (Chapter 1 of AP-42) at 1.1-5.

> Class 3: Elements which are emitted in the gas phase (primarily mercury and, in some cases, selenium).

Class 1 emissions were known to be "directly related to control of total particulate matter emissions."[51] Class 2 emissions were known to "depend[] on collection of fine particulate."[52] However, it was known that "[b]ecause of the volatility of Class 3 metals, particulate controls have only a limited impact on emissions of these metals."[53]

84. It was known that coal combustion "also results in emissions of chlorine and fluorine."[54] The chlorine and fluorine were known to be "primarily in the form of hydrogen chloride (HCl) and hydrogen fluoride (HF)" but may also be found in lesser quantities as chlorine gas and fluorine gas.[55]

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[51] EX1053 (Chapter 1 of AP-42) at 1.1-5.

[52] EX1053 (Chapter 1 of AP-42) at 1.1-5.

[53] EX1053 (Chapter 1 of AP-42) at 1.1-5.

[54] EX1053 (Chapter 1 of AP-42) at 1.1-5.

[55] EX1053 (Chapter 1 of AP-42) at 1.1-5.

5. Components Downstream of the Combustion Chamber

85. The EPA's AP-42 report also provided a brief summary of the various downstream components that were known to be used to control certain undesirable flue gas constituents.[56]

a. Particulate Matter Emissions Controls

86. Known particulate matter controls included "combustion modifications (applicable to small stoker-fired boilers) and post-combustion methods (applicable to most boiler types and sizes)."[57] It was also known that post-combustion control of particulate matter could be accomplished using one or more of the following: an electrostatic precipitator ("ESP"), a fabric filter (or baghouse), a wet scrubber, a cyclone or multi-clone collector, or a side stream separator.[58]

87. It was known to place electrostatic precipitators (ESPs) in one of two primary configurations: ahead of an air preheater in a hot-side (HS-ESP) configuration, or downstream of the air preheater in a cold-side (CS-ESP) configuration. As was widely known, "An electrostatic precipitator (ESP)

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[56] EX1053 (Chapter 1 of AP-42) at 1.1-6 – 1.1-9.

[57] EX1053 (Chapter 1 of AP-42) at 1.1-6.

[58] EX1053 (Chapter 1 of AP-42) at 1.1-6 to 1.1-7;

EX1027 (B&W: Steam) at Chapter 33 ("Particulate Control").

electrically charges the ash particles in the flue gas to collect and remove them."[59] They contain channels that have discharging electrodes to deliver negative charges and collecting electrodes that capture the charged particles. The ash layers that form on the collecting electrodes are intermittently removed by mechanical rapping, which dislodges them into collection hoppers. ESPs remove over 98 % of mineral particles in fly ash as well as unburned particles.[60] The ESP performance with sorbents (such as activated carbon) would be as least as good as for fly ash, because the sorbent particles are typically larger than fly ash particles.[61]

88. It was known that fabric filters contain multiple compartments that contain "several thousand long, vertically supported, small diameter fabric bags."[62] It was known that when mercury-containing flue gas with fly ash passes through the bags, fly ash and unburned carbon are deposited onto thin dust cakes on the outer bag surfaces. The cleaned flue gas then moves into an outlet plenum that recombines the effluents from all bags to proceed further downstream. It was known that as the

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[59] EX1027 (B&W: Steam) at 33-2.

[60] EX1027 (B&W: Steam) at 33-7.

[61] EX1027 (B&W: steam) at 33-4 & Fig. 5.

[62] EX1027 (B&W: steam) at 33-7.

dust cakes accumulate, the increasing pressure drop across the filter is managed by pulsing air jets to dislodge the dust cakes into collection hoppers.

b. SO_x Emissions Controls

89. Multiple techniques were known for controlling SO_x emissions. For example, it was known that "[p]ost combustion flue gas desulfurization (FGD) techniques can remove SO_2 formed during combustion by using an alkaline reagent to absorb SO_2 in the flue gas."[63] These FGD systems would treat coal flue gas "using wet, dry, or semi-dry desulfurization processes of either the throwaway type (in which all waste streams are discarded) or the recovery/regenerable type (in which the SO_2 absorbent is regenerated and reused)."[64] The most common type of FGD systems were wet FGDs that "generally use alkali slurries as the SO_2 absorbent medium and can be designed to remove greater than 90 percent of the incoming SO_2."[65] It was known that commercially viable and accepted wet FGDs include lime/limestone scrubbers, sodium scrubbers, and dual alkali scrubbers.[66]

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[63] EX1053 (Chapter 1 of AP-42) at 1.1-7.

[64] EX1053 (Chapter 1 of AP-42) at 1.1-7.

[65] EX1053 (Chapter 1 of AP-42) at 1.1-7.

[66] EX1053 (Chapter 1 of AP-42) at 1.1-7.

c. NO_x Emissions Controls

90. It was known that NO_x emissions could be controlled using combustion control techniques and post-combustion control.[67] Known post-combustion control techniques included "selective noncatalytic reduction (SNCR) and selective catalytic reduction (SCR)" systems.[68]

91. SNCR systems were known to "involve[] injecting ammonia (NH_3) or urea into specific temperature zones in the upper furnace or convective pass."[69] The SNCR system was known to remove NO_x by reacting the ammonia or urea with NO_x in the flue gas to produce nitrogen and water.[70] Specifically, it was known that "[a] nitrogen based reducing agent (reagent), such as ammonia or urea, is injected into the post combustion flue gas."[71]

92. Known SCR systems operated in a similar way that "involves injecting NH_3 into the flue gas in the presence of a catalyst to reduce NO_x to nitrogen and then

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[67] EX1053 (Chapter 1 of AP-42) at 1.1-7 - 1.1-8.

[68] EX1053 (Chapter 1 of AP-42) at 1.1-8.

[69] EX1053 (Chapter 1 of AP-42) at 1.1-9.

[70] EX1053 (Chapter 1 of AP-42) at 1.1-9.

[71] U.S. EPA, Air Pollution Control Cost Manual EPA/452/B-02-001 6th Edition, Section 4 NOx Controls, Section 4.2 NOx Post-Combustion, Chapter 1 Selective Noncatalytic Reduction (October 2000), available at https://www3.epa.gov/ttn/ecas/docs/cs4-2ch1.pdf, at 1-4.

water." Similar to SNCR systems, it was known that "the SCR process is based on the chemical reduction of the NO_x molecule."[72] The known SCR systems differed from known SNCR systems because they "employ[] a metal-based catalyst with activated sites to increase the rate of the reduction reaction.[73] Similar to known SNCR systems, "[a] nitrogen based reducing agent (reagent), such as ammonia or urea, is injected into the post combustion flue gas."[74] The SCR reactor was known to be flexible and could "be located at various positions in the process including before an air heater and particulate control device, or downstream of the air heater, particulate control device, and flue gas desulfurization systems."[75] It was known

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[72] U.S. EPA, Air Pollution Control Cost Manual EPA/452/B-02-001 6th Edition, Section 4 NOx Controls, Section 4.2 NOx Post-Combustion, Chapter 2 Selective Catalytic Reduction (October 2000), available at https://www3.epa.gov/ttn/ecas/docs/cs4-2ch2.pdf, at 2-4.

[73] U.S. EPA, Air Pollution Control Cost Manual EPA/452/B-02-001 6th Edition, Section 4 NOx Controls, Section 4.2 NOx Post-Combustion, Chapter 2 Selective Catalytic Reduction (October 2000), available at https://www3.epa.gov/ttn/ecas/docs/cs4-2ch2.pdf, at 2-4.

[74] U.S. EPA, Air Pollution Control Cost Manual EPA/452/B-02-001 6th Edition, Section 4 NOx Controls, Section 4.2 NOx Post-Combustion, Chapter 2 Selective Catalytic Reduction (October 2000), available at https://www3.epa.gov/ttn/ecas/docs/cs4-2ch2.pdf, at 2-4.

[75] EX1053 (Chapter 1 of AP-42) at 1.1-9.

that SCR systems were "often designed to meet control targets of over 90%" but typically "operate at efficiencies in the range of 70% to 90%" NO_x reduction.[76]

93. By January 2004, it was also known that adding a halogen "also reduces NO_x emissions in a selective catalytic reduction (SCR) and/or SNCR process, especially if the additive is injected with a nitrogen agent (N-agent) into NO_x and O_2 containing flue gas at flue gas temperatures in a range of 1600° F (Fahrenheit) to 2300° F."[77] Specifically, it was known that "[t]he halogen additive can also be added with ammonia, urea or other N-agent solution . . . to increase efficiency of NO_x reduction."[78]

94. By 2002, it was known that the catalysts in SCR units could also oxidize elemental mercury (Hg^0) while they eliminated NOx from the flue gas. Field tests across several SCRs at commercial power plants indicated that SCR systems "may also promote Hg^0 oxidation to Hg^{2+}, and this effect appeared to be coal-specific and possibly catalyst-specific."[79] The coal-specific aspect was attributed to a coal's

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[76] U.S. EPA, Air Pollution Control Cost Manual EPA/452/B-02-001 6th Edition, Section 4 NOx Controls, Section 4.2 NOx Post-Combustion, Chapter 2 Selective Catalytic Reduction (October 2000), available at https://www3.epa.gov/ttn/ecas/docs/cs4-2ch2.pdf, at 2-3.

[77] EX1014 (Lissianski) at 3:51-55.

[78] EX1014 (Lissianski) at 4:40-42.

[79] EX1037 (Paul Chu, Power Plant Evaluation).

native chlorine content, as researchers interpreting the full-scale SCR field test data noted that significant increases in mercury oxidation (to Hg^{2+}) across the SCR that "correlate[s] with the amount of chloride in the coal."[80]

95. Thus, a POSITA would have readily realized that adding chlorine compounds to the coal or furnace to produce HCl in flue gas would promote oxidation of elemental mercury across an SCR. It would have been a simple extension to recognize that other halogens, particularly bromine and iodine, would promote mercury oxidation on SCR catalysts as well as, or better than, chlorine.

d. Mercury Emissions Controls

96. By January 2003, numerous projects had been completed that demonstrated components for effective mercury control from coal-fired power plants.[81] For example, in Colorado "the DOE/FETC Mega PRDA program, DOE, Public Service Company of Colorado (PSCo), and EPRI" funded an evaluation of "carbon injection as a mercury control technology. ADA Technologies [for which Starns and Sjostrom worked] performs the fabrication, pilot operation, and reporting."[82] Further research in Colorado sponsored by TDA evaluated "a low cost

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[80] EX1045 (Laudal).

[81] EX1049 (U.S. DOE, Completed Mercury Projects, February, 2003).

[82] EX1049 (U.S. DOE, Completed Mercury Projects, February, 2003).

route to a carbon-based, sulfur containing sorbent that should have a high capacity for mercury and also for other air toxins including chlorine and hydrogen chloride."[83] Similarly, testing in Pennsylvania evaluated "the use of a granular activated carbon (GAC) fixed bed adsorption system for mercury adsorption from flue gas."[84]

C. SORBENTS / ACTIVATED CARBON

1. Sorbent Overview

97. In the late 1990's and early 2000's, sorbent technology was already being used to remove mercury, and researchers were investigating methods to further reduce costs and improve the effectiveness of sorbents. In particular, research by the EPA in the mid-1990s suggested that "activated carbon has been shown to be a promising technology."[85] Activated carbon's general use as a sorbent dates back as far as 1500 B.C. where the ancient Egyptians used carbonized wood "as an adsorbent for medicinal purposes and also as a purifying agent."[86] Industrial production of activated carbon "was established in 1900-1901 in order to replace bone char in the

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[83] EX1049 (U.S. DOE, Completed Mercury Projects, February, 2003).

[84] EX1049 (U.S. DOE, Completed Mercury Projects, February, 2003).

[85] EX1060 (EPA 1997 Mercury Study Report Vol. VIII) at 2-54.

[86] EX1070 (Bansal) at vii.

sugar refining process."[87] It was known in the 1980s that activated carbons "are excellent adsorbents and thus are used to purify, decolorize, deodorize, dechlorinate, detoxicate, filter, or remove or modify the salts, separate, and concentrate in order to permit recovery."[88] It was known that "adsorption" refers to a process by which an adsorbate (e.g., atoms, ions, or molecules) in a fluid (typically a gas) are bound to the surface of a sorbent.

98. By the 1930's, it was known that activated carbon could be used for mercury capture in gas streams.[89] U.S. Patent No. 1,984,164 to Stock, issued in 1934, explained that "[i]t has already been suggested to employ active carbon as a means of protection against the effects of mercury vapors."[90] By 1998, "[a]ctivated carbons ha[d] been the most thoroughly studied sorbent for the capture of mercury."[91, 92]

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[87] EX1070 (Bansal) at vii.

[88] EX1070 (Bansal) at viii.

[89] EX1029 (Stock).

[90] EX1029 (Stock) at 1:27-30.

[91] EX1038 (Granite) at 22.

[92] The named inventors of the Challenged Patent agree that they were not the first to work with activated-carbon sorbents. EX1096 (Holmes), 41:5-9; EX1095 (Olson) at 114:21-25; EX1097 (Pavlish) at 210:4-18.

99. By 1998, it was known that sorbents may capture mercury from coal flue gas by "chemical adsorption, or by chemical reaction.[93] Chemisorption was known to refer to "a surface reaction, limited to a monolayer."[94] Chemisorption and chemical reaction processes both were known to "occur over a wide range of temperatures" and "typically have higher activation energies and heats of reaction than does physisorption."[95]

100. In June 2002, Starns and others at ADA-ES and DOE-NETL presented a report discussing the activated carbon injection they had performed and confirmed the maturity of the technology:

> The most mature, retrofit technology available today is the injection of sorbents such as powdered activated carbon (PAC) into the flue gas upstream of the particle control equipment. The gas-phase mercury in the flue gas contacts the sorbent and attaches to its surface. Existing particle control equipment collects the sorbent with mercury attached along with the fly ash.[96]

101. In December 2002, a report entitled, "Evaluation of the Technological and Economic Feasibility of Controlling and Eliminating Mercury Emissions from

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[93] EX1038 (Granite) at 4.

[94] EX1038 (Granite) at 5.

[95] EX1038 (Granite) at 5.

[96] EX1008 (Starns) at 2.

the Combustion of Solid Fossil Fuel," was published by the Massachusetts Dept. of Environmental Protection. The Mass-EPA report assessed the maturity of activated carbon injection (ACI) as a mercury control technology:

> <u>Activated carbon (AC) has been the most extensively studied sorbent for mercury adsorption</u>. Currently, AC seems to be the most likely candidate to reach commercialization for mercury removal in the near future. Mercury adsorption on activated carbon is affected by the following major factors: Temperature and composition of the gas (including the concentration of acid gases), the concentration of Hg in the gas exhaust system, the residence time in the duct and the dispersion of the sorbent in the gas, and the chemical and physical properties of the activated carbon (or the impregnated activated carbon).[97]

On the following page, the report continues that activated carbon injection started with municipal waste combustors, in which it was able to remove 90% of mercury, and that "[e]xtensive tests have been performed at the bench, laboratory, pilot, and full scale for application of AC in the coal-fired utility boiler gas."[98]

102. By 2003, Thomas Feeley, administrator of DOE-NETL, concluded that activated carbon injection ("ACI") in coal-fired power plants had "the most promise as a near-term mercury control technology."[99]

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[97] EX1009 (Mass-EPA) at 32.

[98] EX1009 (Mass-EPA) at 33.

[99] EX1039 (Feeley) at 10.

103. By January 2004, the EPA had already proposed rules relating to mercury emissions, and had identified "types of sorbent that may be viable for use in sorbent injection [that] include two basic types of activated carbon (AC; regular and impregnated)."[100] Of these two types of recommended sorbents—regular activated carbon and chemically-impregnated activated carbons—the EPA identified Sorbalit™ ("a mixture of lime with additives and 3 to 5 percent AC [activated carbon]) and Darco FGD" as brand-name activated-carbon sorbents of interest.[101]

2. <u>Well-Known Structure of Activated Carbon</u>

104. By 1988, it was well known that activated carbon would adsorb oxidized mercury ions (Hg^{2+} or Hg(II)).[102] The surface structure of activated carbon (also referred to as "active carbon"), and the interaction with mercury and halogens, was discussed in a textbook authored in 1988 by Roop Chand Bansal and others, entitled "Active Carbon."[103] Bansal describes "the basic steps involved in the manufacture of activated carbons, the selectivity and suitability of different raw

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[100] EX1050 (EPA-Proposal) at 4676.

[101] EX1050 (EPA-Proposal) at 4676.

[102] EX1070 (Bansal) at 391.

[103] EX1070 (Bansal).

materials, and the probable mechanism of the physical and chemical activation processes."[104]

105. Bansal explains that "[a]ctivated carbons are unique and versatile adsorbents because of their extended surface area, microporous structure, universal adsorption effect, high adsorption capacity, and high degree of surface reactivity."[105] Specifically, Bansal teaches that activated carbons "are extensively used to purify, decolorize, deodorize, dechlorinate, and detoxicate potable waters; for solvent recovery and air purification in inhabited spaces such as restaurants, food processing, and chemical industries; in the purification of many chemical and foodstuff products; and in a variety of gas phase applications."[106]

106. Bansal explains in 1988 that the adsorbent properties of activated carbon were known to be "attributed to their large surface area, a high degree of surface reactivity, universal adsorption effect, and favorable pore size, which makes the internal surface accessible, enhances the adsorption rate, and enhances mechanical strength."[107] By the 1980s, it was known that "commercial active

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[104] EX1070 (Bansal) at iv.

[105] EX1070 (Bansal) at iii.

[106] EX1070 (Bansal) at iii.

[107] EX1070 (Bansal) at viii.

carbons have a specific surface area of the order of 800-1500 m^2/g."[108] It was known that the surface area of activated carbon may be "contained predominantly within micropores, which have effective diameters smaller than 2 nm."[109] A typical activated carbon particle was known to be "made up of a complex network of pores which have been classified into micropores (diameters < 2 nm), mesopores (diameter between 2 and 50 nm), and macropores (diameters > 50 nm)."[110] Although the "macropores do not contribute much toward surface area," it was known that they "act as conduits for the passage of the adsorbate into the interior mesopore and the micropore surface where most of the adsorption takes place."[111]

107. It was known that an activated-carbon sorbent generally is formed from graphene sheets (or layers). The Bansal reference in 1988 described activated carbon as having "a st[r]ucture consisting of sheets of aromatic condensed ring systems stacked in nonpolar layers."[112] This can be pictured as a stack of sheets of the following structure:

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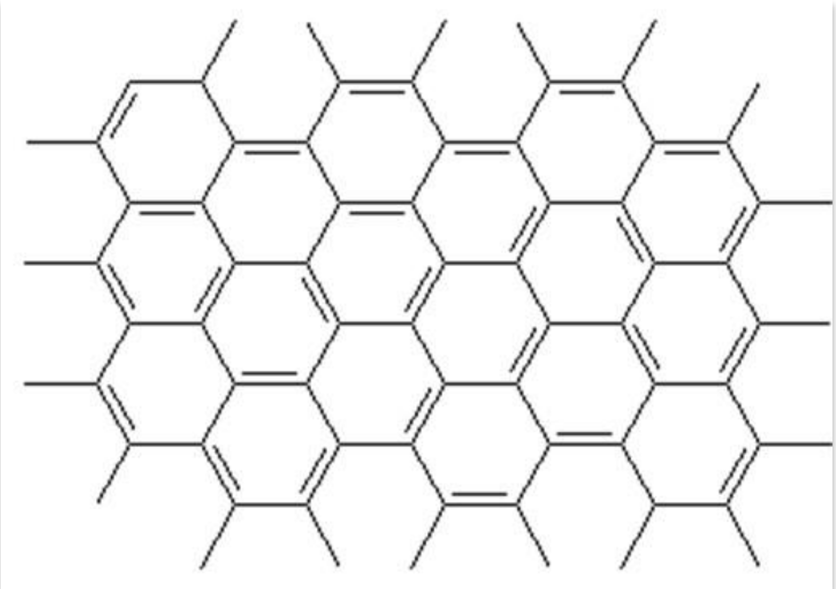
[108] EX1070 (Bansal) at viii.

[109] EX1070 (Bansal) at viii.

[110] EX1070 (Bansal) at viii.

[111] EX1070 (Bansal) at viii.

[112] EX1070 (Bansal) at 238.



Each vertex in the above structure represents a carbon atom, and each hexagon in the above figure represents an aromatic ring.

108. Each such graphene sheet was known to have "limited dimensions and therefore present edges."[113] Further, it was known that "these sheets are associated with defects, dislocations, and discontinuities."[114] In particular, the location and number of these defects, dislocations, and discontinuities could depend, among other things, on the particular relationship between the graphene sheets. It was known that once a carbon atom is partially exposed from a sheet at a discontinuity, a pair of its valence electrons are no longer able to be delocalized into (shared by) the

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[113] EX1070 (Bansal) at 238.

[114] EX1070 (Bansal) at 238.

surrounding carbon items. This pair of electrons becomes localized to its parent carbon atom, instead of interacting with its neighbors. Such carbons were known to "have unpaired electrons and residual valences and are richer in potential energy."[115] Thus, research showed that "these carbon atoms are highly reactive and constitute active sites or active centers."[116] Bansal emphasized "[t]he importance of active sites and their characterization and of active surface area and its measurement in determining the reactivity of carbons."[117]

3. Reaction Between Activated Carbon and Halogens

109. It was known that activated carbon "can also fix … chlorine on treatment with the gas; and bromine on treatment in the gaseous or solution phase" that "give rise to stable … carbon-chlorine, or carbon-bromine surface structures (surface compounds) respectively."[118] Additionally, "[x]-ray diffraction studies have shown that these heteroatoms or molecular species are bonded or retained at the edges and corners of the aromatic sheets or to carbon atoms in defect positions of the aromatic sheets, or they can be incorporated within the carbon layer, forming

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[115] EX1070 (Bansal) at 238.

[116] EX1070 (Bansal) at 238.

[117] EX1070 (Bansal) at iv.

[118] EX1070 (Bansal) at 259.

heterocyclic ring systems."[119] In other words, the Bansal reference explained in 1988, based on surface chemistry studies, that activated carbon has reactive carbenes (lone pairs of electrons) at the edge sites of graphene sheets, and that bromine bonds to these sites.

110. In 1970, it was documented that almost 100 years prior, researchers had reported that substantial loadings of both chlorine (Cl) and bromine (Br) can be bound onto carbon sorbents by simply heating them under gas mixtures containing the molecular (Cl_2, Br_2, I_2) or acid halide (HCl, HBr, HI) forms of the halogens, among other methods.[120] For example, it was shown that a sugar charcoal bound 24 % Cl by weight and a coconut charcoal bound 40 wt. % Cl.[121] Similarly, it was shown that charcoal bound up to a saturation limit (adsorption equilibrium) of 38 wt. % Br, and carbon black bound up to a saturation limit (adsorption equilibrium) of around 31 wt. % Br.[122]

111. A person of ordinary skill in the art would expect that in an actual industrial application, the amount of halogen atoms actually bound could be less

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[119] EX1070 (Bansal) at 259.

[120] EX1042 (Puri) at 255-257.

[121] EX1042 (Puri) at 256-257.

[122] EX1042 (Puri) at 260.

than the saturation limit. Binding refers to the element-to-element chemical bonding of the halogen (e.g., Cl, Br, or I) with activated carbon, whereas loading refers to a weight ratio. It was known that the loading of Br is greater than that for Cl at the same conditions, because Br has a greater molecular weight than Cl (79.9 vs. 35.5 g/mol).[123] It was known that the loading of I is influenced considerably by the nature of the charcoal surface.[124] It was known that halogens are bound in rough proportion to the hydrogen content of the carbon sorbent.[125] Thus, it was known that even in situations where Br was bound on a lower mole-to-mole basis than Cl under the same thermal conditions, its overall loading is greater due to the disparity in molecular weights.[126] Additionally, for mercury removal at electric utility boilers, research by the EPA in the mid-1990s suggested that "even greater mercury removal may be possible with impregnated activated carbons" above what was already well understood for untreated sorbent injection.[127] It was also known that iodine vapors

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[123] EX1042 (Puri) at 260.

[124] EX1042 (Puri) at 261-262.

[125] EX1042 (Puri) at 257 (chlorine) and 260 (bromine).

[126] EX1042 (Puri) at 261.

[127] EX1060 (EPA 1997 Mercury Study Report Vol. VIII) at 2-54.

readily bind to activated carbon, though the adsorption rate is lower than with Cl and Br.[128]

4. Reaction Between Activated Carbon and Mercury

112. It was widely understood in the late 1990s that only sorbents that bound both elemental and oxidized mercury by chemical adsorption (a.k.a. chemisorption) and chemical reaction were suitable, because this form would not be leached into the groundwater from fly ash holding ponds or otherwise released during fly ash disposal.[129] In 1999, researchers demonstrated that mercury formed chemical bonds with the species on activated carbons exposed to simulated coal-derived flue gas.[130] Researchers found that with carbon sorbents promoted by halogens (such as iodine) and sulfur, "the XAFS data confirm that it is the activating element (I or S) that forms a sorption complex with mercury."[131] Researchers also found that with unpromoted activated carbon exposed to flue gas that contained HCl and SO_2, the XAFS spectra showed that, first, HCl was bound to the carbon and then, elemental

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[128] EX1042 (Puri) at 256.

[129] EX1038 (Granite) at 40.

[130] EX1043 (XAFS) at 119.

[131] EX1043 (XAFS) at 114.

and oxidized Hg were bound to the chlorinated surface sites on the carbon.[132] The XAFS spectra "indicate that the LAC carbon readily sorbs a form of chlorine present in the synthetic flue gas", and that the chlorinated surface bonds to mercury "with Hg^{2+}-Cl, as in $HgCl_2$, and/or Hg^{2+}-S, as in HgS (cinnabar)."[133]

113. By 2004, these findings had been generalized to interpret both oxidation and capture of elemental and oxidized mercury on both inherent unburned carbon and injected activated-carbon sorbents.[134] As my team and I explained in a paper from 2004:

> Mercury transformations occur while flue gases are cooled along an exhaust system. At the superheater section, only Hg^0 is present and the carbon is oxidized but otherwise clean. The process begins when temperatures are cooled into the range where HCl chlorinates some of the carbon sites in a reversible reaction. With further cooling, Hg^0 adsorbs at appreciable rates onto the chlorinated sites. Since desorption remains relatively fast, the HgCl rapidly desorbs into the gas phase, where it oxidizes into $HgCl_2$. In this temperature range, there is little sorption but extensive oxidation. As the particles are cooled further, the desorption rate becomes controlling, which implies that surface coverage increases, ultimately, to the equilibrium sorption capacity . . . . And HgCl on the carbon surface constitutes sorbed or "particulate" Hg.[135]

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[132] EX1043 (XAFS) at 117, 119.

[133] EX1043 (XAFS) at 117, 119.

[134] EX1044 (Hg Speciation).

[135] EX1044 (Hg Speciation) at 4-5.

5. Removing Mercury by Controlling Sorbent Injection Rate

114. It was widely understood to a person of ordinary skill in the art in the early 2000s that one could achieve desired mercury removal by controlling the sorbent injection rate. In 2002, ADA-ES, a prominent company providing mercury mitigation, recognized that the "amount of carbon [sorbent] injected" was one of a number of "factors [that] may influence the mercury removal obtained with sorbent injection upstream" of a particulate collector—other generalized factors include the type of sorbent, the injection method, and flue gas conditions.[136] The researchers at ADA-ES conducted testing in which "[m]ercury removal was monitored as a function of the sorbent injection concentration."[137] By December 2002, the Massachusetts Dept. of Environmental Protection published that "a fraction of a pound increase in carbon injection rate increase[es] mercury removal from the gas by [as] much as 30%."[138] In reporting test results, "areas of interest included mercury removal as a function of [sorbent] injection rate."[139] By December 2003, if

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[136] EX1059 (Field Studies of Mercury Control) at 2.

[137] EX1008 (Starns) at 11.

[138] EX1009 (Mass-EPA) at 33; *see also* p. 50 ("PAC injection rate requirements increase nonlinearly with increases in Hg removal efficiency."); EX1009 p. 73 ("mercury removal as a function of [sorbent] injection rate").

[139] EX1009 (Mass-EPA) at 73.

not earlier, the EPA drafted proposed rules that when using sorbents such as activated carbon, the "extent of potential Hg removal is dependent on: (1) Efficient distribution of the sorbent (e.g., activated carbon) in the flue gas; (2) <u>the amount of **sorbent** needed</u> to achieve a specific level of Hg removal which will vary depending on the fuel being burned."[140]

115. Injection rates are commonly represented as "injection concentration in lb/MMacf," which stands for pounds of activated carbon per 1 million actual cubic feet of flue gas. To account for variabilities in coal, it was known to use injection rates between 0 and 30 lb/MMacf, as represented by Figures 1-6 of the 2002 ADA-ES article.[141] However, by 2002, engineers had determined to generally use approximately 10 lb/MMacf activated carbon to remove mercury, finding that the "maximum removal [is] achievable at injection concentrations between 5 and 10 lb/MMacf" with "little improvement . . . above 10 lb/MMacf."[142] Ultimately, it was known that the selected injection rate of the sorbent material comes down to routine

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[140] EX1050 (EPA-Proposal) at 4676.

[141] EX1059 (Field Studies of Mercury Control) at Figures 1-6.

[142] EX1059 (Field Studies of Mercury Control) at 13. The Massachusetts EPA also discussed testing activated carbon sorbent injection rates of "1, 3, 10, and 20 lb/Mmacf." EX1009 (Mass-EPA) at 73-74.

design tradeoffs between the "effectiveness and costs associated"[143] with increased rates of the injected sorbent among other routine design parameters.[144]

D. REGULATIONS TO REDUCE MERCURY EMISSIONS

116. By the 1990s, it was known that excess mercury in the environment can pose a significant threat to the health and safety of plants, birds, and mammals.[145] In particular, it was known that mercury may cause death, reduced reproductive success, impaired growth, and developmental/behavioral abnormalities.[146] The 1990 Clean Air Act Amendments ("CAAA") listed various hazardous air pollutants ("HAPs") and details the relevant regulatory foundation for Hg (and other) emissions that were to be regulated by establishing national emissions standards.[147]

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[143] EX1059 (Field Studies of Mercury Control) at 2.

[144] EX1059 (Field Studies of Mercury Control) at 4-5.

[145] EX1052, U.S. EPA, "Mercury Study Report to Congress Volume 1: Executive Summary," EPA-452/R-97-003 (Dec. 1997), available at https://www.epa.gov/sites/production/files/2015-09/documents/volume1.pdf, at 2-6.

[146] EX1052, U.S. EPA, "Mercury Study Report to Congress Volume 1: Executive Summary," EPA-452/R-97-003 (Dec. 1997), available at https://www.epa.gov/sites/production/files/2015-09/documents/volume1.pdf, at 2-6.

[147] EX1049 (U.S. EPA, "Background Information on Mercury Sources and Regulations," available at https://web.archive.org/web/20030419191659/http:/www.epa.gov/grtlakes/bnsdocs/mercsrce/mercreg.html.

For control of HAPs, the CAAA required the maximum degree of reduction in emissions of the regulated pollutant.[148] Specifically, the EPA issued maximum available control technology ("MACT") standards that were based on the average emission level achieved by controls on the best performing 12 percent of existing sources, by category of industrial and utility sources.[149]

117. The EPA conducted several field test programs to assess contributions from the electric power utility industry to the total emissions inventories for the regulated HAPs.[150] For the mercury-emissions inventory prepared by EPA from tests in 1994–1995, coal-fired power plants accounted for one-third of the total mercury in the environment.[151]

118. During the next few years, the EPA surveyed the technical information needed to both refine the Hg emissions inventory and to contemplate Hg emissions control technologies, should federal regulations on Hg emissions be enacted.[152] This period laid the foundation for EPA's Information Collection Request ("ICR") to

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[148] EX1054 (Mercury Emissions Control).

[149] EX1054 (Mercury Emissions Control).

[150] EX1039 (Feeley) at 4.

[151] EX1039 (Feeley) at 3.

[152] EX1039 (Feeley) at 4-7.

coal-fired utility operators, which began implementation in late 1998 and was carried out from 1999-2000.[153]

119. In the early 2000's, the EPA announced that regulations on mercury-emissions from coal-fired power plants were both appropriate and necessary.[154] The timetable for the national emissions standard for mercury was initially set for the EPA to propose the standard by December 2003 and to finalize a standard by December 2004.[155]

120. On March 15, 2005, the "EPA issued the first-ever federal rule to permanently cap and reduce mercury emissions from coal-fired power plants," titled the Clean Air Mercury Rule (CAMR), which builds on the "EPA's Clean Air Interstate Rule (CAIR) to significantly reduce emissions from coal-fired power plants."[156] The EPA explained that "these rules will reduce utility emissions of mercury from 48 tons a year to 15 tons, a reduction of nearly 70 percent."[157] In a

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[153] EX1039 (Feeley) at 4.

[154] EX1039 (Feeley) at 7-8.

[155] EX1039 (Feeley) at 8.

[156] EX1055 (Clean Air Mercury Rule).

[157] EX1055 (Clean Air Mercury Rule).

press release posted on March 15, 2005, the EPA announced the signing of the CAMR and emphasized the “70 percent” reduction in mercury emissions:

> (Washington, D.C. -- 03/15/05) Acting Administrator Steve Johnson will sign today the Clean Air Mercury Rule, a rule that will significantly reduce mercury emissions from coal-fired power plants across the country. Taken together, the recently issued Clean Air Interstate Rule and the new Clean Air Mercury Rule will reduce electric utility mercury emissions by nearly 70 percent from 1999 levels when fully implemented.[158]

Accordingly, with passage of the CAMR, those in the power-generation industry actively sought to reduce mercury emissions by 70 percent such that their plants would be compliant when the reduction limits were fully implemented.

121. But even before the EPA officially passed the CAMR in 2005, the industry was put on notice of the upcoming rule (including through state governments, such as Mass-EPA in 2002).[159] On December 15, 2003, the EPA signed proposed rules, and published them on January 30, 2004 in the Federal Register.[160] The EPA further explained that the “rules would significantly reduce emissions of sulfur dioxide (SO_2), nitrogen oxides (NO_x), and mercury from power plants,” and explained that publication “in the Federal Register marks the beginning

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[158] EX1056 (3/15/2005 EPA Press Release).

[159] EX1009 (Mass-EPA).

[160] EX1050 (EPA-Proposal).

of a 60 day comment period" that included public hearings.[161] The proposed rules stated that a "primary goal in this rulemaking is to reduce power plant emissions of Hg by 70 percent from today's levels by 2018."[162] The EPA again announced this "70 percent" reduction in mercury emissions on February 24, 2004, when it further sought public comment.[163] Accordingly, as of January 2004, if not earlier, the EPA put the power-generation industry on notice that upcoming regulations would require a 70% reduction in mercury emissions, and researchers actively sought processes that would achieve those limits. Various state regulatory authorities (such as the Massachusetts Department of Environmental Protection) put the industry on notice years earlier.[164]

E. DOE AND NETL

122. Since the early 1990s the National Energy Technology Laboratories ("NETL") of the U.S. Department of Energy ("DOE") has been carrying out a comprehensive R&D program to develop low-cost mercury control technologies for

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[161] EX1057 (1/29/2004 EPA Press Release).

[162] EX1050 (EPA-Proposal) at 4698.

[163] EX1058 (2/24/2004 EPA Press Release).

[164] EX1009 (Mass-EPA).

coal-fired power plants.[165] The NETL sponsored field-test programs at coal-fired power plants, such as the research conducted by Starns[166] and Sjostrom[167] at ADA-ES, to characterize Hg emissions for the coals and plant configurations representing the American utility industry.[168]

123. Mercury-emissions control programs were managed from the Pittsburgh site. This site has a long and distinguished record in the inception and development of air pollution control for power plants, starting with early R&D on electrostatic precipitators in the 1960s, flue gas desulfurization units in the 1970s, and low-NO_x firing practices in the 1980s. The NETL was a major sponsor of the early demonstrations of the technologies that ultimately dominated markets for air pollution control devices ("APCDs"). It played a similarly important role in the demonstration of Hg control technologies, including inherent control with existing APCDs and activated carbon injection, both with and without halogens.[169]

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[165] EX1039 (Feeley) at 2.

[166] EX1008 (Starns).

[167] EX1010 (Sjostrom).

[168] EX1039 (Feeley) at 10-11.

[169] EX1039 (Feeley) at 10-11.

F. ADDITIONAL MARKET DEMAND AND INDUSTRY TRENDS

124. As a direct result of the regulatory actions and intentions promulgated by the EPA, various state-level regulatory authorities (such as the Massachusetts Department of Environmental Protection),[170] and funding provided by the DOE NETL, the American electric power utility industry mobilized a massive response to develop and evaluate technologies for mercury-emissions control as soon as the ICR database was assimilated at EPA in 2000.[171]

125. Immediately afterward, findings of the industry's R&D programs were fast-tracked and widely disseminated to industry leaders at technical conferences, primarily at the MEGA, AWMA, and EUEC conferences from 1998 and 1999 onward, and at Air Quality from 2002 onward. These conferences were widely attended by business, sales, and project managers from the vendors; they were also attended by engineers, compliance specialists, technical staff, and environmental control managers from the utilities. There was also a sizeable representation of consultants and academic, government (including funding agencies such as DOE and EPA), and commercial researchers plying their services regarding environmental control and cleanup to both vendors and utility representatives, as

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[170] EX1009 (Mass-EPA).

[171] EX1039 (Feeley).

well as project managers for government R&D programs. Researchers in the field would have found papers presented at the MEGA, AWMA, and EUEC conferences to be important pieces of scientific literature and would have reviewed them to keep updated on environmental research in the coal-power industry. The Starns reference (EX1008) was presented at AWMA in 2002, and the Sjostrom (EX1010) and Eckberg (EX1011) references were presented at EUEC in 2005.

126. By the early 2000s, the DOE and NETL had funded projects, and been provided with successful large-scale demonstrations, of mercury capture from coal-fired power plants.[172] As Thomas Feeley of the NETL stated in 2003 in summarizing the history of mercury removal, the early goal of the DOE was to "develop mercury control technologies that can achieve 50 to 70% mercury capture at three-quarters or less than current estimated costs for powdered activated carbon injection."[173] The longer-term goals were "to develop advanced mercury control technologies to achieve 90% or greater capture at one-half to three-quarters the cost of existing technology and that would be available for commercial demonstration by 2010."[174]

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[172] EX1039 (Feeley) at 11.

[173] EX1039 (Feeley) at 11.

[174] EX1039 (Feeley) at 11.

127. To meet these goals, the DOE and various industry partners co-sponsored numerous mercury removal testing projects. For example, the DOE co-sponsored projects with industry partners including, but not limited to, UND EERC, ADA-ES Inc., Babcock & Wilcox, Mobotec USA, Southern Company, URS, Sorbent Technologies Corporation, SaskPower, ALSTOM Power, Inc., GE EER, and Amended Silicates, LLC. The testing with these industry partners was focused on meeting or exceeding the DOE's targets.

128. As discussed above, the NETL launched a three-phase plan for mercury-control research.[175] The first phase of testing was for so-called inherent mercury controls that relied on existing air pollution control devices (APCDs), including ESPs, fabric filters (FF), SCRs, and FGDs.[176] The second phase of testing characterized activated carbon injection (ACI) installations, and a third phase covered halogenated sorbents, SDAs, and halogen/lime injections.[177] Before 2004, testing had been run mostly at about 20 plants operated by regional utility companies

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[175] EX1039 (Feeley) at 2.

[176] EX1039 (Feeley) at 2.

[177] EX1039 (Feeley) at 2.

and cooperatives. Several of these plants are discussed in Mass-EPA[178] and Starns.[179]

G. ENHANCING MERCURY REMOVAL BY PROMOTING ACTIVATED CARBON

129. Typical sorbents, including activated carbon, were known to have low native capacities for adsorbing mercury.[180] Traditional mercury sorbents were known to have capacities "on the order of 100 micrograms Hg/gram sorbent, and range from 10^{-6} to 10^{-2} gram Hg/gram sorbent."[181] However, researchers in 1998 also suggested that an activated carbon/mercury ratio between 3000:1 to 50,000 to 1 would be required to meet mercury removal demands.[182]

130. Before 2003, researchers worked to develop ways to increase activated carbon's sorption efficiency (i.e., its ability to adsorb mercury). In particular, researchers had found that "[o]ther compounds act as promoters for the removal of mercury from flue gas."[183] The term "promoter" was used to describe chemicals—

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[178] EX1009 (Mass-EPA).

[179] EX1008 (Starns).

[180] EX1038 (Granite) at 5.

[181] EX1038 (Granite) at 5.

[182] EX1038 (Granite) at 5.

[183] EX1038 (Granite) at 5.

including halides and halogens—that "increase the capacity of activated carbon."[184] A promoter was known to be "a chemical dispersed on or within a high surface area substrate, which aids in the removal of mercury from flue gas."[185] Specifically, promoters were known to "increase the chemisorption and chemical reaction of mercury on the sorbents."[186]

1. Alkali Promoters of Activated Carbon

131. An example of a well-known early promoter for activated-carbon sorbents was hydrated lime, calcium hydroxide, represented chemically as $Ca(OH)_2$.[187] Lime was known for its use "in conjunction with activated carbon in some commercial sorbent processes."[188] These are also called composite sorbents, which are "composite powdered activated carbon (PAC) lime."[189] Researchers noted that "lime has been demonstrated to reduce mercury emissions in coal flue

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[184] EX1038 (Granite) at 15.

[185] EX1038 (Granite) at 15.

[186] EX1038 (Granite) at 15.

[187] EX1038 (Granite) at 15.

[188] EX1038 (Granite) at 5.

[189] EX1009 (Mass-EPA) p. 15; *see also* p. 50 (referring to how "use of composite PAC-lime sorbent … lowers the total annual costs").

gas, even though lime neither sorbs nor reacts directly with mercury."[190] One reason for this is that the lime and other alkaline materials adsorb other constituents from the flue gas (e.g., SO_3), which would otherwise compete with mercury for the active binding sites on activated-carbon sorbent.

2. Halogen Promoters of Activated Carbon

132. By 1934, it was known in the art that halogens improved the ability of activated carbon to remove mercury. The Stock patent, issued in 1934, states:

> [I]t was found that in the process of purifying air vitiated with mercury vapors, adsorption agents which are impregnated with a halogen will constitute a protective agent, which is incomparably superior to any of the above mentioned protectives. For instance, active carbon impregnated with iodine will surpass the protective action of non-impregnated active carbon about ten times.[191]

133. U.S. Patent No. 4,196,173 to deJong, issued in 1980, presented "an improved process for adsorbing mercury vapor from a gas containing it in admixture with other gaseous materials on activated carbon containing an adsorbed halogen."[192]

134. In 1998, Carey at Radian International (working with Ramsay Chang from EPRI) studied the adsorption of mercury by Norit Darco activated carbon and

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[190] EX1038 (Granite) at 5.

[191] EX1029 (Stock) at 1:33-41.

[192] EX1046 (deJong) at 1:37-40.

reported that the "adsorption capacity for both types of mercury [elemental and oxidized] increased as the HCl concentration increased; however, elemental mercury adsorption was affected more dramatically by HCl and SO_2 than mercuric chloride adsorption."[193]

135. U.S. Patent No. 5,695,572 to Lerner, issued in 1995, presented that "the presence of sufficient HCl in the waste combustion gases [is necessary] to react with mercury, cadmium and/or thallium metals and oxides to yield conversion to metal chlorides."[194] The Lerner patent further emphasizes "it is only the mercury, cadmium or thallium chlorides that are significantly adsorbable by activated carbon sorbents and absorbable in aqueous solution" and "in the combustion of wood, coal and other wastes that are chlorine-deficient in this respect, i.e., do not generate sufficient HCl to effect the conversion of the vaporized metals and oxides to chlorides, it is advantageous to add to the waste a material that will generate HCl [i.e., addition of halogen to the activated carbon] on combustion." [195]

136. By 1997, numerous studies had also been conducted that further described how halides interacted with mercury. For example, it was known that

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[193] EX1048 (Carey) at 1169 (Table 1, discussing chemical analysis of Norit FGD).

[194] EX1047 (Lerner) at 5:35-38.

[195] EX1047 (Lerner) at 5:38-46.

"halides are the most familiar compounds of mercury(I) and all contain the Hg_2^{2+} ion."[196] In particular, it was known that mercury could form HgF_2, $HgCl_2$, $HgBr_2$, HgI_2, Hg_2F_2, Hg_2Cl_2, Hg_2Br_2, and Hg_2I_2.[197] It was also known that solubility of HgX_2 compounds (where "X" refers to a halogen) in water "decrease[s] with increasing molecular weight."[198] As such, it was known that Hg_2Br_2 was easier to precipitate out from an aqueous solution (e.g., in a scrubber), as compared to Hg_2Cl_2. And that $HgCl_2$ and $HgBr_2$ readily dissolves in aqueous scrubber solutions, whereas Hg^0 is insoluble.

137. In the December 2002 report from the Massachusetts EPA, it was discussed that the "sorbent content of certain chemicals" (particularly halogens) would affect the ability of the activated carbon to remove mercury.[199] It was demonstrated in tests that a "chlorine-impregnated activated carbon" would provide "a very efficient cost effective activated carbon that can be used as a sorbent in ESP-

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[196] EX1041 (Greenwood) p. 1212.

[197] EX1041 (Greenwood) p. 1212-13.

[198] EX1041 (Greenwood) p. 1212.

[199] EX1009 (Mass-EPA) at 32.

equipped coal-fired boilers," including reduced costs and a mercury removal efficiency of 80%.[200]

138. It was well-known that halides, such as chlorine, "improve[d] Hg capture both by conversion of the Hg^0 to the more easily removed Hg^{2+} forms and by enhancing the reactivity of Hg^0 with activated carbons."[201] As such, it was known that the introduction of halogens helped remove mercury through at least two mechanisms: (1) by oxidizing the mercury, and thus rendering the mercury more susceptible to removal; (2) and by increasing the ability of the activated carbon to bind with the mercury. For each of these mechanisms, it was known that halogens improved mercury removal.

139. It was known that using halogens to oxidize mercury had the beneficial effect of increasing mercury removal in wet systems, because oxidized mercury is more soluble in water as compared to elemental mercury. For example, Vosteen589 (which discussed both wet processes and dry processes) compared "quasi-insoluble" elemental mercury to "ionic" (oxidized) mercury:

> At a high chlorine content the proportion of ionic mercury in the flue gas is high. Ionic mercury may be readily removed in scrubbers. The quasi-water-insoluble metallic mercury can be converted into ionic mercury, for example by adding oxidizing

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[200] EX1009 (Mass-EPA) at 34.

[201] EX1062 (Crocker) at 2-3.

> agents, such as peroxides, ozone or sodium chlorite, in the boiler exit gas upstream of the flue gas cleaning system or in the dedusted boiler gas, and then removed in the flue gas cleaning system as for example in scrubbers.[202]

Granite reported in 1998 that elemental mercury had a solubility in water of only 20 micrograms/liter at 68ºF.[203] However, mercuric chloride ($HgCl_2$) had a solubility in water of 69 grams/liter and mercuric bromide (HBr_2) had a solubility in water of 6.1 grams/liter.[204] Both of these solubilities were over 5 orders of magnitude higher than the solubility of elemental mercury. Among these candidates, it was also known that "bromine compounds oxidize mercury more effectively under the given conditions of high-temperature processes" as compared to "chlorine compounds."[205]

140. It was also known in the art that adding halogens increased the effectiveness of dry-cleanup systems, such as activated-carbon sorbent, in removing mercury. Granite reported in 1998 that an "example of promoters are the halides and sulfides, which are often dispersed on high surface-area carbons and aluminosilicates."[206]

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[202] EX1005 (Vosteen589) ¶[0003].

[203] EX1038 (Granite) at 11-12.

[204] EX1038 (Granite) at 12-13.

[205] EX1005 (Vosteen589) ¶[0016].

[206] EX1038 (Granite) at 5.

141. Some of the earlier DOE-NETL sponsored field tests on Hg emissions control monitored Hg capture efficiencies with untreated powdered-activated carbons (PAC) like Norit Darco FGD. Norit Darco FGD was a product sold by Norit Americas that was a form of plain activated carbon (not halogenated ahead of time, like BPAC) that had been in use since well before 1998.[207] These trials showed that the efficiencies increased in proportion to the halogen:coal ratio, which prompted the understanding that adding chlorine to the PAC was an effective and inexpensive way to control Hg emissions with lower PAC injection rates and, therefore, at lower cost.[208] Moreover, it was known for nearly a century[209] that halogen-containing gases, particularly Cl_2 and HCl, could be bound to a wide variety of carbons simply by heating the chlorine-containing gas mixture together with the PAC to moderate temperatures. Consequently, the incentive and the basic production scheme for halogenated PAC was easily surmised soon after the first trials on untreated PAC.

142. The EPA recognized such benefits of promoting activated carbon with halogens, and included the technology in its proposed mercury-reduction rules published in January 2004. By January 2004, the EPA had identified two "types of

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[207] EX1048 (Carey) at 1169 (Table 1, discussing chemical analysis of Norit FGD).

[208] EX1028 (Bustard).

[209] EX1042 (Puri) at 255.

sorbent that may be viable for use in sorbent injection include two basic types of activated carbon (AC; regular and impregnated)."[210] The EPA described chemically-impregnated AC as follows:

> Chemically-impregnated AC [activated carbon] is AC that has been supplemented with chemicals to improve its Hg removal. The Hg in the flue gas reacts with the chemical that is bound to the AC, and the resulting compound is removed by the PM [(particulate matter)] control device. Typical impregnants for AC are Cl, sulfur, and iodide. Chemically-impregnated AC have shown enhanced Hg removal over regular AC. Chemically-impregnated AC require smaller rates of carbon injection than does regular AC for equivalent Hg removals. The required carbon-to-mercury mass ratio may be reduced by a factor of from 3 to 10 with the chemically-impregnated AC. The cost per mass unit of impregnated AC may, however, be significantly greater than that of unmodified AC.[211]

143. As reflected in the EPA proposed rules, researchers had earlier recognized the benefits of promoting activated carbon with halogens and sulfur in terms of mercury removal:

> Activated carbons are the most studied mercury sorbents. Activated carbons have some serious drawbacks, including high cost, poor utilization/selectivity for mercury, and limited regenerability. Activated carbons are often promoted with halogens or sulfur to improve their ability to sorb elemental mercury. This improvement comes at a price; promoted

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[210] EX1050 (EPA-Proposal) at 4676.

[211] EX1050 (EPA-Proposal) at 4676.

> activated carbons are three times more costly than unpromoted carbons.[212]

As such, it was known long before the earliest filing date of the Challenged Patent that promoting activated carbon with halogens, such as chlorine or iodine, were beneficial but with attendant costs. "In order for a sorbent to attain wide usage for mercury removal from flue gas, it must be highly active, selective, and cost effective."[213] Accordingly, researchers sought, and successfully demonstrated, more economic methods for promoting the activated carbon.

144. Once the superior performance of PACs with appreciable chlorine was demonstrated, a person of skill in the art had good reasons to expect that Hg-control efficiencies using bromine (Br) and iodine (I) were at least as good as chlorine in activated-carbon applications. Indeed, as reflected by the EPA proposed rules discussed above, government agencies had recognized the benefits of both chlorine and iodine when used with activated carbon, and bromine sits between the two in the same group in the periodic table.[214] A person of skill in the art would have further understood the applicability of bromine, because untreated PACs are known to be basic in their chemical character, whereas the halides of Cl, Br, and I were often

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[212] EX1038 (Granite) at 32.

[213] EX1038 (Granite) at 6.

[214] EX1009 (Mass-EPA) at 32-35.

referred to in the utility industry as "acid gases." A person of skill in the art, and anyone with a rudimentary understanding of chemistry, would have known that acids have a strong affinity for bases, and quickly surmise that Br and I would readily bind with PAC, because Cl and PAC behave like any combination of acids and bases.

145. Moreover, a person of skill in the art would have known that, like any carbon, PACs are not uniformly homogeneous materials whose reactivities are determined by a single configuration of atoms on the surface. Rather, it was known that their most reactive "sites" are the atoms at the edges and in defects on large sheets of atoms that constitute the bulk of PAC structure. The edge sites contain unpaired electrons that impart the basic character (i.e., ability to donate electrons and thus act as Lewis bases) to PAC and have the strongest affinity for protons when acid gases contact the carbon. A person of skill in the art would have considered bond-dissociation energy as a relevant molecular characteristic when evaluating halogens for Hg control with activated-carbon injection. It was known that the dissociation energies are 428 kJ/mol for HCl, 363 for HBr, and 294 for HI.[215] Based on these values a POSITA would expect Br and I to have an even greater affinity for PAC than Cl, because it takes less energy to form the ions of Br and I than those of Cl.

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[215] EX1041 (Greenwood) at 804.

146. In addition to the reaction between acid gases (e.g., HCl, HBr, HI) and activated carbon, a person of skill in the art would have known that mercury-bromide compounds stick more effectively to activated carbon than mercury-chloride compounds, and thus are more effectively removed. "Mercury bromide $HgBr_2$ adsorbs more strongly to dry sorbents than mercury chloride $HgCl_2$."[216]

147. For these reasons, a person of skill in the art would have known, and would have been motivated to try, other forms of halogens for mercury removal, beyond chlorine. Such a person would have known that binding Br and I to activated carbon has the potential to improve Hg capture efficiencies in activated-carbon injection applications, and that the same process used to make chlorinated activated carbon would have likely worked with Br and I in gas mixtures. Several researchers prior to the earliest filing date of the Challenged Patent had tried both chlorine and bromine, and found bromine to be more effective.

148. By 2002, Vosteen Consulting GmbH had also conducted "experiments to demonstrate the effect of bromine on mercury removal in a coal-fired power

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[216] EX1005 (Vosteen589) ¶[0019].

station of Bayer AG in Uerdingen."[217, 218] In particular, "an experiment was carried out with addition of aqueous $HgCl_2$ solution and aqueous NaBr solution into the combustion chamber to demonstrate the effect of bromine on Hg oxidation."[219]

149. In addition to Vosteen and his team, other prior-art researchers had succeeded in providing methods for a more cost-effective, activated carbon for mercury removal. Other researchers filed patent applications and published articles for using bromine-containing promoters to improve the effectiveness of activated carbon in capturing both elemental and oxidized mercury.[220] Nelson recognized in a patent dating back to at least May 2003 that chlorinated PAC improved mercury capture, as compared to untreated PAC, but that brominated PAC improved mercury capture even more.[221]

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[217] EX1005 (Vosteen589) ¶[0046].

[218] Named inventor of the Challenged Patent, Dr. Olson, provided similar testimony. EX1095 (Olson) at 144:25-146:4 (recognizing that Vosteen disclosed adding a bromide compound to the furnace or the flue gas).

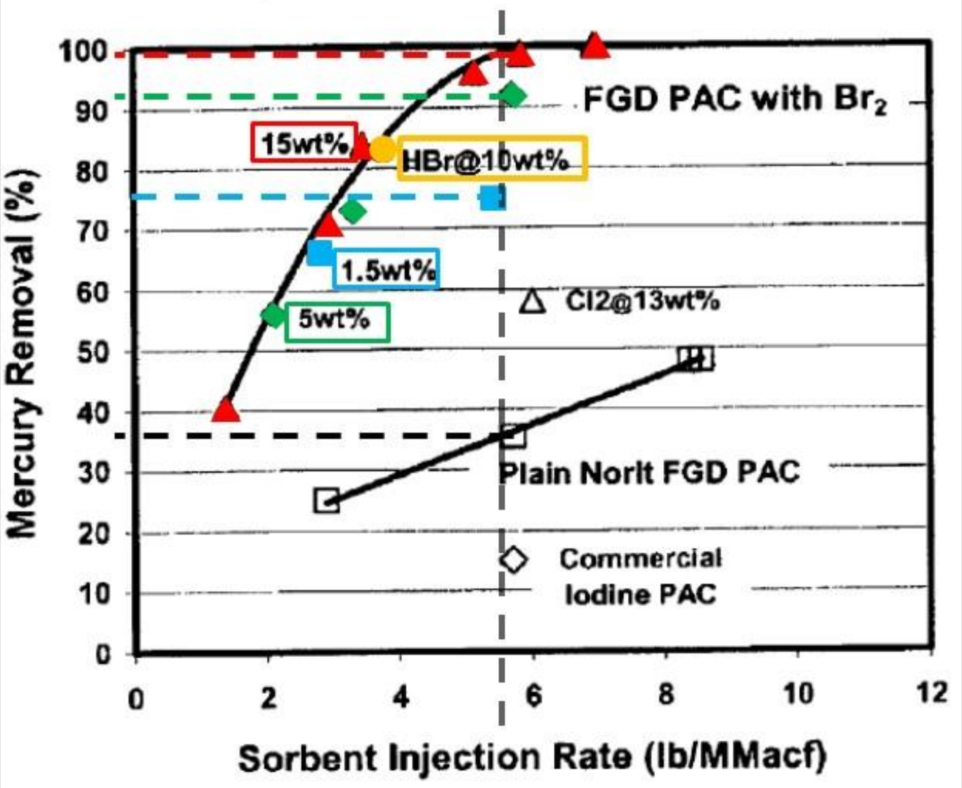
[219] EX1005 (Vosteen589) ¶[0047].

[220] EX1006 (Downs-Boiler); EX1005 (Vosteen589); EX1013 (Nelson); EX1014 (Lissianski).

[221] EX1013 (Nelson) at Figure 14 (annotated).

Figure 14.

Duct-Injection Pilot Plant with ESP



In the annotated figure, points with a similar halogen loading are colored the same. Nelson provided data for a sorbent injection rate of approximately 5.8 pounds per million actual cubic feet (lb/MMacf), indicated by the vertical dashed black line. Nelson indicated that at this sorbent injection rate, untreated activated carbon ("Plain Norit FGD PAC") was able to remove less than 40% mercury. In contrast, Nelson was able to achieve mercury removal greater than 70% at the same activated-carbon sorbent injection rate by applying bromine (Br_2) gas. Nelson achieved: 75% mercury removal by loading the activated carbon with 1.5 wt% bromine (indicated by the ■);

approximately 92% mercury removal by loading the activated carbon with 5 wt% bromine (indicated by the ♦); and near 100% mercury removal by loading the activated carbon with 15 wt % bromine (indicated by the ▲).[222] When using hydrogen bromide (HBr) gas to load the activated carbon with 10 wt% bromine (indicated by the ●), Nelson achieved approximately 85% mercury removal with a lower sorbent injection rate of 3.7 lb/MMacf.

150. Accordingly, Nelson and other researchers had recognized the desirability of adding bromine to activated carbon for purposes of mercury removal and various processes to accomplish the bromine promotion. Researchers had also figured out, and filed patents on, multiple other ways to promote the activated carbon with bromine, including by injecting activated carbon directly into the flue gas, and adding a bromine-containing promoter into either the combustion chamber and/or onto the coal, as in Vosteen589,[223] Downs-Boiler, [224] or Lissianski.[225]

151. By the time of the January 2005 EUEC conference—which took place in Tucson, Arizona—researchers even outside the patent context had reported their

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[222] EX1013 (Nelson) at Figure 14, 8:35-53.

[223] EX1005 (Vosteen589).

[224] EX1006 (Downs-Boiler).

[225] EX1014 (Lissianski) at Figure 1-3, 9.

research results, including specific process conditions, for how to achieve greater than 90% mercury removal by using bromine-containing promoters with activated carbon.[226]

X. OVERVIEW OF THE CHALLENGED PATENT FAMILY

A. SPECIFICATION OF THE '114 PATENT

152. The '114 Patent "relates to methods and materials for the removal of pollutants from flue gas or product gas from a gasification system."[227] The '114 Patent discloses that "mercury is removed from gas streams generated during the burning or gasification of fossil fuels by highly reactive regenerable sorbents."[228]

153. The '114 Patent admits that known "mercury control methods" included "injection of fine sorbent particles into a flue gas duct" such as "activated carbon."[229] However, the '114 Patent acknowledged that "[a] major problem with existing carbon injection systems is that the sorbent is relatively unreactive toward mercury" and therefore "must be used in large amounts, at high sorbent-to-mercury

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[226] EX1011 (Eckberg); EX1010 (Sjostrom).

[227] EX1001 ('114 Patent) at 1:27-29.

[228] EX1001 ('114 Patent) at 1:29-31.

[229] EX1001 ('114 Patent) at 1:56-60.

ratios, to effectively capture the mercury."[230] The '114 Patent acknowledges this is a problem because activated carbon is "relatively expensive and cannot be easily separated from the ash for regeneration and reuse."[231] The '114 Patent admits that it was "known in the art" to inject "halogen or halogen precursors in a hot zone, followed by contact with an alkaline material in a wet or dry scrubber."[232] The '114 Patent explains that "elemental mercury is claimed to be oxidized by the halogen to Hg(II) which is collected by the alkaline material in the scrubber."[233]

154. The '114 Patent purports to "provide[] a cost-effective way to capture pollutants by utilizing exceptionally reactive halogen/halide-promoted sorbents using a bromide (or other halogen/halide) treatment of the promoted sorbent, that capture mercury via mercury-sorbent surface reactions."[234] The '114 Patent explains that "[t]he reactivity of the promoted sorbent toward the pollutants (i.e., mercury) is

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[230] EX1001 ('114 Patent) at 2:10-14.

[231] EX1001 ('114 Patent) at 2:14-16.

[232] EX1001 ('114 Patent) at 2:60-62.

[233] EX1001 ('114 Patent) at 2:63-65.

[234] EX1001 ('114 Patent) at 9:51-55.

greatly enhanced, and the sorption capacity can be regenerated; i.e., the promoted sorbent may be regenerated, recycled and/or reused."[235]

155. Figure 1 of the '114 Patent is "a block flow diagram illustrating some preferred embodiments of the process of the present invention to prepare promoted sorbents useful for mercury capture in a mercury containing gas, such as a flue gas."[236]

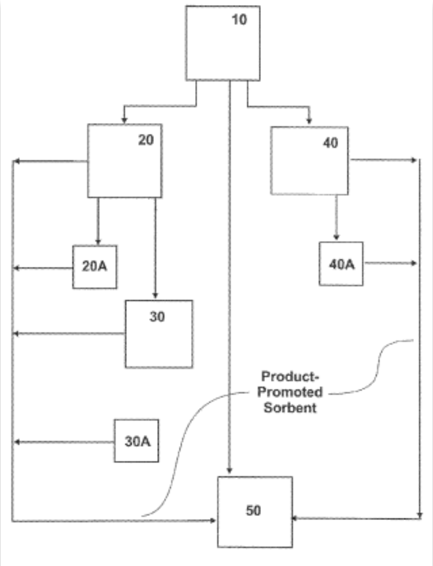

FIG. 1

The specification contemplates "providing a base sorbent as shown by block 10, adding a halogen or halide promoter that reacts with the base sorbent, illustrated at block 20, and adding a secondary component illustrated at block 30 that reacts with

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[235] EX1001 ('114 Patent) at 9:56-60.

[236] EX1001 ('114 Patent) at 10:9-14, Figure 1.

the result of block 20 to produce a product-promoted sorbent."[237] The specification also describes a second embodiment that includes "providing a base sorbent as illustrated at block 10 and adding a halogen or halide promoter and a secondary component to the base sorbent together, with which they react to produce a product-promoted sorbent as illustrated by block 40."[238] Finally, the specification identifies a third embodiment wherein "a base sorbent as illustrated by block 10 is introduced to the mercury containing gas as illustrated by block 50 while a halogen or halide promoter as illustrated by block 20 is introduced to the mercury containing gas stream."[239] For all embodiments, the specification explains that block 50 is "a mercury containing gas stream [that] is treated with product-promoted carbon sorbent prepared as described above."[240]

156. Figure 6 of the '114 Patent, which was added to the patent specification in 2018, "is a block diagram illustrating the use of the invention in a coal fueled facility."[241]

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[237] EX1001 ('114 Patent) at 10:27-32.

[238] EX1001 ('114 Patent) at 10:42-46.

[239] EX1001 ('114 Patent) at 10:55-58.

[240] EX1001 ('114 Patent) at 11:5-7.

[241] EX1001 ('114 Patent) at 29:60-61, Figure 6.

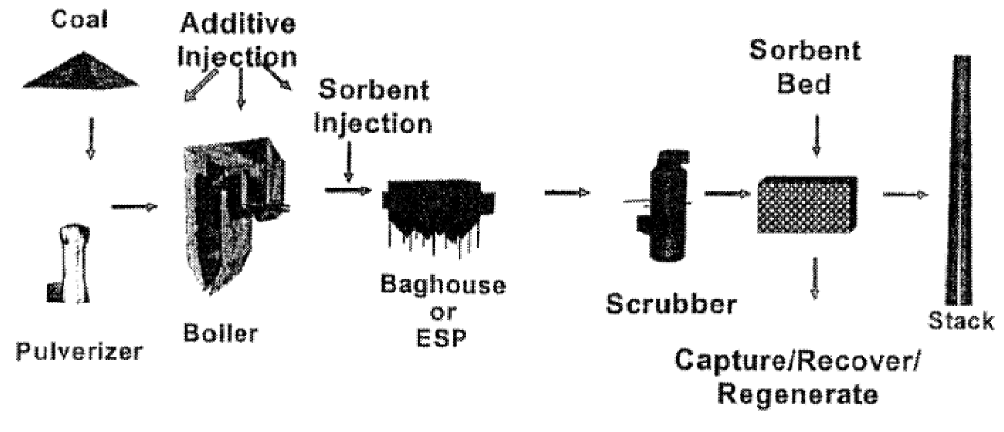

FIG. 6

Figure 6 "shows a boiler for burning pulverized coal" that includes "various devices to clean the exhaust of the boiler."[242] For example, Figure 6 shows "a baghouse or ESP used to collect particulates in the exhaust."[243] The specification explains that "[a] scrubber and sorbent bed are also used to remove undesired constituents from the flue gas stream, before being fed to the stack."[244] I discuss this figure in more detail regarding the priority date of the challenged claims.

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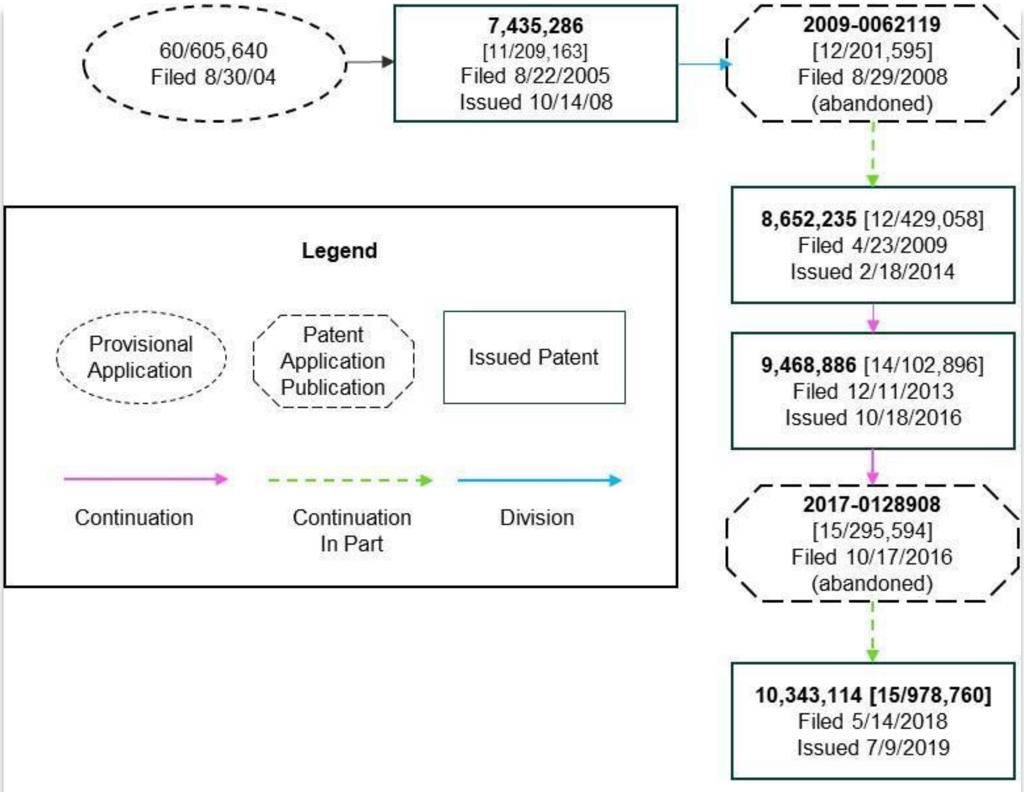
[242] EX1001 ('114 Patent) at 29:63-64.

[243] EX1001 ('114 Patent) at 29:65-66.

[244] EX1001 ('114 Patent) at 29:66-30:1.

B. Family Tree

157. I understand that the family tree below depicts the ’114 Patent, and the patent applications to which it claims priority. This is excerpted from the larger family tree set forth in Exhibit 1004, which includes other branches.[245]



C. Prosecution History of the ’114 Patent

158. As shown in the family tree provided above, the ’114 Patent was filed as U.S. Patent Application No. 15/978,760 (the “’760 Application”) and claims priority as a continuation-in-part application of U.S. Patent Application No.

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[245] EX1004 (Family Tree).

15/295,594 filed on Oct. 17, 2016 (the "'594 Application"). I have been informed that a "continuation-in-part" application is a type of patent application that is filed during the lifetime of an earlier nonprovisional application, repeating a portion or all of the earlier nonprovisional application, but then adding matter not disclosed in the earlier nonprovisional application. The '594 Application is a continuation of U.S. Patent Application No. 14/102,896, filed on Dec. 11, 2013 (the "'896 Application"). The '896 Application is a continuation of U.S. Patent Application No. 12/429,058, filed on Apr. 23, 2009 (the "'058 Application"). The '058 Application is itself another continuation-in-part of U.S. Patent Application No. 12/201,595 (the "'595 Application"). The '595 Application is a division of U.S. Patent Application No. 11/209,163 (the "'163 Application") that published as U.S. Patent App. Pub. 2006/0048646. Ultimately, the '163 Application purports to claim priority to U.S. Provisional Pat. Application No. 60/605640 (the "Provisional"), filed August 30, 2004.[246] This history is also traced on the cover and Page 2 of the '114 Patent. I understand that Exhibit 1063 is a redline comparison showing the changes made

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[246] EX1021 ('163 Application File History) at exhibit page 236.

between the first non-provisional application (filed Aug. 22, 2005) and the ’114 Patent.[247] The changes are extensive.

1. Filing of U.S. Patent No. 10,343,114

159. The continuation-in-part application that ultimately issued as the ’114 Patent was filed on May 14, 2018 as U.S. Patent Application No. 15/978,760 (the “’760 Application”).

160. When the applicants filed the ’760 Application on May 14, 2018, they repeated a substantial portion of the ’594 Application (published as 2017/0128908), but then added matter not disclosed in the ’594 Application. Attached as Exhibit 1068 is a redline comparison between the ’594 Application (as published as 2017/0128908) and the ’760 Application (as published at 2018/0257031). I understand that the redline was prepared by using the ’594 Application as the starting document, and then showing what was changed with the filing of the ’760 Application.[248] As can be seen, significant modification to the specification was made, and I refer to these changes below. Among other changes that were made when filing the ’760 Application, the applicants added Figure 2 and surrounding text

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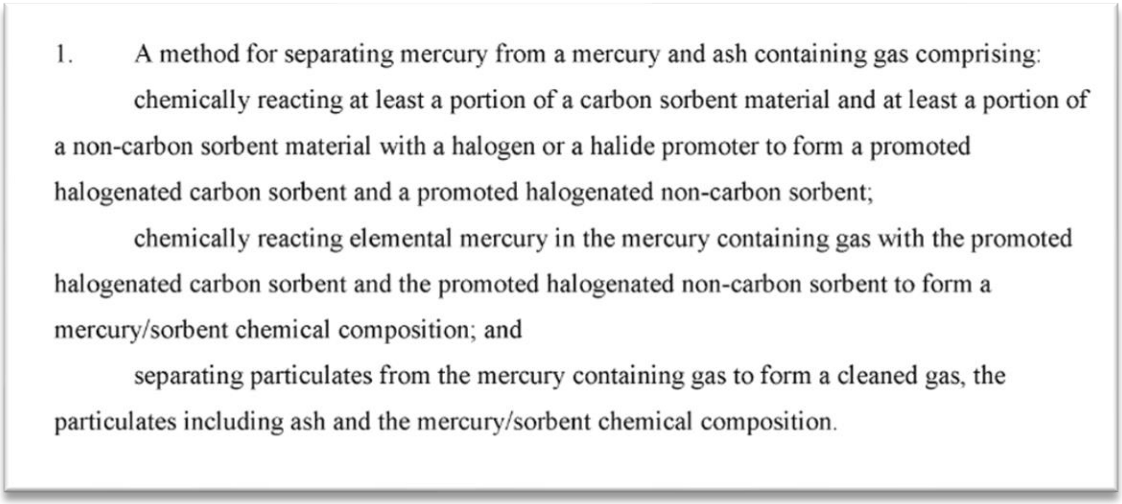
[247] EX1063 (Redline Comparison, showing changes from ’163 Application (as published at 2006/0048646) to ’760 Application (as published at 2018/0257031)).

[248] EX1068 (Redline Comparison, showing changes from ’594 Application (as published at 2017/0128908) to ’760 Application (as published at 2018/0257031)).

from the Provisional.[249] The applicants renumbered Figure 2 of the Provisional as Figure 6 of the ’760 Application.

161. As originally filed, the ’760 Application on May 14, 2018 included 1 claim and 6 drawings (Figures 1-4, 5A, 5B, and 6).[250] As filed, claim 1 of the ’760 Application is reproduced below:[251]



1. A method for separating mercury from a mercury and ash containing gas comprising:

chemically reacting at least a portion of a carbon sorbent material and at least a portion of a non-carbon sorbent material with a halogen or a halide promoter to form a promoted halogenated carbon sorbent and a promoted halogenated non-carbon sorbent;

chemically reacting elemental mercury in the mercury containing gas with the promoted halogenated carbon sorbent and the promoted halogenated non-carbon sorbent to form a mercury/sorbent chemical composition; and

separating particulates from the mercury containing gas to form a cleaned gas, the particulates including ash and the mercury/sorbent chemical composition.

2. Preliminary Amendment to the Claims of U.S. Patent No. 10,343,114

162. On May 15, 2018, the day after filing the ’760 Application, a preliminary amendment was submitted that canceled Claim 1 and added new Claims

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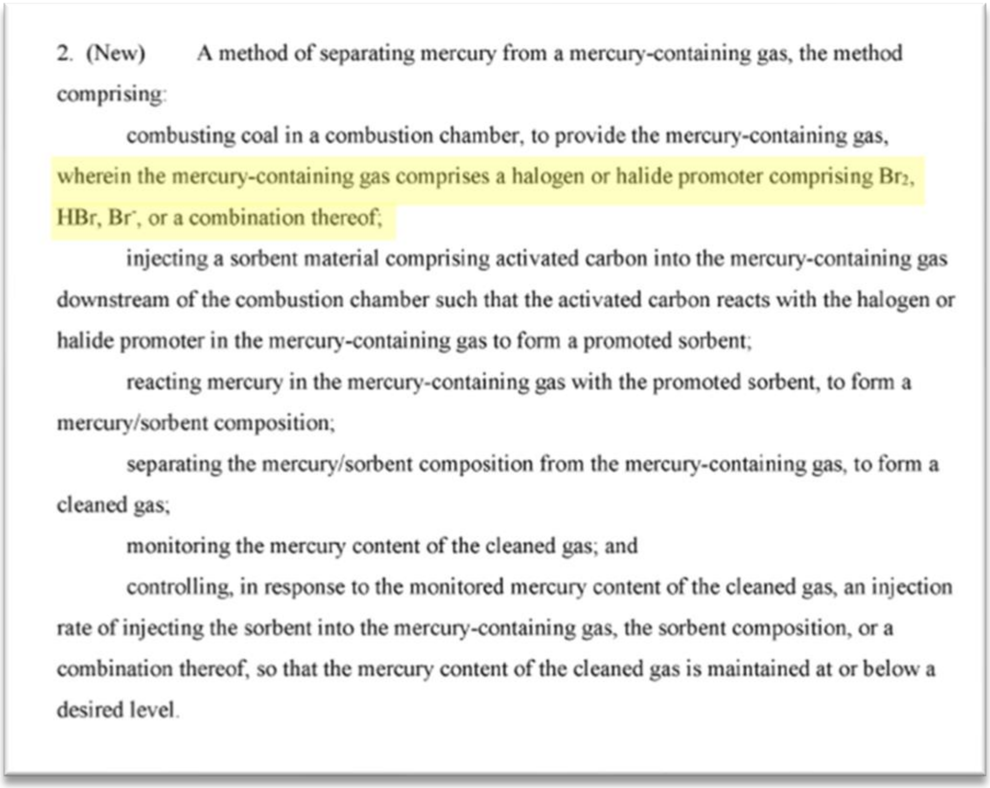
[249] EX1001 (’114 Patent) at 21:33-33:3, Figure 6; see also EX1068 (Redline Comparison, showing changes from ’594 Application (as published at 2017/0128908) to ’760 Application (as published at 2018/0257031)).

[250] EX1026 (’114 Patent File History) at 809-861.

[251] EX1026 (’114 Patent File History) at 854.

2 through 21.[252] Representative Claims 2, 6, and 7 are reproduced below as emphasized:[253]



2. (New) A method of separating mercury from a mercury-containing gas, the method comprising:

combusting coal in a combustion chamber, to provide the mercury-containing gas, wherein the mercury-containing gas comprises a halogen or halide promoter comprising Br_2, HBr, Br^-, or a combination thereof;

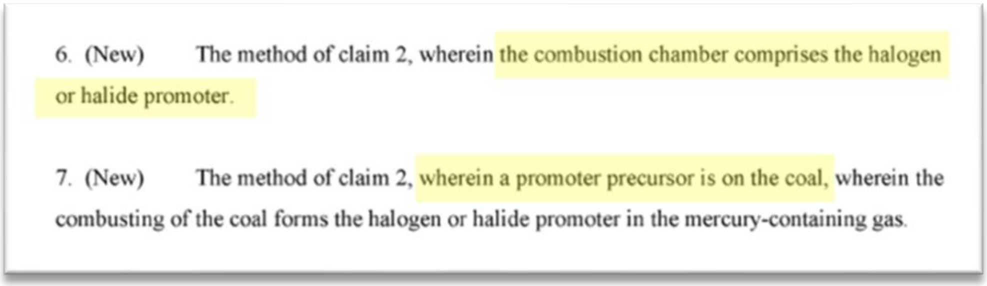
injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber such that the activated carbon reacts with the halogen or halide promoter in the mercury-containing gas to form a promoted sorbent;

reacting mercury in the mercury-containing gas with the promoted sorbent, to form a mercury/sorbent composition;

separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas;

monitoring the mercury content of the cleaned gas; and

controlling, in response to the monitored mercury content of the cleaned gas, an 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.



6. (New) The method of claim 2, wherein the combustion chamber comprises the halogen or halide promoter.

7. (New) The method of claim 2, wherein a promoter precursor is on the coal, wherein the combusting of the coal forms the halogen or halide promoter in the mercury-containing gas.

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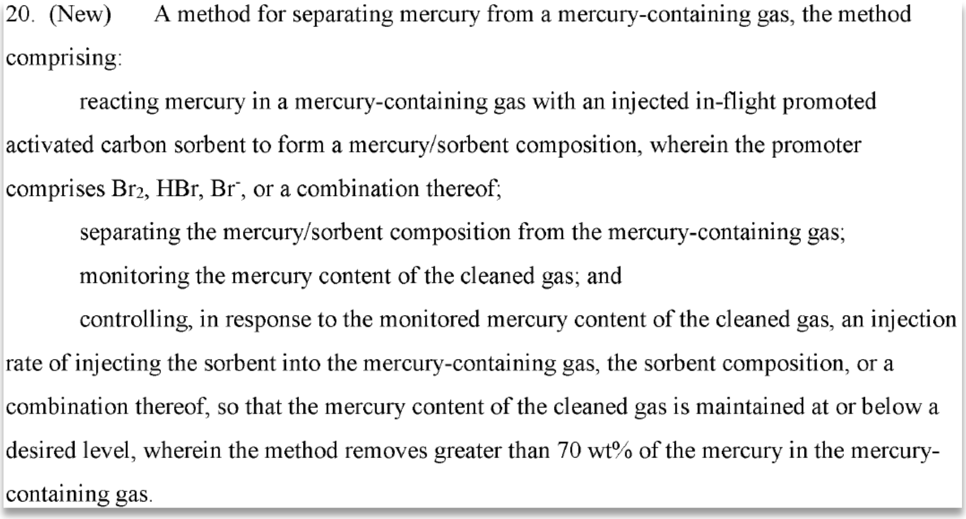
[252] EX1026 ('114 Patent File History) at exhibit pages 790-796 ('114 Patent File History, 5/15/2018 Preliminary Amendment).

[253] EX1026 ('114 Patent File History) at exhibit pages 791-792 ('114 Patent File History, 5/15/2018 Preliminary Amendment).

Claims 3 through 19 all depended from Claim 2.[254] The other independent claim, Claim 20, also recited "wherein the promoter comprises Br$_2$, HBr, Br$^-$, or a combination thereof."[255]



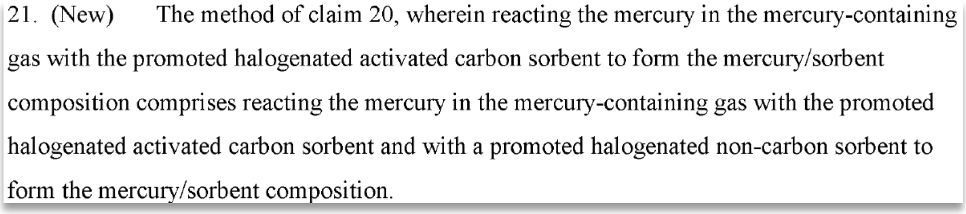
20. (New) A method for separating mercury from a mercury-containing gas, the method comprising:

reacting mercury in a mercury-containing gas with an injected in-flight promoted activated carbon sorbent to form a mercury/sorbent composition, wherein the promoter comprises Br$_2$, HBr, Br$^-$, or a combination thereof;

separating the mercury/sorbent composition from the mercury-containing gas;

monitoring the mercury content of the cleaned gas; and

controlling, in response to the monitored mercury content of the cleaned gas, an 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, wherein the method removes greater than 70 wt% of the mercury in the mercury-containing gas.



21. (New) The method of claim 20, wherein reacting the mercury in the mercury-containing gas with the promoted halogenated activated carbon sorbent to form the mercury/sorbent composition comprises reacting the mercury in the mercury-containing gas with the promoted halogenated activated carbon sorbent and with a promoted halogenated non-carbon sorbent to form the mercury/sorbent composition.

At this point in the prosecution history, the independent claims did not require any halogen addition to the coal or to the combustion chamber (e.g., as opposed to being natively present in the coal), and at best used general terms such as "halogen or

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[254] EX1026 ('114 Patent File History) at exhibit pages 792-794 ('114 Patent File History, 5/15/2018 Preliminary Amendment).

[255] EX1026 ('114 Patent File History) at exhibit page 794 ('114 Patent File History, 5/15/2018 Preliminary Amendment).

halide promoter" (claim 6) or "promoter precursor is on the coal" (claim 7). Through subsequent amendments, the applicants introduced limitations into the independent claims relating to adding specific types of bromine-containing species to either the coal itself or to the combustion chamber that were ultimately included in each of the independent claims of the '114 Patent.

3. Subsequent Prosecution History

163. On June 29, 2018, the examiner found claims 2-19 allowable, but issued a non-final rejection of only application claims 20-21.[256] Claim 20 was rejected as being obvious over a combination of U.S. Patent App. Pub. No. 2004/0003716 by Nelson (the "Nelson Publication") in view of U.S. Patent No. 6,878,358 to Vosteen *et al*.[257] Claim 21 was rejected as being obvious over a combination of the Nelson Publication in view of Vosteen and further in view of U.S. Patent App. Pub. No. 2007/0168213 by Comrie.[258] With regard to Vosteen, the Examiner relied on the reference solely for purposes of disclosing the features of claims 20 and 21 that related to "monitoring the mercury content of the cleaned gas" for controlling the

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[256] EX1026 ('114 Patent File History) at exhibit pages 565-572 ('114 Patent File History, 6/29/2018 Office Action).

[257] EX1026 ('114 Patent File History) at exhibit pages 568-569 ('114 Patent File History, 6/29/2018 Office Action).

[258] EX1026 ('114 Patent File History) at exhibit page 569 (6/29/2018 Office Action).

"injection rate of injecting the sorbent, . . . the sorbent composition, or a combination thereof."[259] The Examiner found regarding Vosteen:

> The Vosteen et al. reference discloses monitoring the mercury content of the cleaned gas; and controlling, in response to the monitored mercury content of the cleaned gas, an injection rate of injecting the sorbent into the mercury-containing gas, the sorbent composition, or a combination thereof (column 5, lines 47-63).
>
> * * *
>
> The Vosteen reference clearly shows that complete removal of the mercury in the mercury-containing gas (i.e. greater than 70% closer to 100% is desired) and is desired and obtainable by adding more adsorbent.[260]

The Examiner relied on the Nelson Publication and Comrie (U.S. Patent App. Pub. No. 2007/0168213) to disclose the remaining claim limitations.[261] In that same June 29, 2018 office action the examiner found claims 2-19 allowable.[262] However, the Examiner did not take a position as to whether or not either of the Nelson Publication

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[259] EX1026 ('114 Patent File History) at exhibit pages 568-569 (6/29/2018 Office Action).

[260] EX1026 ('114 Patent File History) at exhibit pages 568-569 (6/29/2018 Office Action).

[261] EX1026 ('114 Patent File History) at exhibit pages 568-569.

[262] EX1026 ('114 Patent File History) at exhibit page 569.

or Vosteen disclosed these limitations. Throughout subsequent prosecution of the ’114 Patent, Vosteen was not applied again by the Examiner.

164. On July 13, 2018, the applicant filed a response to the non-final rejection cancelling claims 20 and 21.[263] On October 10, 2018, the Examiner issued a non-final rejection withdrawing the statement of allowability regarding claims 2-19. The Examiner rejected all pending claims (claims 2-19) as obvious over a combination of U.S. Patent No. 5,435,980 to Felsvang (as the primary reference) and the Nelson Publication (as a secondary reference).[264] The Examiner found that Felsvang disclosed almost all the limitations from claims 2-19, including combusting coal, mercury-containing gas containing a halide promoter, injecting a sorbent material, reacting the activated carbon with the sorbent material, separating the mercury/sorbent composition to form a cleaned gas, monitoring the mercury content of the cleaned gas, and controlling a sorbent injection rate.[265] The Examiner relied on the Nelson Publication as a secondary reference to supply one limitation from claim 2, and certain dependent claims:

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[263] EX1026 (’114 Patent File History) at exhibit page 546.

[264] EX1026 (’114 Patent File History) at exhibit page 490 (10/10/2018 Office Action).

[265] EX1026 (’114 Patent File History) at exhibit pages 490-494 (10/10/2018 Office Action).

> [claim 2]: The Nelson reference discloses the halogen or halide promoter comprising Br_2, HBr, Br–, or a combination thereof to promote activated carbon . . . so as to provide an effective carbon sorbent for mercury.
>
> [claim 5]: The Nelson reference discloses optimizing the amount [of bromine] so as to obtain a desired mercury reactivity. It would have been obvious to one having ordinary skill in the art before the invention was made to have modified [Felsvang] to include the promoted sorbent comprises about 1 g to about 30 g of the halogen or halide promoter per 100 g of the sorbent material so as to . . . ensure optimum reaction between the halogen and the activated carbon (Nelson paragraph [0054]).
>
> [claim 18]: The Nelson reference discloses the injection of the sorbent material into the mercury-containing gas occurs upstream of a particulate separator or a scrubber (figure 4, objects 71, 64 and 22 and paragraph [0062]). It would have been obvious to one having ordinary skill in the art before the invention was made to have modified the Felsvang et al. reference to include the injection of the sorbent material into the mercury-containing gas occurs upstream of a particulate separate or a scrubber . . . so the process can be used in a plant which has a “hot-side” ESP and still have effective mercury capture.
>
> [claim 19]: Nelson Felsvang et al. [sic] reference discloses the injection of the sorbent material into the mercury-containing gas occurs upstream of a particulate separate or a scrubber (figure, objects 4, 12, 14, 1 and 2).[266]

The Examiner also rejected claim 7 for failing the written-description requirement, stating:

> [Claim 7] contains subject matter which was not described in the specification in such a way as to reasonably convey to one skilled

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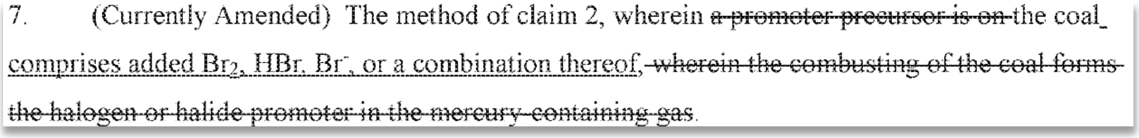
[266] EX1026 (’114 Patent File History) at exhibit pages 490-494 (10/10/2018 Office Action).

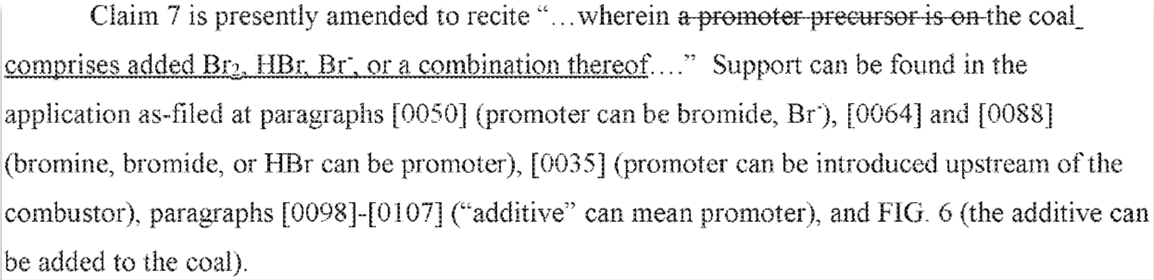
> in the relevant art that the inventor . . ., at the time the application was filed, had possession of the claimed invention. The combusting of the coal forming the halogen or halide promoter in the mercury-containing gas is not within the originally filed specification."[267]

165. On December 3, 2018, the applicants sought to overcome the written-description rejection by amending dependent claim 7 as follows:[268]



7. (Currently Amended) The method of claim 2, wherein ~~a promoter precursor is on~~ the coal comprises added Br$_2$, HBr, Br$^-$, or a combination thereof, ~~wherein the combusting of the coal forms the halogen or halide promoter in the mercury-containing gas~~.

As support for this amendment, the applicant cited the following from the as-filed U.S. Patent Application No. 15/978,760 (which ultimately matured into the '114 Patent):[269]



Claim 7 is presently amended to recite "…wherein ~~a promoter precursor is on~~ the coal comprises added Br$_2$, HBr, Br$^-$, or a combination thereof…." Support can be found in the application as-filed at paragraphs [0050] (promoter can be bromide, Br$^-$), [0064] and [0088] (bromine, bromide, or HBr can be promoter), [0035] (promoter can be introduced upstream of the combustor), paragraphs [0098]-[0107] ("additive" can mean promoter), and FIG. 6 (the additive can be added to the coal).

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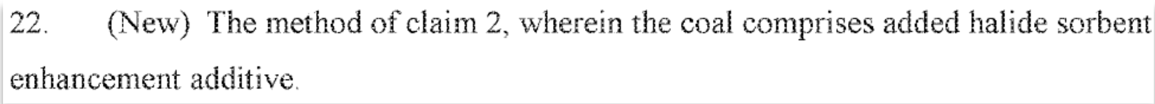
[267] EX1026 ('114 Patent File History) at exhibit page 489 (10/10/2018 Office Action).

[268] EX1026 ('114 Patent File History) at exhibit page 442.

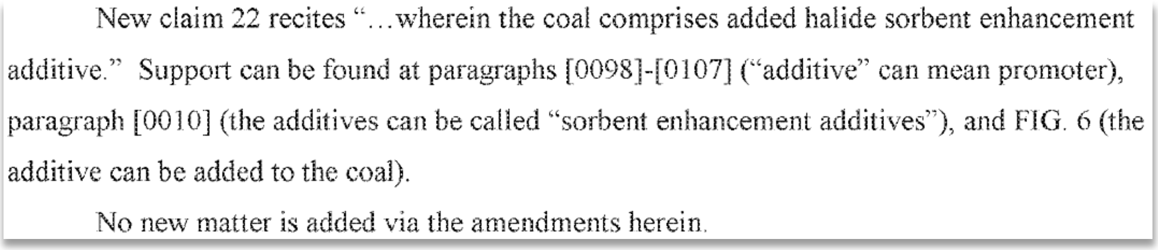
[269] EX1026 ('114 Patent File History) at exhibit page 444 (12/3/2018 Resp. to Office Action); EX1026 ('114 Patent File History) at 809-855 (Originally Filed U.S. Patent Application No. 15/978,760).

The applicants also added claim 22 (which ultimately issued as claim 19 in the '114 Patent)



22. (New) The method of claim 2, wherein the coal comprises added halide sorbent enhancement additive.

In an effort to support this new claim, the applicants cited the following from the as-filed U.S. Patent Application No. 15/978,760, and told the Examiner that no new matter was being introduced:



New claim 22 recites "…wherein the coal comprises added halide sorbent enhancement additive." Support can be found at paragraphs [0098]-[0107] ("additive" can mean promoter), paragraph [0010] (the additives can be called "sorbent enhancement additives"), and FIG. 6 (the additive can be added to the coal).

No new matter is added via the amendments herein.

166. On December 26, 2018, the Examiner again rejected the claims for obviousness over Felsvang in view of the Nelson Publication. With respect to the Nelson Publication, the Examiner simply copied and repeated the cited disclosure of the Nelson Publication with respect to the rejection of claims 2, 18, and 19 from the preceding October 10, 2018 office action.[270]

167. As part of the applicants' response on March 20, 2019, the applicants submitted four concurrent declarations totaling forty-five pages from one of the

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[270] EX1026 ('114 Patent File History) at exhibit pages 398-418 ('114 Patent File History, 12/26/2018 Office Action).

named inventors, John Pavlish, and also with Nicholas Lentz, the applicants' field technical manager, included on one of the four declarations.[271] Additionally as part of the response, the applicants amended the sole independent claim 2 to add features from dependent claims—including dependent claim 7—and introduced new independent claims to the application with limitations similar to those found in amended claim 2.[272] In particular, the applicants amended claim 2 of the '760 Application (which ultimately issued as independent claim 1 of the '114 Patent), added application claim 26 (which ultimately issued as independent claim 23), added application claim 27 (which ultimately issued as independent claim 24), and added application claim 28 (which ultimately issued as independent claim 25).[273] The amendment is shown below for application claim 2, and similar limitations were introduced to the remaining independent claims.[274]

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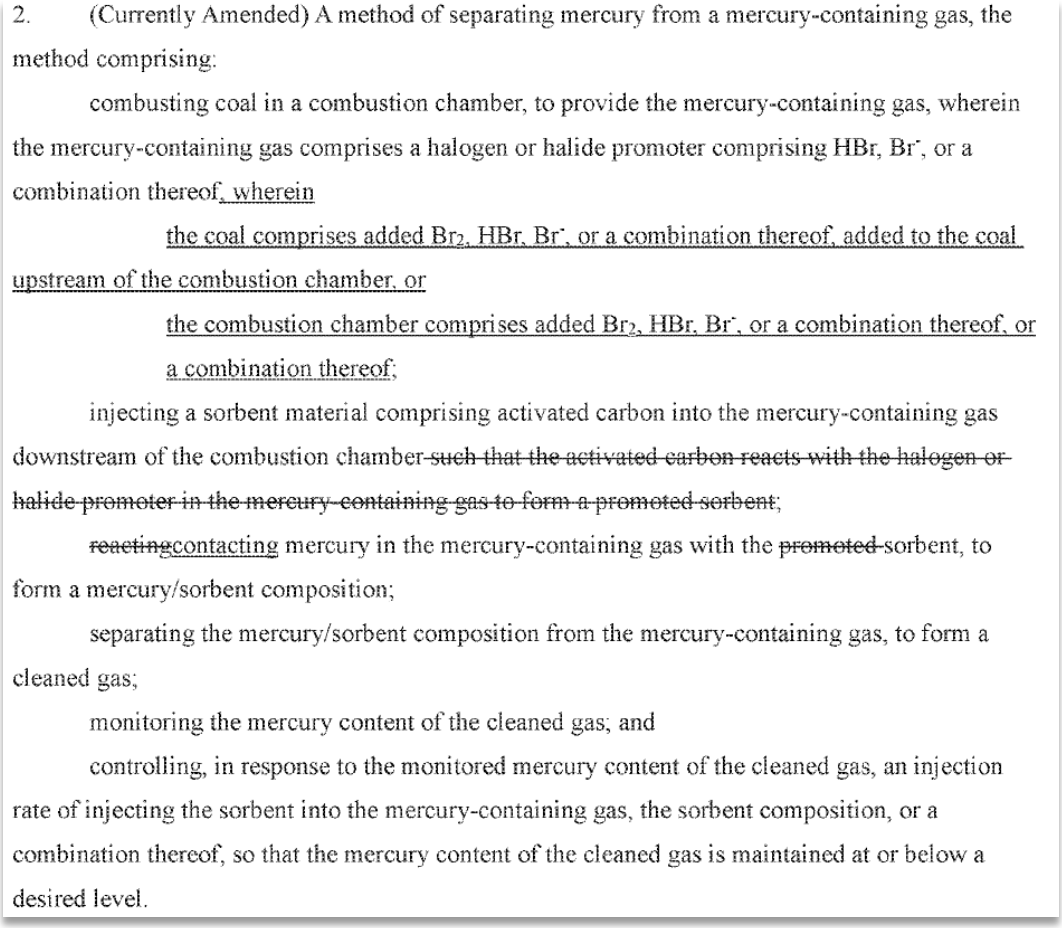
[271] EX1026 ('114 Patent File History) at exhibit pages 468-479

[272] EX1026 ('114 Patent File History) at exhibit pages 220-221.

[273] EX1026 ('114 Patent File History) at exhibit pages 220-221.

[274] EX1026 ('114 Patent File History) at exhibit pages 220.



2. (Currently Amended) A method of separating mercury from a mercury-containing gas, the method comprising:

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

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;

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~~;

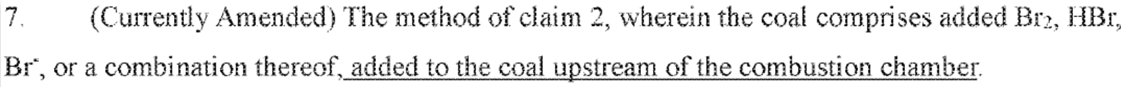
~~reacting~~contacting mercury in the mercury-containing gas with the ~~promoted~~ sorbent, to form a mercury/sorbent composition;

separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas;

monitoring the mercury content of the cleaned gas; and

controlling, in response to the monitored mercury content of the cleaned gas, an 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.

The applicants also amended claim 7 to recite:[275]



7. (Currently Amended) The method of claim 2, wherein the coal comprises added Br_2, HBr, Br^-, or a combination thereof, added to the coal upstream of the combustion chamber.

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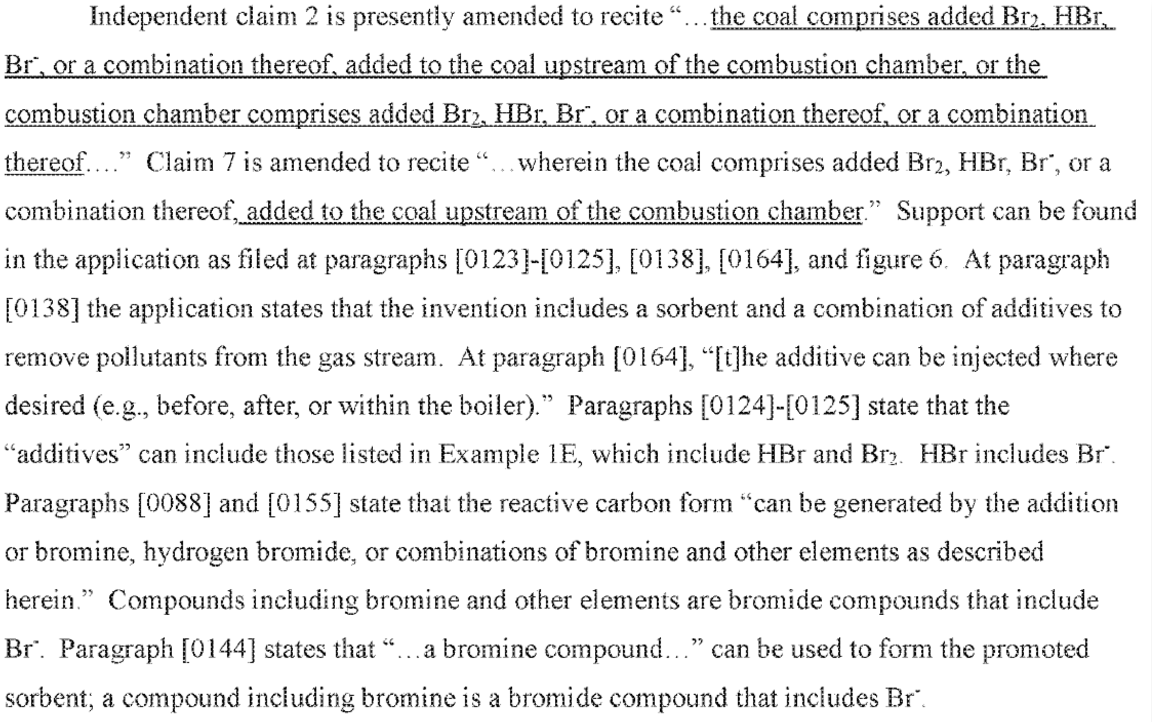
[275] EX1026 ('114 Patent File History) at exhibit pages 302.

In support of the amendment of the claims regarding the specific type of bromine chemical and its location of addition, applicants identified the following from the ’760 Application:[276]



Independent claim 2 is presently amended to recite "…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…" Claim 7 is amended to recite "…wherein the coal comprises added Br_2, HBr, Br^-, or a combination thereof, added to the coal upstream of the combustion chamber." Support can be found in the application as filed at paragraphs [0123]-[0125], [0138], [0164], and figure 6. At paragraph [0138] the application states that the invention includes a sorbent and a combination of additives to remove pollutants from the gas stream. At paragraph [0164], "[t]he additive can be injected where desired (e.g., before, after, or within the boiler)." Paragraphs [0124]-[0125] state that the "additives" can include those listed in Example 1E, which include HBr and Br_2. HBr includes Br^-. Paragraphs [0088] and [0155] state that the reactive carbon form "can be generated by the addition or bromine, hydrogen bromide, or combinations of bromine and other elements as described herein." Compounds including bromine and other elements are bromide compounds that include Br^-. Paragraph [0144] states that "…a bromine compound…" can be used to form the promoted sorbent; a compound including bromine is a bromide compound that includes Br^-.

168. On April 19, 2019, the Examiner agreed to allow claims 2-19 and 22-28 because "as shown within the declarations, in flight promotion with HBR [*sic*, HBr] or Br promoters is more effective for mercury removal than treating the sorbent with HBr, Br or Br_2 outside the mercury-containing gas."[277]

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[276] EX1026 (’114 Patent File History) at exhibit page 220 (3/20/2019 Resp. to Office Action); see EX1026 (’114 Patent File History) at exhibit page 809-855.

[277] EX1026 (’114 Patent File History) at exhibit page 203.

169. With this indication of allowance, the Examiner also maintained a non-statutory double patenting rejection of claims over a prior patent. After the applicants filed a terminal disclaimer (i.e., agreeing that the two patents would expire at the same time) to address the double patenting rejection, the Examiner ultimately allowed the claims on April 23, 2019.[278]

D. PRIORITY DATE OF THE CHALLENGED CLAIMS OF THE ’114 PATENT

170. I have been asked to review the ’114 Patent, and its earlier filed parent applications,[279] from the perspective of a POSITA. I have then been asked to analyze several things. First, I have been asked to analyze whether each of the claim limitations of the ’114 Patent are disclosed (either expressly or inherently) in those earlier filed parent applications. Second, I have been asked to analyze whether each of the claim limitations of the ’114 Patent are disclosed (expressly or inherently) in the Provisional, filed on August 30, 2004. Third, I was asked whether the Provisional is necessary to provide support (either expressly or inherently) for any of the claims of any parent patents.

171. First, I conclude that there are claim limitations in each of the issued claims of the ’114 Patent claims that are not disclosed (either expressly or inherently)

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[278] EX1026 (’114 Patent File History) at exhibit pages 142-148 (5/8/2019 Notice of Allowance).

[279] EX1004 (Family Tree).

in earlier-filed applications. These include limitations missing from each independent claim (claims 1, 23, 24, 25), such as the limitations below:

- "the coal comprises added Br_2, HBr, Br^-, or a combination thereof, added to the coal upstream of the combustion chamber" (claims 1, 23, 24);
- "the coal comprises added Br_2, HBr, a bromide compound, or a combination thereof, added to the coal upstream of the combustion chamber" (claim 25);
- "the combustion chamber comprises added Br_2, HBr, Br^-, or a combination thereof" (claims 1, 23, 24);
- "the combustion chamber comprises added Br_2, HBr, a bromide compound, or a combination thereof" (claim 25);

In the subsections below, I explain why each of these limitations were not present in the '594 Application (filed Oct. 17, 2016), which is the immediate parent of the '114 Patent. I also explain why these limitations were not present in other earlier patent applications.

172. Second, I conclude that there are claim limitations in each of the issued claims of the '114 Patent that are not disclosed (either expressly or inherently) in the Provisional.

173. Third, I have concluded that there is at least one patent, U.S. Patent No. 9,468,886, that has claims which lack support in its specification and in which the only support comes from the Provisional.

1. **The Passages Cited by the Applicants for Support During Prosecution of the ’114 Patent Were Added in 2018**

174. As described above, on March 20, 2019, the applicants amended the sole independent claim and added three new independent claims to the ’760 Application (which ultimately issued as claims 1, 23, 24, and 25 of the ’114 Patent) to recite certain bromine-containing species being added to the combustion chamber or to the coal upstream of the combustion chamber.[280] The applicants further amended claim 7 of the ’760 Application to recite that “the coal comprises added Br_2, HBr, Br^-, or a combination thereof, added to the coal upstream of the combustion chamber.”[281] In support of these amendments, the applicants cited to paragraphs [0088], [0123]–[0125], [0138], [0144], [0155], and [0164] and Figure 6 of the ’760 Application.[282]

175. I reviewed each of the above-cited portions of the ’760 Application that the applicants cited. With the exception of paragraph [0088], each of these paragraphs were not present in earlier applications, but were instead added in the continuation-in-part ’760 Application filed May 14, 2018. This can be seen in

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[280] EX1026 (’114 Patent File History) at exhibit pages 301-307.

[281] EX1026 (’114 Patent File History) at exhibit pages 302.

[282] EX1026 (’114 Patent File History) at exhibit page 220; see EX1026 (’114 Patent File History) at 809-855.

Exhibit 1068, which is a redline comparison between the ’760 Application and the ’594 Application (the immediate parent of the ’760 Application).[283] This is further evidenced by the fact that the last paragraph of the ’594 Application is paragraph [0109].[284] Figure 6 of the ’114 Patent was also added on May 14, 2018, and is not present in the ’594 Application.[285] Paragraph [0088] of the ’760 Application was present in the ’594 Application,[286] but it discusses the surface structure of activated carbon and its interaction with halogens, not the addition of bromine prior to combustion or the particular species of bromine required by the claims.

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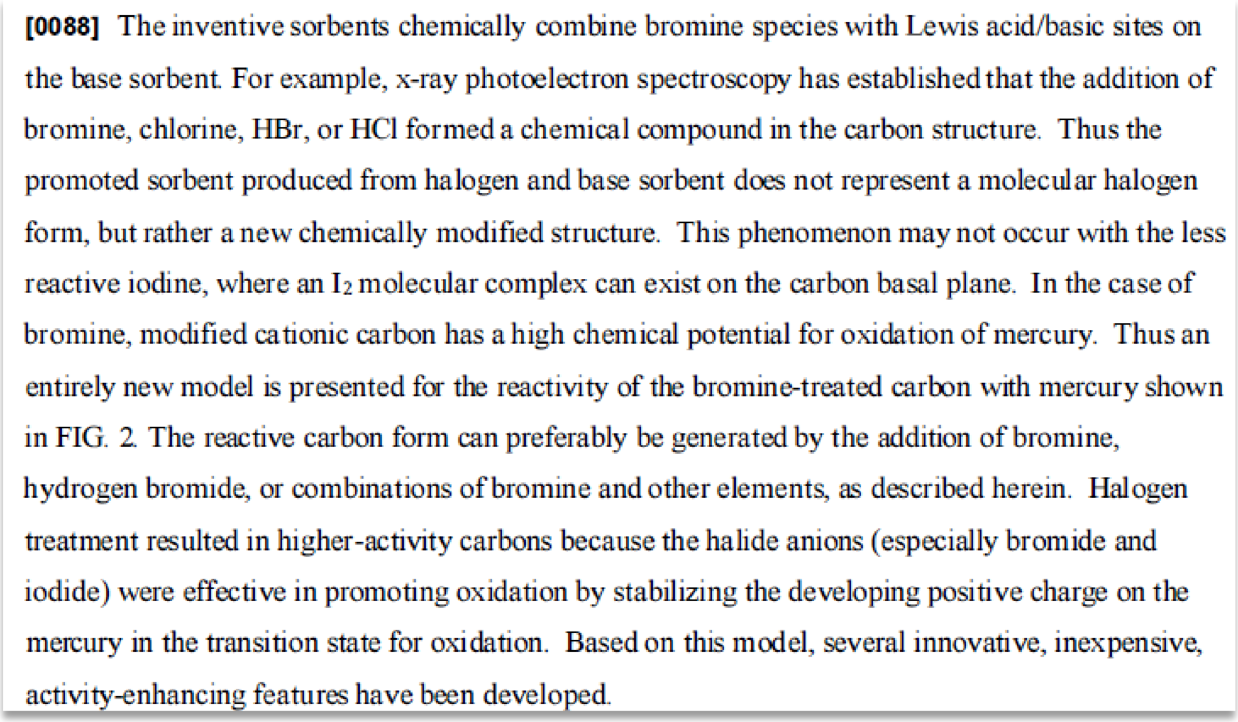
[283] EX1068 (Redline Comparison, Showing changes from ’594 Application (as published at 2017/0128908) to ’760 Application (as published at 2018/0257031)).

[284] EX1025 (’594 Application File History) at exhibit page 37 (Originally Filed Application).

[285] EX1025 (’594 Application File History) at exhibit pages 43-47 (Originally Filed Drawings).

[286] EX1025 (’594 Application File History) at exhibit page 30 ¶[0087].



[0088] The inventive sorbents chemically combine bromine species with Lewis acid/basic sites on the base sorbent. For example, x-ray photoelectron spectroscopy has established that the addition of bromine, chlorine, HBr, or HCl formed a chemical compound in the carbon structure. Thus the promoted sorbent produced from halogen and base sorbent does not represent a molecular halogen form, but rather a new chemically modified structure. This phenomenon may not occur with the less reactive iodine, where an I_2 molecular complex can exist on the carbon basal plane. In the case of bromine, modified cationic carbon has a high chemical potential for oxidation of mercury. Thus an entirely new model is presented for the reactivity of the bromine-treated carbon with mercury shown in FIG. 2. The reactive carbon form can preferably be generated by the addition of bromine, hydrogen bromide, or combinations of bromine and other elements, as described herein. Halogen treatment resulted in higher-activity carbons because the halide anions (especially bromide and iodide) were effective in promoting oxidation by stabilizing the developing positive charge on the mercury in the transition state for oxidation. Based on this model, several innovative, inexpensive, activity-enhancing features have been developed.

Paragraph [0088] does not describe bromine-containing species being added to the combustion chamber, the coal, or anywhere else.[287] Thus, I conclude that the paragraphs identified by applicants from the ’760 Application as supporting the independent claims (other than paragraph [0088]) were not present in the family of the ’760 Patent Application prior to May 14, 2018. And as discussed further below regarding the Provisional, to the extent one considered the disclosure in the Provisional, even those paragraphs do not fully support the claims of the ’114 Patent.

176. I have also reviewed the portion of the ’760 Application cited by applicants in support of its amendments regarding claim 7. On May 15, 2018, the

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[287] EX1026 (’114 Patent File History) at exhibit page 829.

applicants added claim 7 to the ’760 Application, which recites “wherein a promoter precursor is on the coal, wherein the combusting of the coal forms the halogen or halide promoter in the mercury-containing gas.”[288] On December 3, 2018, the applicants amended claim 7 to recite, “wherein the coal comprises added Br_2, HBr, Br–, or a combination thereof.”[289] In arguing written-description support for dependent claim 7 as amended, the applicants cited to paragraphs [0035], [0050], [0064], [0088], [0098]-[0107], and Figure 6 of the ’760 Application.[290]

177. I reviewed the portions of the ’760 Application (the second continuation-in-part in the chain of patents) cited by the applicants in support of claim 7 of the ’760 Application[291] and have also reviewed the corresponding portions of the ’058 Application (the first continuation-in-part in the chain of patents filed April 23, 2009), as originally filed. First, as described above, Figure 6 of the ’114 Patent was also added on May 14, 2018, and is not present in the earlier

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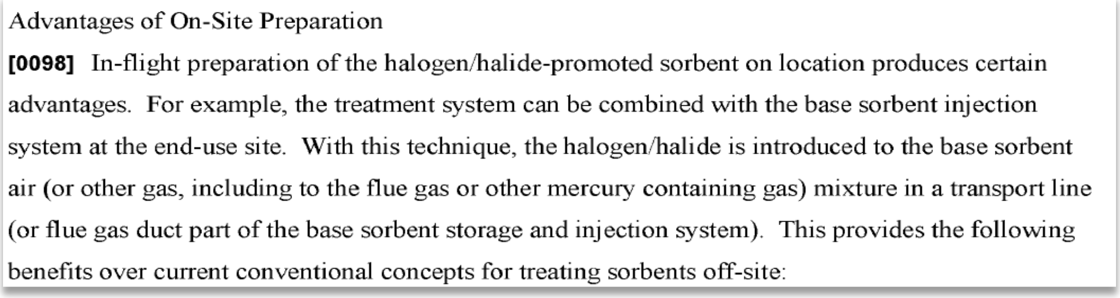
[288] EX1026 (’114 Patent File History) at exhibit pages 790-796 (5/15/2018 Preliminary Amendment).

[289] EX1026 (’114 Patent File History) at exhibit page 442.

[290] EX1026 (’114 Patent File History) at exhibit page 444 (12/3/2018 Resp. to Office Action).

[291] EX1026 (’114 Patent File History) at exhibit page 444 (12/3/2018 Resp. to Office Action); EX1026 (’114 Patent File History) at exhibit pages 809-855 (Originally Filed U.S. Patent Application No. 15/978,760).

applications.[292] Second, paragraphs [0050], [0064], and [0088] of the ’760 Application simply describe the characteristics of a promoted sorbent (which is injected downstream into the mercury-containing gas, and halogens are not added to coal) and a mechanism for how it reacts with mercury, but do not describe any bromine-containing species being added to either the combustion chamber, the coal, or anywhere else. Third, paragraphs [0098]–[0107] of the ’760 Application merely refer to a halogen promoter being contacted with a base sorbent in a flue gas, but again do not refer to any bromine-containing species being added to the combustion chamber or coal.[293] I also note that paragraph [0098], as found in the ’760 Application was amended significantly in April 2009 in the ’058 Application. Paragraph [0098] of the ’760 Application is shown below:[294]



Advantages of On-Site Preparation

[0098] In-flight preparation of the halogen/halide-promoted sorbent on location produces certain advantages. For example, the treatment system can be combined with the base sorbent injection system at the end-use site. With this technique, the halogen/halide is introduced to the base sorbent air (or other gas, including to the flue gas or other mercury containing gas) mixture in a transport line (or flue gas duct part of the base sorbent storage and injection system). This provides the following benefits over current conventional concepts for treating sorbents off-site:

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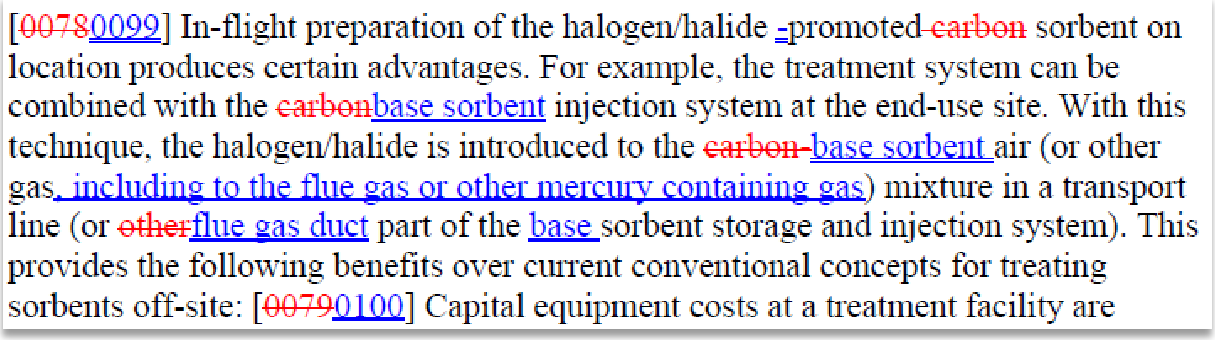
[292] EX1025 (’594 Application File History) at exhibit pages 43-47 (Originally Filed Drawings).

[293] EX1026 (’114 Patent File History) at exhibit page 832.

[294] EX1026 (’114 Patent File History) at exhibit page 832 ¶[0098].

The corresponding paragraph is shown below, as it was amended from the ’595 Application (filed Apr. 29, 2008) to the ’058 Application (as filed Apr. 23, 2009)[295]



[~~0078~~0099] In-flight preparation of the halogen/halide -promoted~~ carbon~~ sorbent on location produces certain advantages. For example, the treatment system can be combined with the ~~carbon~~base sorbent injection system at the end-use site. With this technique, the halogen/halide is introduced to the ~~carbon-~~base sorbent air (or other gas, including to the flue gas or other mercury containing gas) mixture in a transport line (or ~~other~~flue gas duct part of the base sorbent storage and injection system). This provides the following benefits over current conventional concepts for treating sorbents off-site: [~~0079~~0100] Capital equipment costs at a treatment facility are

178. Last, while paragraph [0035] of the ’760 Application states that “the promoter is introduced into the mercury-containing gas upstream of the introduction of base sorbent,”[296] it does not state how far upstream of the base sorbent the promoter is injected, or whether the promoter is introduced upstream or downstream of the combustion chamber. Paragraph [0035] does not refer to bromine-containing species being added to the combustion chamber or the coal. I also note that this entire paragraph was first added by the continuation-in-part ’058 Application when filed April 23, 2009.[297]

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[295] EX1064 (Redline Comparison, showing changes from ’595 Application (as published at 2009/0062119) to ’058 Application (as published at 2009/0297413)).

[296] EX1026 (’114 Patent File History) at exhibit page 817.

[297] EX1064 (Redline Comparison, Showing changes from ’595 Application (as published at 2009/0062119) to ’058 Application (as published at 2009/0297413))

2. **The Provisional Does Not Support the ’114 Patent Claim Limitations**

179. As described above, the applicants pasted the contents of the Provisional into the ’760 Application when they filed the ’760 Application.[298][299] Earlier applications in the priority chain of the ’760 Application (e.g., ’594 Application, ’896 Application, ’058 Application) had not expressly copied in the contents of the ’640 Provisional, but had instead stated that the Provisional was “hereby incorporated herein by reference to the extent appropriate.” These applications do not state which parts of the Provisional they are incorporating. However, even if a person of ordinary skill in the art were to consider the fully technical disclosures of the Provisional, the Provisional fails to disclose limitations from the issued claims of the ’114 Patent.

a. Adding Bromine-Containing Components to Coal

180. The passages cited by the applicants during prosecution of the ’760 Application in support of the claims do not, by themselves or collectively, support

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¶[0037]; EX1026 (’114 Patent File History) at exhibit page 18 ¶[0035] (original ’760 Application).

[298] EX1068 (Redline Comparison, showing changes from ’594 Application (as published at 2017/0128908) to ’760 Application (as published at 2018/0257031)).

[299] Patent Owner’s expert acknowledged that Figure 2 of the Provisional and the surrounding text was essential material for the Challenged Patent. EX1093 (O’Keefe Tr. 1) at 237:20-241:9.

the limitations from the independent claims (issued claims 1, 23, 24, and 25) of the ’114 Patent that “the coal comprises added” bromine-containing species that were “added to the coal upstream of the combustion chamber.”

181. Where the applicant cited paragraph [00164] that the “additive can be injected where desired (e.g., before, after, or within the boiler),”[300] a person of ordinary skill in the art would not conclude that this discloses the “additive” being added to the coal.[301] Generically adding components to a system “before” the boiler does not equate to those components being added to the coal (a more specific location), because there are other ways to add a component “before” the boiler, as I discuss later in this section. Paragraph [00164] originates from the Provisional and, other than referring to corresponding Figure 2, is identical to the language of the Provisional reproduced below as emphasized:[302]

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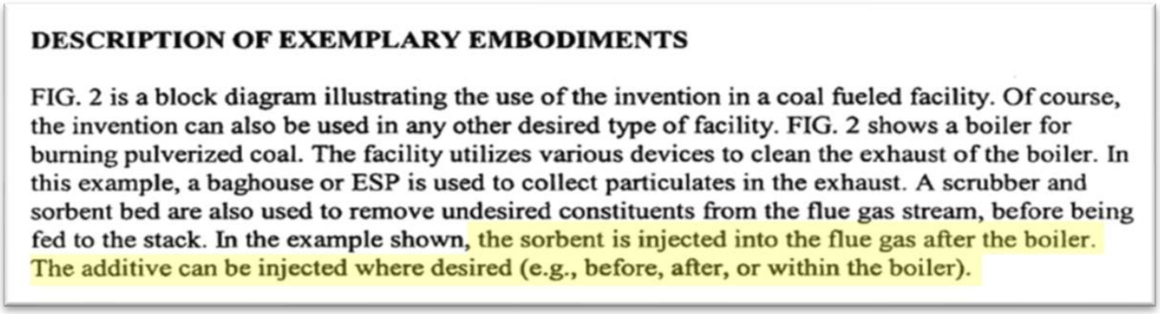
[300] EX1026 (’114 Patent File History) at exhibit page 809; see EX1026 (’114 Patent File History) at exhibit pages 847-848 ¶[00164].

[301] EX1026 (’114 Patent File History) at exhibit page 809.

[302] EX1026 (’760 Application) at exhibit pages 847-848 ¶[00164]; EX1020 (Provisional) at exhibit pages 12, 15.



DESCRIPTION OF EXEMPLARY EMBODIMENTS

FIG. 2 is a block diagram illustrating the use of the invention in a coal fueled facility. Of course, the invention can also be used in any other desired type of facility. FIG. 2 shows a boiler for burning pulverized coal. The facility utilizes various devices to clean the exhaust of the boiler. In this example, a baghouse or ESP is used to collect particulates in the exhaust. A scrubber and sorbent bed are also used to remove undesired constituents from the flue gas stream, before being fed to the stack. In the example shown, the sorbent is injected into the flue gas after the boiler. The additive can be injected where desired (e.g., before, after, or within the boiler).

Likewise, the illustration associated with this description appears as Figure 2 of the Provisional (and Figure 6 of the ’114 Patent), as reproduced below:[303]

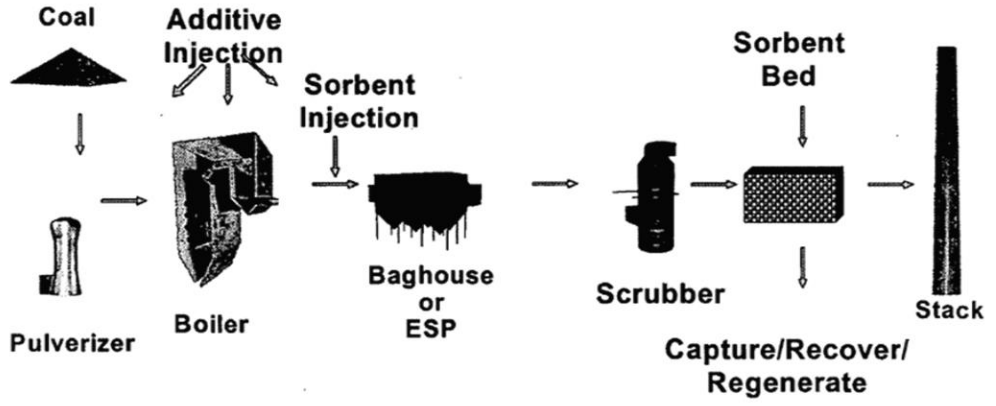


FIG. 2

182. This Figure 2 of the Provisional and corresponding Figure 6 of the ’114 Patent includes a label with “Additive Injection” having three arrows pointing generically in the direction of the boiler of a coal-fired power plant. Even if “the

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[303] EX1020 (Provisional) at Figure 2; EX1001 (’114 Patent) at Figure 6.

additive can be injected" were to refer to injecting a bromine-containing promoter—as opposed to injecting an alkali component used to capture "acid gases or other [flue] gas constituents"[304]—paragraph [0164] in the '760 Application (and corresponding language in the Provisional) does not support adding the additive "to the coal." A POSITA would not understand that injecting an additive "before . . . the boiler" requires adding the promoter to the coal, as there are a number of systems ahead of the boiler that do not interface with coal, such as secondary-air systems and/or low-NOx overfire air systems.[305] For example, the figure below from Babcock & Wilcox Steam shows coal being fed to a combustion chamber, but also shows a separate stream (labeled "Secondary Air") also fed to the combustion chamber.[306]

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[304] EX1020 (Provisional) at exhibit page 7 (item 9: "additives of base chemistry").

[305] EX1027 (B&W: Steam) at 13-3 to 13-5.

[306] EX1027 (B&W: Steam) at 13-5.

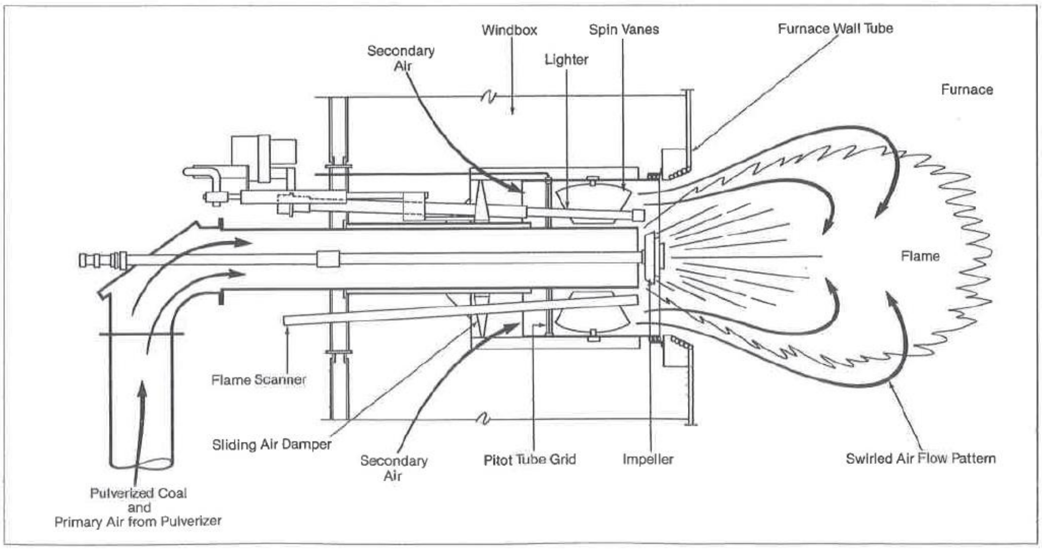

Fig. 5 S-type burner and components.

Steam 40 / *Burners and Combustion Systems for Pulverized Coal* **13-5**

Injecting an additive "before … the boiler" could also involve a specialized additive injection system leading to the boiler that does not interact with the coal before being introduced to the combustion chamber. Thus, this passage in the specification does not expressly or inherently disclose providing the additive to coal.

183. Accordingly, Figure 2 and its accompanying text in the '640 Provisional (and paragraph [0164] and Figure 6 of the '760 Application) fails to clearly disclose that "<u>the coal</u> comprises" bromine-containing species "<u>added to the coal upstream of the combustion chamber</u>," as required by each of the independent claims of the '114 Patent.

b. No Disclosure of a Promoter Comprising Br_2, Br^-, or Combinations of Br_2 and HBr with Bromide Compounds in the Earlier-Filed Patent Applications

184. The Provisional also does not disclose:

- the coal or combustion chamber comprising "added Br_2, . . . Br^-, or a combination thereof" (claims 1, 23, 24); and
- the coal or combustion chamber comprising "added Br_2, . . . a bromide compound, or a combination thereof" (claim 25).

In addition to not disclosing adding any bromine-containing species to the coal upstream of the combustion chamber (as discussed above), the Provisional also fails to disclose adding to the coal or to the combustion chamber the particular bromine-containing species recited in the claims of the '114 Patent. Regarding Paragraphs [00124]-[00125] of the '760 Application and corresponding text in the Provisional, Example 1E recites that the "additional substance is hydrohalide (HI, HBr, HCl), etc., 1%B-10% of bromine."[307]

185. First, as explained above, the Provisional refers to an "additional substance" rather than an "additive."[308] But even if the "additional substance" of a bromine-based chemical were to include hydrogen bromide (HBr) (as per example 1E), a POSITA would understand that, as confirmed by the declaration of one of the inventors, John Pavlish, submitted on March 20, 2019 during prosecution of the '114 Patent, "hydrogen bromide" is defined as "the diatomic molecule with the formula

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[307] EX1020 (Provisional) at exhibit page 3 (Example 1E); EX1026 ('114 Patent File History) at exhibit pages 837-838 ¶¶[00123]-[00125].

[308] EX1020 (Provisional) at exhibit page 3.

HBr. It is a colorless compound and a hydrogen halide."[309] This is different than the Br_2, Br^-, and bromine compound recited in the claims of the '114 Patent.

186. The Provisional does not disclose that "the coal comprises added Br_2" or that "the combustion chamber comprises added Br_2" as is required in all of the independent Claims 1, 23, 24, and 25 of the '114 Patent. As admitted by Mr. Pavlish during prosecution of the '114 Patent, "[h]ydrogen halides have different properties than elemental halogens and are therefore different compounds…. Hydrogen halides are not part of and cannot be extracted or isolated from elemental halides; rather, only via a chemical reaction that results in a chemical and structural change can hydrogen halides be formed from elemental halides."[310] As Mr. Pavlish stated more succinctly: "Br_2 is not HBr and does not include HBr."[311] Thus, the Provisional does not disclose adding Br_2 to the combustion chamber or to the coal, and Br_2 is one of the species recited in the claims.

187. A disclosure of HBr (hydrogen bromide) in the Provisional also does not necessarily disclose that "the coal comprises added Br^-" or that "the combustion

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[309] EX1026 ('114 Patent File History) at exhibit pages 320-321 ¶ 12 (3/20/2019 Decl. C from John Pavlish and Nicholas Lentz).

[310] EX1026 ('114 Patent File History) at exhibit page 322 ¶ 17 (3/20/2019 Decl. C from John Pavlish and Nicholas Lentz).

[311] EX1026 ('114 Patent File History) at exhibit page 322 ¶ 17 (3/20/2019 Decl. C from John Pavlish and Nicholas Lentz).

chamber comprises added Br^-," as is required in independent Claims 1, 23, and 24 of the '114 Patent. As Mr. Pavlish stated in his declaration, Br^- refers to "a bromine atom with an ionic charge of -1 (Br^-)," as opposed to "bromide" which is "a binary compound of bromine with another element or a radical."[312] Thus, a POSITA reviewing the Provisional would not have concluded that the use of HBr necessarily disclosed that "the coal comprises added Br^-."

188. Last, a disclosure of HBr in the Provisional does not support that the coal and/or combustion chamber includes added "bromide compound[s]," as required by Claim 25. Indeed, there are a nearly infinite number of forms of bromide compounds, because as stated by Mr. Pavlish, a "bromide compound" may be any "chemical compound containing a bromide ion or ligand."[313] Thus, a disclosure in the Provisional of a particular type of chemical (HBr) does not demonstrate that the inventors were in possession of the broad class of chemicals of any "bromide compound."

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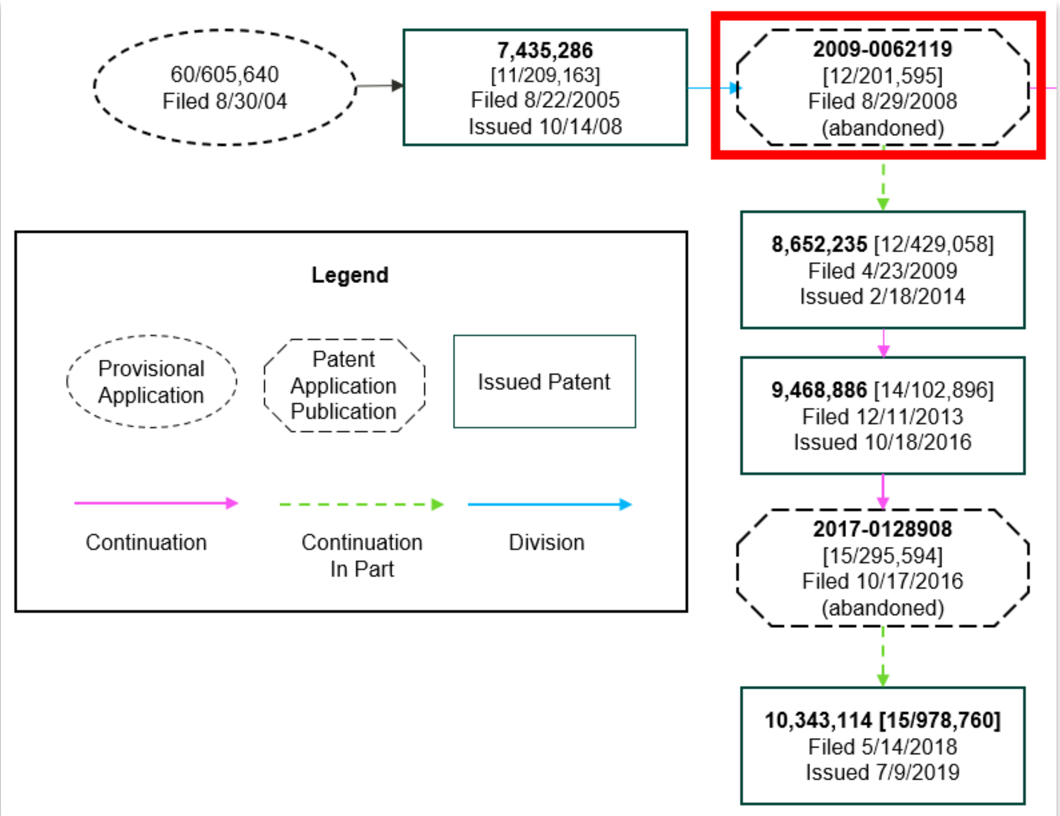
[312] EX1026 ('114 Patent File History) at exhibit page 319 ¶ 9 (3/20/2019 Decl. C from John Pavlish and Nicholas Lentz).

[313] EX1026 ('114 Patent File History) at exhibit page 319 ¶ 9 (3/20/2019 Decl. C from John Pavlish and Nicholas Lentz).

3. The ’595 Application (Filed Aug. 29, 2008) and ’163 Application (Filed Aug. 22, 2005) Do Not Support the ’114 Claims

189. I have also reviewed the ’595 Application (ultimately published as Publication No. 2009-0062119 and then abandoned), as originally filed August 29, 2008.[314] This application is shown below:[315]



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[314] EX1022 (’595 Application File History) at exhibit pages 256-284 (Description), 285-288 (Claims), 289 (Abstract).

[315] EX1004 (Family Tree) (annotated)

Figure 6 of the '114 Patent, and the paragraphs cited by the applicants during prosecution of the '114 Patent as support for their amended '114 Patent claims,[316] were either not present at all in the '595 Application or were substantially amended between the '595 Application and the '760 Application.[317] In this section, I discuss Application No. 12/201,595, but the discussion also applies to Application No. 11/209,163, as the two share a specification. Nothing in the text or figures of the '595 Application (or the '163 Application) discloses the following limitations from the '114 Patent:

- "the coal comprises added Br_2, HBr, Br^-, or a combination thereof, added to the coal of the combustion chamber" (claims 1, 23, 24) and "the coal comprises added Br_2, HBr, a bromide compound, or a combination thereof, added to the coal upstream of the combustion chamber" (claim 25);

- "the combustion chamber comprises added Br_2, HBr, Br^-, or a combination thereof" (claims 1, 23, 24) and "the combustion chamber comprises added Br_2, HBr, a bromide compound, or a combination thereof" (claim 25);

- the coal or combustion chamber comprising "added Br_2, . . . Br^-, or a combination thereof" (claims 1, 23, 24) and the coal or combustion chamber comprising "added Br_2, . . . a bromide compound, or a combination thereof" (claim 25).

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[316] EX1026 ('114 Patent File History) at exhibit page 861; see EX1026 ('114 Patent File History) at exhibit pages 809-855.

[317] EX1066 (Redline Comparison, Showing changes from '595 Application (as published at 2009/0062119) to '760 Application (as published at 2018/0257031)); see also EX1063 (Redline Comparison, Showing changes from '163 Application (as published at 2006/0048646) to '760 Application (as published at 2018/0257031)).

190. Nothing in the ’595 Application or ’163 Application discloses adding a bromine-containing species in the combustion chamber or to the coal, let alone the specific types of bromine-containing species recited in the ’114 Patent claims. This is because the ’595 Application and ’163 Application are directed to preparing a brominated activated carbon outside of the mercury-containing flue gas, and then injecting the pre-brominated sorbent into the mercury-containing flue gas downstream from the combustion chamber. This can be seen in Figure 1, annotated below:

1/7

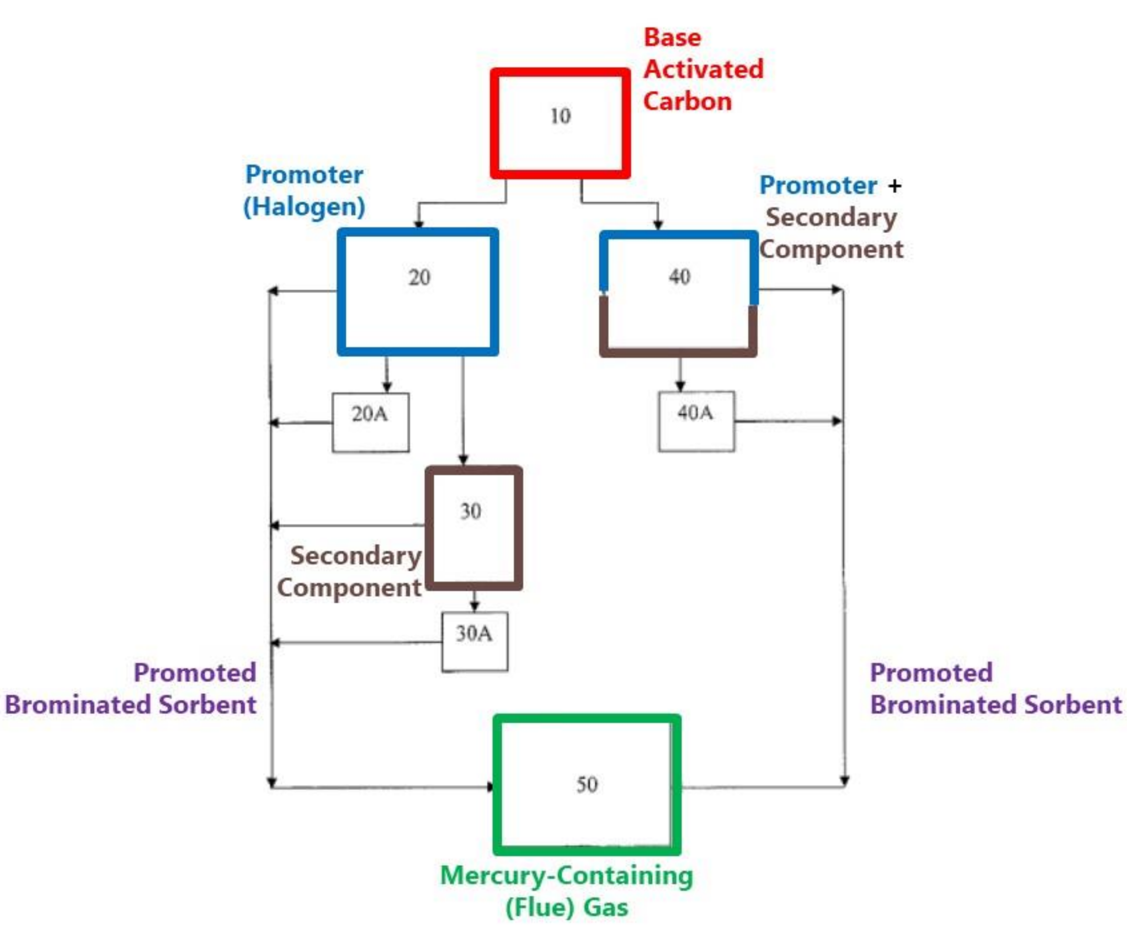

FIG. 1

First, Figure 1 identifies an embodiment along the left path, in which “block 10 illustrates providing a base activated carbon, and adding a halogen or halide promoter that reacts with the carbon, illustrated at block 20.”[318] Second, they

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[318] EX1021 (’163 Application File History) at exhibit page 243; EX1022 (’595 Application File History) at exhibit page 263.

identify another embodiment along the right path that includes "providing a base activated carbon as illustrated at block 10, and adding a halogen or halide promoter and a secondary component to the activated carbon together, with which they react as illustrated by block 40."[319] For both embodiments, the '163 and '595 Applications explain that block 50 is "a flue gas stream [that] is treated with product promoted carbon sorbent prepared as described above."[320] Whether through block 20 (left path) or block 40 (right path), both of these embodiments describe adding the halide promoter to the activated carbon and allowing them to react <u>before int</u>roducing them to the flue gas, as represented by block 50.

191. Similarly for Figure 3 of the '595 Application and '163 Application, the bromine contacts the sorbent outside of the mercury-containing gas (i.e., the brominated sorbent is prepared outside the system and then injected). A transport gas is used to co-inject the bromine-containing promoter and sorbent material <u>from the</u> non-mercury-containing transport gas <u>into the</u> mercury-containing flue gas. The

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[319] EX1021 ('163 Application File History) at exhibit page 243; EX1022 ('595 Application File History) at exhibit page 263.

[320] EX1021 ('163 Application File History) at exhibit page 244; EX1022 ('595 Application File History) at exhibit page 264.

transport (purple) occurs before the mercury-containing gas (green). Fig. 3 from the ’163 and ’595 Applications is annotated below:[321]

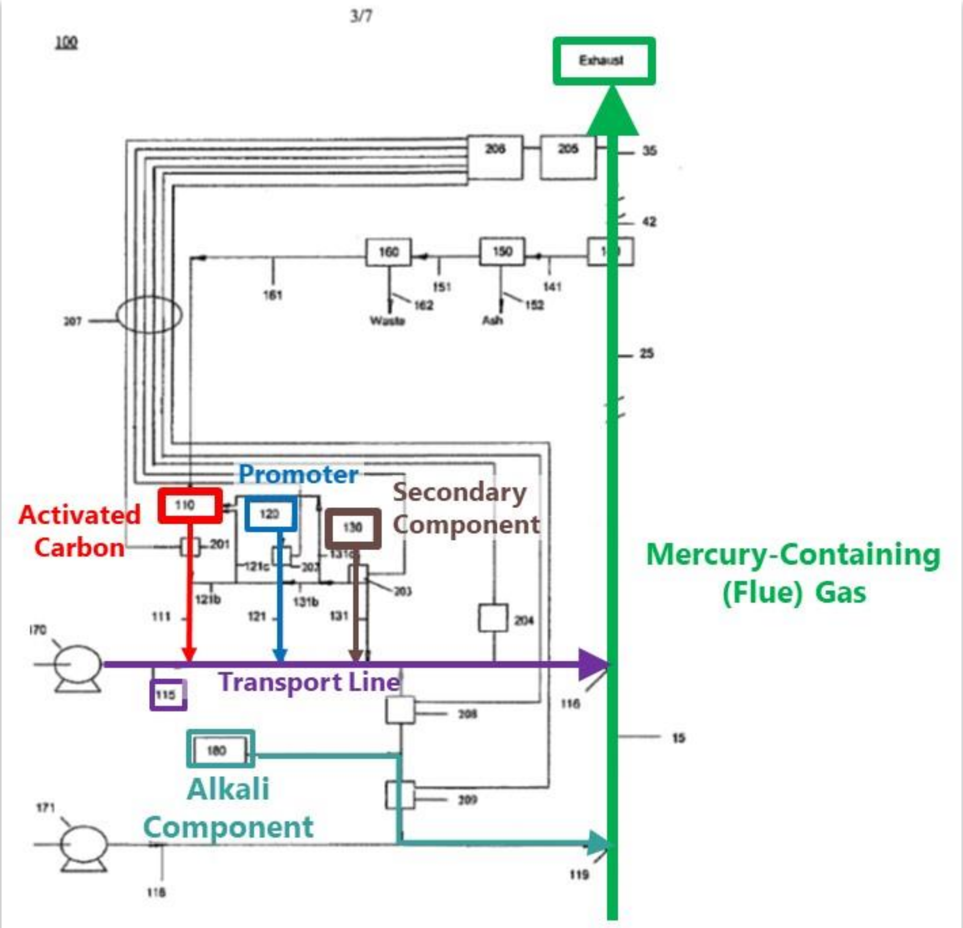

FIG. 3

Figure 3 depicts four reservoirs: “base activated carbon reservoir 110” (red), “halogen/halide promoter reservoir 120” (blue), “secondary component reservoir

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[321] EX1021 (’163 Application File History) at exhibit page 272 (Fig. 3) (annotated); EX1022 (’595 Application File History) at exhibit page 297 (Fig. 3).

130" (brown), and "alkali component reservoir 180" (turquoise).[322] The reservoirs 110, 120, and 130 "each connect through respective flow control devices and via associated piping, to transport line 115."[323] Transport line 115 is highlighted purple. "A source of air, nitrogen, or other transport gas(es) may be provided by gas source 170 to transport line 118 for the purpose of entraining materials discharged from reservoirs 110, 120, 130, and 180 and injecting such materials, via injection point 116, <u>into contaminated flue gas stream 15</u> [green]."[324]

192. There is no disclosure of adding bromine to the coal or to the combustion chamber.[325] Rather, the bromine is contacted with the activated-carbon system outside the gas-cleaning system, and then the brominated powdered activated carbon (BPAC) is introduced into the mercury-containing gas. In another passage, the '595 Application and '163 Application state:

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[322] EX1021 ('163 Application File History) at exhibit page 245 (¶ [0054]); EX1022 ('595 Application File History) at exhibit page 265 (¶ [0054]).

[323] EX1021 ('163 Application File History) at exhibit page 245 (¶ [0055]); EX1022 ('595 Application File History) at exhibit page 265 (¶ [0055]).

[324] EX1021 ('163 Application File History) at exhibit page 245 (¶ [0055]); EX1022 ('595 Application File History) at exhibit page 265 (¶ [0055]).

[325] The named inventors of the '114 Patent, Dr. Olson and Mr. Pavlish, and Patent Owner's expert were asked about the specification of the '147 Patent (12/419,219) and each confirmed that none of the examples disclosed adding bromine to coal. EX1095 (Olson) at 128:20-25; EX1097 (Pavlish) at 116:22-125:17; EX1093 (O'Keefe 1) at 156:5–170:5.

> In this example, the halogen/halide promoted carbon sorbent was injected into the flue gas after the boiler. In general however, the inventive sorbent can be injected where desired (e.g., before, after, or within the boiler).[326]

Nothing in the above paragraph discusses where to add the bromine-containing promoter itself, and it certainly does not describe its addition to the coal or to the combustion chamber. The quote is not related to the production or formation of the bromine-promoted sorbent at all. Rather, the quote discusses testing the bromine-promoted sorbent (the patent's alleged "inventive sorbent"), as discussed above for Figures 1 and 3, that has already been made outside of the gas-cleaning system, and before being introduced into a mercury-containing gas stream. As an aside, a POSITA would not understand this to be any kind of disclosure for adding bromine to coal, as a POSITA would know that adding brominated activated carbon (BPAC) to or before a combustion chamber would defeat the purpose of the invention, as the activated carbon would be combusted in a fireball and thus unavailable to adsorb mercury. Activated carbon can be expensive, and there would be no reason to add the activated-carbon sorbent upstream of the combustion chamber. In short, nothing in the '595 Application describes adding the bromine promoter independently from the activated-carbon sorbent, let alone to the coal or to the combustion chamber.

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[326] EX1022 ('595 Application File History) at exhibit page 280 ¶[00107].

4. The ’594, ’896, and ’058 Applications in the ’114 Chain also Do Not Support the ’114 Claims

193. As shown in the family tree provided above,[327] the ’114 Patent claims priority as a continuation-in-part application to Application No. 15/295,594 (the ’594 Application, filed Oct. 17, 2016), which was published as Publication No. 2017-0128908 and then abandoned. The ’594 Application[328] is a continuation of the ’896 Application (filed Dec. 11, 2013),[329] which ultimately issued as U.S. Patent No. 9,468,886. The ’896 Application is a continuation of the ’058 Application (filed Apr. 23, 2009).[330] These applications are shown below:[331]

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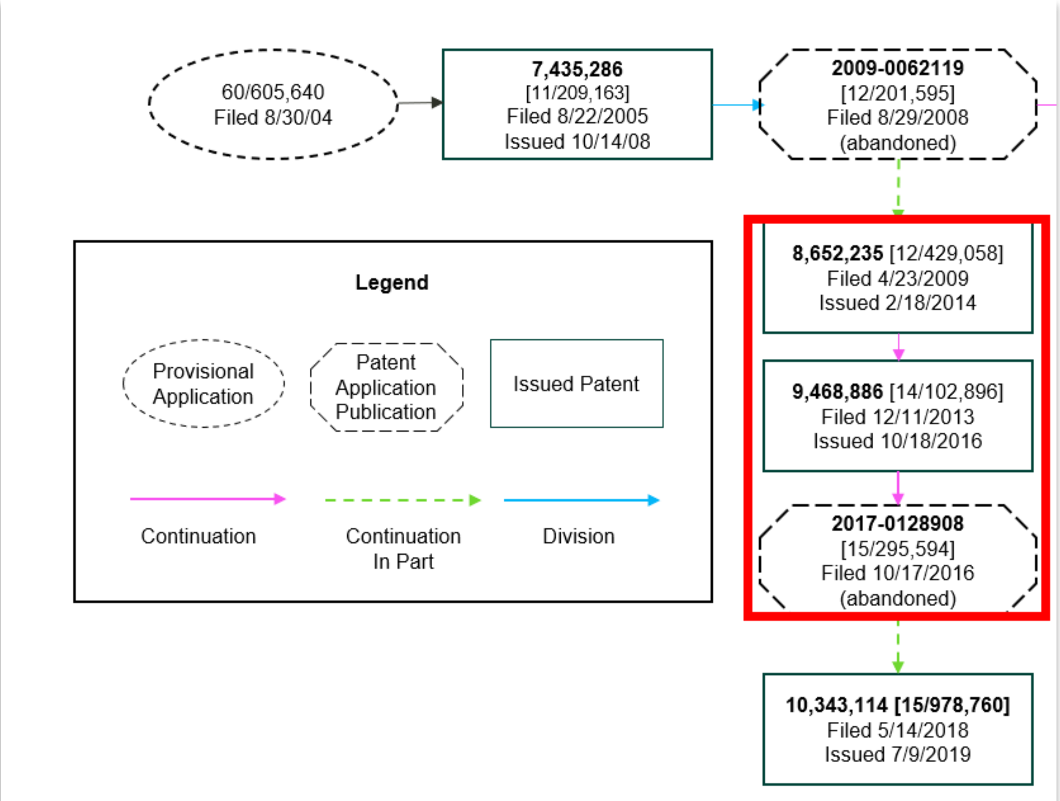
[327] EX1004 (Family Tree).

[328] EX1025 (’594 Application File History).

[329] EX1024 (’896 Application File History).

[330] EX1023 (’058 Application File History).

[331] EX1004 (Family Tree) (annotated)



The figures and description (i.e., everything other than the claims) are substantively identical between the '594, '896, and '058 Applications. Figure 6 of the '114 Patent, and the paragraphs cited by the applicants during prosecution of the '114 Patent as support for their amended '114 Patent claims,[332] were not present in any of the '594, the '896, or the '058 Applications.[333]

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[332] EX1026 ('114 Patent File History) at exhibit page 861; see EX1026 ('114 Patent File History) at exhibit pages 809-855.

[333] EX1068 (Redline Comparison, Showing changes from '594 Application (as published at 2017/0128908) to '760 Application (as published at 2018/0257031)); EX1065 (Redline Comparison, Showing changes from '058 Application (as published at 2009/0297413) to '594 Application (as published at 2017/0128908)).

194. I note that Claims 5, 11, and 18 of the ’594 Application (as filed Oct. 17, 2016) and the ’896 Application (as filed Dec. 11, 2013) recite that “halogen or halide promoter is introduced into at least one of before a combustion chamber that produces a mercury-containing gas, into a combustion chamber that produces a mercury-containing gas . . .”[334] First, these claims are not present in the ’058 Application that was filed on Apr. 23, 2009.[335] Second, as described above regarding Figure 2 of the Provisional, a person of ordinary skill in the art would understand that introduction of a promoter before the combustion chamber would not necessarily refer to adding that promoter to the coal. For example, the promoter could be introduced into any number of systems upstream of the combustion chamber that do not interface with coal—such as a secondary air system, a low-NOx overfire air system, or potentially even a specialized dedicated additive injection system having a nozzle directly into the boiler.[336] Nothing in the remainder of these applications describe adding a promoter to the coal.

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[334] EX1025 (’594 Application File History) at exhibit pages 29-32; EX1024 (’896 Application File History) at exhibit pages 29-32.

[335] EX1023 (’058 Application File History) at exhibit pages 34-37.

[336] EX1027 (B&W: Steam) at 13-3 to 13-5.

195. The ’594, ’896, and ’058 Application do include new Figures 5A and 5B (not present in the ’595 Application filed Aug. 29, 2008) that are reproduced below:[337]

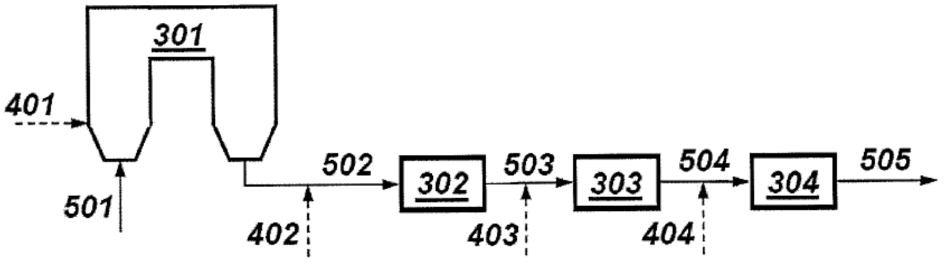

FIG. 5A

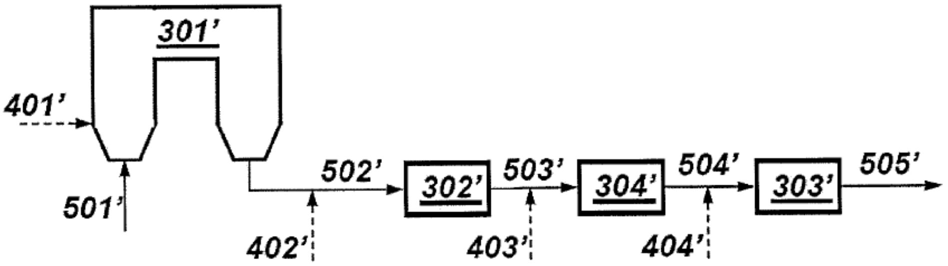

FIG. 5B

Figures 5A and 5B and their newly added descriptions in the specification provide the first arguable support for any embodiment where the bromide promoter is introduced independently from the sorbent into the combustion chamber or the flue gases:

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[337] EX1023 (’058 Application File History) at exhibit page 43.

> Injection streams 401, 402, 403 and 404, in addition to stream 501, are multiple locations wherein promoter, base sorbent, or a combination of promoter and base sorbent may be introduced.[338]

* * *

> In an embodiment, a promoter is introduced to chamber 301 at location 401. A base sorbent (carbon, non-carbon, or their combination) is introduced at location 402 upstream of air heater 302.[339]

196. Even considering Figure 5A and 5B that were added to the specification and the surrounding text in 2009,[340] the applications are still missing disclosure. First, there is no disclosure in the specification of these applications (or even in Figures 5A and 5B) of adding halogen promoters "before" or "upstream" of the combustion chamber. At best, Figures 5A and 5B disclose adding promoter into combustion chamber 301 (e.g., such as through a port). Second, even if one were to imagine that Figures 5A and 5B disclose adding promoter before the combustion chamber (which they do not), there is still no disclosure in these applications (or even in Figures 5A and 5B) of adding any halogen promoter (let alone particular species of bromine-containing reagents) to coal. For example, and as discussed

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[338] EX1023 ('058 Application File History) at exhibit pages 27-28 ¶[0092].

[339] EX1023 ('058 Application File History) at exhibit pages 28 ¶[0095].

[340] The '058 Application was filed April 23, 2009, which is after the publication dates of Vosteen589, Downs-Boiler, Starns, Mass-EPA, Sjostrom, and Eckberg.

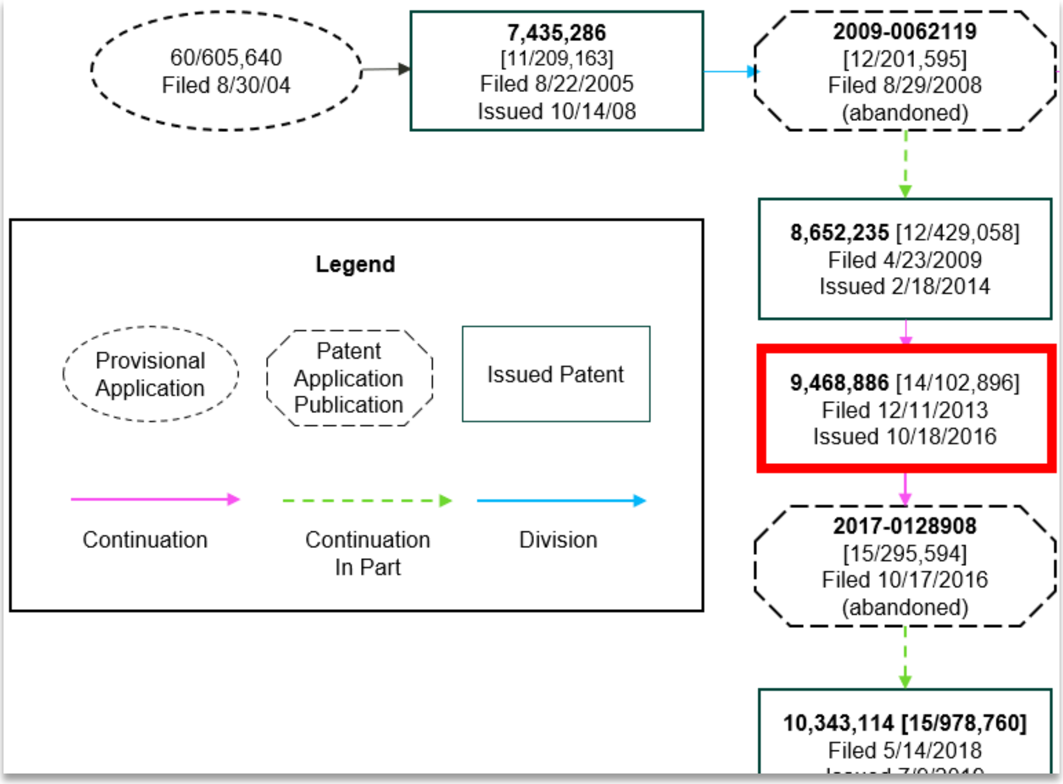
above, the promoter could be added to the combustion chamber by first introducing the promoter into any one of the multitude of auxiliary systems located upstream of the combustion chamber (e.g., secondary air systems, low NOx overfire air systems, or a specialized promoter injection system), which do not necessarily add the promoter to the coal. I understand that when a patent claim recites three options (e.g., adding promoter to the combustion chamber, to the coal, or both) all three options must be disclosed expressly or inherently for the claim to be supported.

197. Accordingly, the ’594, ’896, and ’058 Applications fail to disclose the following claim limitations of the ’114 Patent:

- “the coal comprises added Br_2, HBr, Br^-, or a combination thereof, added to the coal of the combustion chamber” (claims 1, 23, 24);
- “the coal comprises added Br_2, HBr, a bromide compound, or a combination thereof, added to the coal upstream of the combustion chamber” (claim 25);
- the coal or combustion chamber comprising “added Br_2, . . . Br^-, or a combination thereof” (claims 1, 23, 24); and
- the coal or combustion chamber comprising “added Br_2, . . . a bromide compound, or a combination thereof” (claim 25).

5. The Claims of U.S. Patent No. 9,468,886 (EX1019) Are Not Supported by Its Specification

198. I understand that the ’896 Application I discuss above (U.S. Patent Application No. 14/102,896) ultimately issued into U.S. Patent No. 9,468,886 (’886 Patent).[341] This patent is shown below:[342]



I have been asked to review the issued claims of the ’886 Patent and then: (a) assess whether claims of the ’886 Patent find support in the specification of the ’886 Patent; and (b) if not, whether those claims find support in the Provisional. I have

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[341] EX1019 (U.S. Patent No. 9,468,886).

[342] EX1004 (Family Tree) (annotated).

determined that Claims 5, 11, and 18 of the ’886 Patent do not have support from the specification of the ’886 Patent, and they would need to rely on the Provisional for support.

199. The claim limitations of the ’886 Patent are different (broader in many respects) than the claim limitations of the ’114 Patent, such that the Provisional may disclose the claim limitations of the ’886 Patent even though it does not disclose the claim limitations of the ’114 Patent. For example, unlike the ’114 Patent claims, none of the issued claims of the ’886 Patent require that “the coal comprises added [halogen-containing ingredients] … added to the coal upstream of the combustion chamber.” Rather, Claims 5, 11, and 18 of the issued ’886 Patent more generally recite, “wherein said halogen or halide promoter is introduced into at least one of before a combustion chamber that produces a mercury-containing gas, into a combustion chamber that produces a mercury-containing gas, and after a combustion chamber that produces a mercury-containing gas, and the non-carbon sorbent material is injected downstream of the combustion chamber.”

200. There is no support in the specification of the ’886 Patent for introducing a halogen or halide promoter “before a combustion chamber.” At best, Figure 5A and Figure 5B (and accompanying text) (which were added to the patent chain in 2009 with the filing of the ’058 Application) disclose introducing halogens <u>into</u> a combustion chamber, but not “before” the combustion chamber.

201. In contrast to the specification of the ’886 Patent, the Provisional does disclose addition of something “before” the combustion chamber. For example, the Provisional states in connection with Figure 2, “The additive can be injected where desired (e.g., <u>before</u>, after, or within the boiler).” To be clear, the Provisional does not disclose adding bromine-containing ingredients <u>to the coal</u> (as required by the ’114 Patent claims) and does not disclose adding specific Br-containing ingredients (e.g., Br_2, HBr, Br-, or bromide compound) to the coal, but the Provisional does generally disclose providing an additive “before” the boiler (as required by Claims 5, 11, and 18 of the ’886 Patent). The ’886 Patent claims 5, 11, and 18 generally recite a “halogen or halide promoter.” Thus, Figure 2 of the Provisional and surrounding text (which is not present in the specification of the ’886 Patent) is the only disclosure for claims of the ’886 Patent, including at least claims 5, 11, and 18 of the ’886 Patent.

E. <u>ADMITTED PRIOR ART</u>

202. The ’114 Patent makes numerous admissions regarding what was known in the art.[343] The ’114 Patent admits that activated carbon, including powdered activated carbon, was known in the art.

> In some preferred embodiments, the carbon base sorbent provided may preferably be any of several types, <u>as understood by those skilled in the art.</u> For example, the carbon base sorbent

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[343] EX1001 (’114 Patent) at 26:62-27:59, 32:46-33:3.

> may include <u>powdered activated carbon</u>, granular activated carbon, carbon black, unburned carbon, carbon fiber, carbon honeycomb or plate structure, aerogel carbon film, pyrolysis char, regenerated activated carbon from product-promoted carbon sorbent, or other types as known in the art.[344]

Not only was activated carbon known, but specifically the injection of activated carbon was known in the art.

> Fine-particle injection sorbents include activated carbon, metal oxide sorbent, sodium sulfide particles, and basic silicate or oxide sorbents. When particle injection is employed, the mercury captured on the sorbent particles is removed from the gas stream in a particulate control device such as a baghouse or electrostatic precipitator (ESP) and collected along with ash particulate.[345]

203. The ’114 Patent admits that it was “known in the art” to inject “halogen or halogen precursors in a hot zone, followed by contact with an alkaline material in a wet or dry scrubber.”[346] The patent explains that using “such an approach, elemental mercury is claimed to be oxidized by the halogen to Hg(II) which is collected by the alkaline material in the scrubber.”[347] The patent further explains that “it is known to inject halogen forms at some stage of the combustion process.”[348]

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[344] EX1001 (’114 Patent) at 11:8-16.

[345] EX1001 (’114 Patent) at 1:59-65; *see also* 25:35-48 (similar quote).

[346] EX1001 (’114 Patent) at 2:60-62.

[347] EX1001 (’114 Patent) at 2:63–3:5 (citing prior-art references).

[348] EX1001 (’114 Patent) at 3:5-6.

204. The ’114 Patent admits that particulate separators, including electrostatic precipitators, were known in the art:

> By way of illustration and not limitation, particulate separator 140 may comprise one or more fabric filters, one or more ESPs, or other particulate 35 removal devices <u>as are known in the art.</u>[349]

XI. CLAIM CONSTRUCTION

205. I have reviewed how a POSITA would have understood terms in the Challenged Claims. While no terms of the ’114 Patent have been previously construed, I note that Magistrate Judge Burke in the District of Delaware provided constructions for two terms in patents from the same family as the ’114 Patent. Specifically, I understand that Magistrate Judge Burke construed the terms “combusting a mixture comprising coal, pyrolysis char, and an additive comprising HBr, a bromide compound, or a combination thereof” (claim1), “combusting coal in a combustor comprising pyrolysis char and an additive comprising HBr, a bromide compound, or a combination thereof, to form the mercury-containing gas” (claim 14), and “combusting a mixture comprising coal, pyrolysis char, and an additive comprising HBr, a bromide compound, or a combination thereof” (claim 17) in U.S. Patent No. 10,589,225 to have their plain and ordinary meaning.[350] In reaching this

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[349] EX1001 (’114 Patent) at 14:32-35.

[350] EX1071 (Midwest Energy Emissions Corp., et al. V. Arthur J. Gallagher & Co., et al., No. 1:19-cv-01334-CJB, Dkt. No. 440 (D. Del. June 24, 2022)).

construction, I understand that Magistrate Judge Burke explained that "[t]he dispute with respect to this term . . . is whether the limitation allows for the pyrolysis char to be created within the combustor -- i.e., by combusting a mixture of coal and a bromine compound that produces pyrolysis char -- and then be combusted along with the coal and the bromine compound in the combustor (Plaintiffs' position), or whether the coal, bromine compound and pyrolysis char must each be added to the combustor, and then be combusted (Defendants' position)."[351] Judge Burke concluded that "[t[he plain language of the claims at issue supports Plaintiffs' position."[352]

206. I further understand that Magistrate Judge Burke construed the term "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 brominated sorbent" (claim 17) in U.S. Patent No. 8,168,147 to have its plain and ordinary meaning.[353] In reaching this construction Magistrate Judge Burke explained that the plain language of the

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[351] EX1071 (Midwest Energy Emissions Corp., et al. V. Arthur J. Gallagher & Co., et al., No. 1:19-cv-01334-CJB, Dkt. No. 440 (D. Del. June 24, 2022)).

[352] EX1071 (Midwest Energy Emissions Corp., et al. V. Arthur J. Gallagher & Co., et al., No. 1:19-cv-01334-CJB, Dkt. No. 440 (D. Del. June 24, 2022)).

[353] EX1072 (Midwest Energy Emissions Corp., et al. V. Arthur J. Gallagher & Co., et al., No. 1:19-cv-01334-CJB, Dkt. No. 447 (D. Del. July 12, 2022)).

disputed phrase counseled against the narrower construction proposed by defendants, which required that: "(a) the injecting term's reference to 'gas stream' after 'the bromine containing promoter' be moved, inter alia, to before 'the bromine containing promoter'; and (b) the bromine promoter and sorbent material must both be injected downstream of a furnace exit."[354]

207. In conducting my analysis below, I applied the guidance given by Magistrate Judge Burke and did not otherwise apply any special meaning to any of the claim terms. Each of the claim terms in the Challenged Patent have well-understood plain meanings to a POSITA.

XII. OVERVIEW OF THE PRIOR ART

A. THE VOSTEEN589 PATENT PUBLICATION [EX1005]

208. EX1005 ("Vosteen589") is U.S. Patent Publication No. 2004/0013589, which names Bernhard Vosteen as the lead inventor. Vosteen589 is entitled, "Process for Removing Mercury from Flue Gases."

1. Prior-Art Status of Vosteen589

209. Vosteen589 was published by the USPTO on January 22, 2004 and was originally filed at the USPTO on July 24, 2002 at U.S. Patent App. No. 10/202,571.

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[354] EX1072 (Midwest Energy Emissions Corp., et al. V. Arthur J. Gallagher & Co., et al., No. 1:19-cv-01334-CJB, Dkt. No. 447 (D. Del. July 12, 2022)).

Accordingly, I understand that Vosteen589 qualifies as prior art at least as of July 24, 2002. July 24, 2002 is before the earliest priority date of the Challenged Patent.

2. Vosteen589 Is Analogous Art

210. Vosteen589 is analogous art to the Challenged Patent, as it is in both the same field of endeavor and reasonably pertinent to the problems faced by the inventors of the Challenged Patent. For example, the field of endeavor of the Challenged Patent is "removal of pollutants from flue gas or product gas from a gasification system," and more specifically removal of "mercury . . . from gas streams generated during the burning or gasification of fossil fuels."[355] The specific problem faced by the inventors of the Challenged Patent was "a need for more economical and effective mercury removal technology."[356] So too, the field of endeavor of Vosteen589 is "removing mercury from flue gases of high-temperature plants, in particular power stations . . .," and the problem faced was that "[p]revious techniques for reduction are not sufficiently effective and . . . are relatively expensive."[357]

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[355] EX1001 ('114 Patent) at 1:28-31.

[356] EX1001 ('114 Patent) at 3:22-23.

[357] EX1005 (Vosteen589) ¶¶[0001], [0004].

3. Overview of the Disclosure of Vosteen589

211. Vosteen589 describes processes for the "removal of mercury from the flue gases in a flue gas emission control system downstream of the combustion," in plants such as "power stations, for example bituminous coal-fired or lignite-fired power stations."[358] Vosteen589 describes removing mercury by applying "bromine and/or a bromine compound and/or a mixture of various bromine compounds" directly onto coal upstream of the combustion chamber, into the "multistage furnace and/or to the flue gas."[359] Vosteen589 explains that the invention also works with iodine compounds, though they are more costly than the bromine compounds: "Iodine compounds oxidize mercury more effectively compared with bromine compounds. However, from economic aspects, bromine compounds are preferably used in the inventive process."[360]

212. In addition to adding halogens directly to the coal and furnace, Vosteen589 included activated carbon (a type of "dry sorbent") as part of the mercury removal process, and found: "Mercury bromide $HgBr_2$ adsorbs more

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[358] EX1005 (Vosteen589) ¶¶[0007]-[0008].

[359] EX1005 (Vosteen589) ¶¶[0006], [0013].

[360] EX1005 (Vosteen589) ¶[0016].

strongly to dry sorbents than mercury chloride $HgCl_2$."[361] The adsorbent is part of the "dry emission control system" of Vosteen589, also referred to as a "dry or semi-dry adsorption-based emission control stage."[362] As a result, Vosteen589 discloses the ability to remove more than 90% of mercury.[363]

B. THE DOWNS-BOILER REFERENCE [EX1006]

213. EX1006 ("Downs-Boiler") is U.S. Patent Application Publication No. 2008/0107579, which names William Downs and George Albert Farthing as co-inventors and was assigned to The Babcock & Wilcox Company. Downs-Boiler is entitled "Bromine Addition for the Improved Removal of Mercury from Flue Gas." Downs-Boiler was not applied in any rejections to the claims during prosecution of the '114 Patent.

1. Prior-Art Status of the Downs-Boiler Reference

214. I have been informed that Downs-Boiler was published by the USPTO on May 8, 2008 as U.S. Patent Pub. No. 2008/0107579 from U.S. Patent Application No. 10/591,855. I have been further informed that App. No. 10/591,855 traces

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[361] EX1005 (Vosteen589) ¶[0019].

[362] EX1005 (Vosteen589) ¶¶[0019]-[0020].

[363] EX1005 (Vosteen589) at Figure 5.

ultimate priority to a U.S. Provisional Patent Application No. 60/555,353 ("Downs-Boiler-Provisional"),[364] which was filed on March 22, 2004.

215. I understand that a U.S. patent qualifies as prior art to the Challenged Patent based on the date of filing a related provisional application before the invention of the Challenged Patent, so long as: at least one of the claims in the issued prior-art patent is supported by the written description of the provisional application; and the provisional application must also describe the subject matter relied upon in the issued U.S. patent.

216. I understand that Downs-Boiler qualifies as prior art at least as of its filing date of March 21, 2005. I further understand that, if the claims and disclosure of Downs-Boiler have written-description support from Downs-Boiler-Provisional, that Downs-Boiler qualifies as prior art as of the March 22, 2004 filing date of Downs-Boiler-Provisional. Accordingly, I have been asked to evaluate Downs-Boiler to determine whether: (a) claim 1 in Downs-Boiler has written-description support in Downs-Boiler-Provisional; and (b) the disclosures that I rely on, when comparing Downs-Boiler to the Challenged Claims, have written-description support in Downs-Boiler-Provisional. For the first inquiry, I have prepared a claim chart in the subsections below that compares claim 1 of Downs-Boiler to the

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[364] EX1007 (Downs-Boiler-Provisional).

disclosures in Downs-Boiler-Provisional. For the second inquiry, I have included parallel cites to both Downs-Boiler and to Downs-Boiler-Provisional for materials I rely on.

2. Downs-Boiler Is Analogous Art

217. Downs-Boiler is analogous art to the Challenged Patent, as it is in both the same field of endeavor and reasonably pertinent to the problems faced by the inventors of the Challenged Patent. For example, the field of endeavor of the Challenged Patent is "removal of pollutants from flue gas or product gas from a gasification system," and more specifically removal of "mercury . . . from gas streams generated during the burning or gasification of fossil fuels."[365] The specific problem faced by the inventors of the Challenged Patent was "a need for more economical and effective mercury removal technology."[366] So too, the field of endeavor of Down-Boiler, as reflected in its title, is "removal of mercury from flue gas," and the problem faced was a need for "cost-effective mercury control techniques."[367]

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[365] EX1001 ('114 Patent) at 1:28-31.

[366] EX1001 ('114 Patent) at 3:22-23.

[367] EX1006 (Downs-Boiler) ¶[0003], Title.

3. Overview of the Disclosure of Downs-Boiler

218. Downs-Boiler describes processes for improving the removal of mercury released from the combustion of coals. Downs-Boiler discloses that the "mercury removal" may be performed with "carbonaceous sorbents [that] include, but are not limited to, powdered activated carbon (PAC)."[368] Downs-Boiler enhances the effectiveness of mercury removal, including through PAC, by using a bromine-containing promoter added to the coal and/or to a combustion chamber.[369] Downs-Boiler describes various example points of application A, B, and C for introducing bromine to the combustion chamber as illustrated in Figure 2, reproduced below as annotated:[370]

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[368] EX1006 (Downs-Boiler) ¶[0025].

[369] EX1006 (Downs-Boiler) at Abstract.

[370] EX1006 (Downs-Boiler) at Figure 2; see also EX1007 (Downs-Boiler-Provisional) at Figure 2.

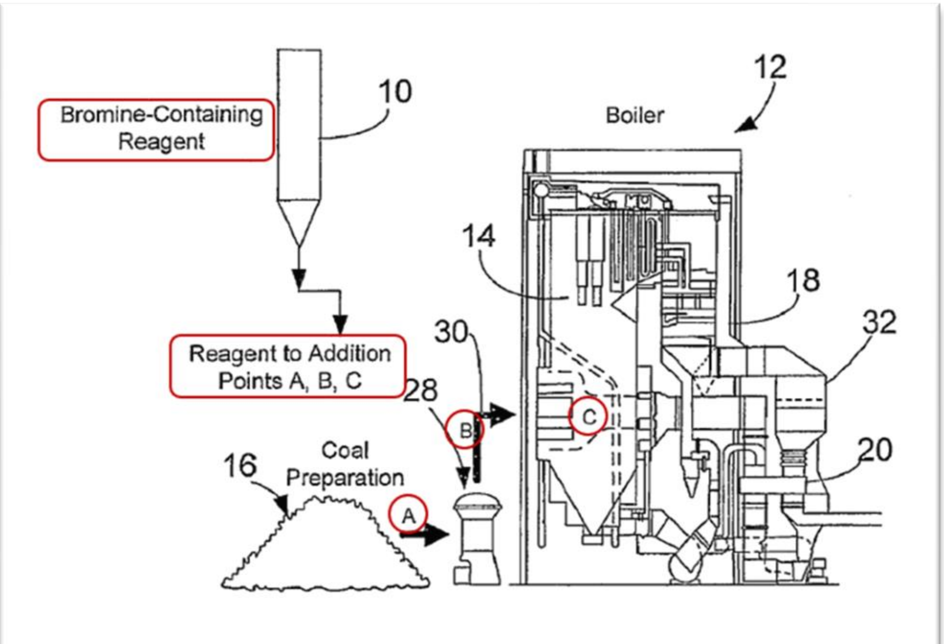

FIG. 2

219. Downs-Boiler further explains:

> A bromine-containing reagent 10 is added to the boiler 12 combustion furnace 14, either directly or by premixing with the incoming coal 16. Bromine species released during the combustion process enhance the oxidation of mercury as the combustion gases pass through the furnace 14 and, in particular, through the cooler sections of the boiler convection pass 18 and combustion air preheater 20. The increased fraction of mercury appearing in the oxidized form enhances mercury removal in downstream pollution control systems such as wet 22 and SDA 24 FGD systems, and PAC injection systems.[371]

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[371] EX1006 (Downs-Boiler) ¶[0015]; EX1007 (Downs-Boiler-Provisional) ¶[0018].

Downs-Boiler describes that the bromine-containing reagent can be fed in either "gaseous, liquid, or solid form."[372] The reagent could be made from "alkali metal and alkaline earth metal bromides, hydrogen bromide (HBr) or bromine (Br_2)."[373] Examples of alkali earth metal bromides include calcium bromide ($CaBr_2$).[374]

4. **<u>Comparison of Downs-Boiler [EX1006] to Downs-Boiler-Provisional [EX1007]</u>**

220. Exhibit 1032 ("Downs-Boiler-Redline") is a redline comparison between U.S. Patent Pub. No. 2008/0107579 (Downs-Boiler) and U.S. Provisional Application No. 60/555,353 (Downs-Boiler-Provisional), using Downs-Boiler-Provisional as the original version.[375] As illustrated by the minor substantive changes shown in Downs-Boiler-Redline, all of the subject matter relied upon in Downs-Boiler is supported in Downs-Boiler-Provisional. Accordingly, I cite Downs-Boiler for purposes of the anticipation and obviousness analysis below. I include parallel citations to Downs-Boiler-Provisional in order to demonstrate that the portions of Downs-Boiler that I rely on are also disclosed in Downs-Boiler-

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[372] EX1006 (Downs-Boiler) ¶[0022].

[373] EX1006 (Downs-Boiler) ¶[0021].

[374] EX1006 (Downs-Boiler) ¶¶[0018], [0021].

[375] EX1032 (Downs-Boiler-Redline).

Provisional. All of the subject matter I rely on in Downs-Boiler is supported in Downs-Boiler-Provisional.

221. I have also compared Claim 1 of Downs-Boiler with the disclosure in Downs-Boiler-Provisional and determined that Downs-Boiler-Provisional provides written-description support for at least Claim 1 of Downs-Boiler. My analysis is summarized in the paragraphs below.

a. Element 1(a): "A method of removing a portion of the elemental mercury in a flue gas created during the combustion of a fossil fuel, comprising:"

222. Downs-Boiler-Provisional discloses this preamble. The title of the disclosure is "Bromine Addition for the <u>Improved Removal of Mercury from Flue Gas.</u>"[376] Downs-Boiler-Provisional further discloses that the "invention promises to significantly reduce the cost of mercury removal at coal-fired electric plants."[377] Downs-Boiler-Provisional discloses that it removes both oxidized mercury and elemental mercury from mercury-containing flue gases.[378] For example, Downs-

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[376] EX1007 (Downs-Boiler-Provisional) at Title;
see also EX1007 (Downs-Boiler-Provisional) at Claim 1 ("1. A method of reducing the mercury concentration of a flue gas comprising; adding a bromine containing agent to the combustion chamber.");
EX1006 (Downs-Boiler) at Title.

[377] EX1007 (Downs-Boiler-Provisional) ¶[0019]; see also EX1006 (Downs-Boiler) ¶[0016].

[378] EX1007 (Downs-Boiler-Provisional) ¶¶[0002]–[0006], [0019], [0027].

Boiler-Provisional discusses that "the current invention can offer a cost-effective method of removing elemental mercury from coal combustion flue gases."[379]

b. Element 1(b): "providing a bromine containing reagent to said flue gas;"

223. Downs-Boiler-Provisional discloses this element. Again, the title of the disclosure is "<u>Bromine Addition for</u> the Improved Removal of Mercury<u> from Flue Gas.</u>"[380] Downs-Boiler-Provisional further describes the ability "to promote the oxidation of elemental mercury if the correct species (in this case bromine species) are present in the flue gases."[381]

224. With reference to annotated Figure 2 of Downs-Boiler, annotated below, Downs-Boiler-Provisional first describes adding a "bromine-containing reagent" "to the boiler combustion furnace."[382]

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[379] EX1007 (Downs-Boiler-Provisional) ¶¶[0021].

[380] EX1007 (Downs-Boiler-Provisional) at Title; see also EX1007 (Downs-Boiler-Provisional) at Claim 1 ("1. A method of reducing the mercury concentration of a flue gas comprising; adding a bromine containing agent to the combustion chamber."); EX1006 (Downs-Boiler) at Title.

[381] EX1007 (Downs-Boiler-Provisional) ¶[0027]; EX1006 (Downs-Boiler) ¶[0024].

[382] EX1007 (Downs-Boiler-Provisional) ¶[0018]; see also EX1006 (Downs-Boiler) ¶[0015].

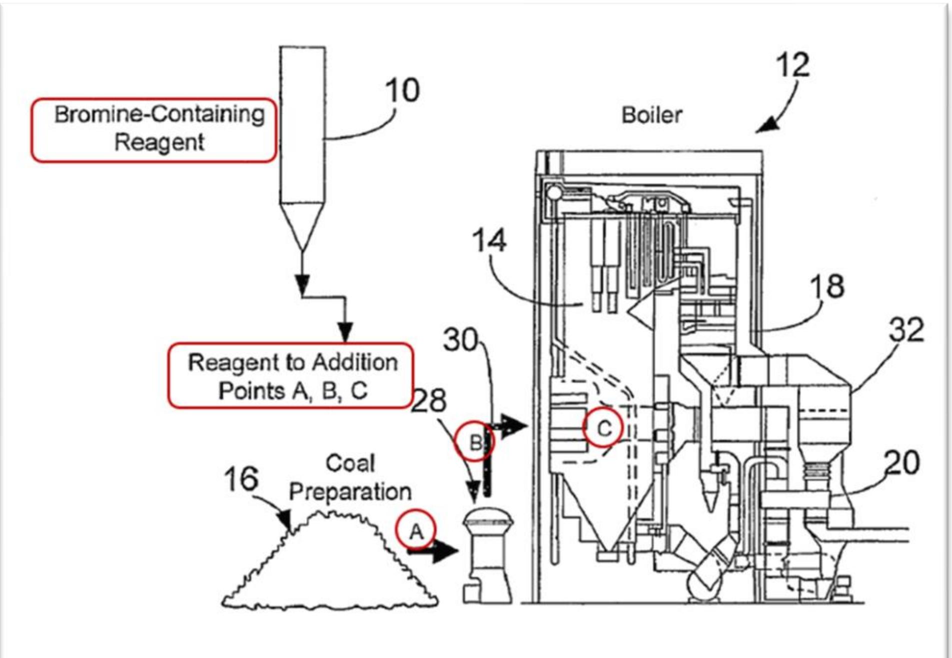

FIG. 2

225. Downs-Boiler-Provisional goes on to explain that a purpose of adding this bromine-containing reagent is ultimately to provide the bromine-containing reagent to the flue gas. "Bromine species released during the combustion process enhance the oxidation of mercury as the combustion gases pass through the furnace," travel downstream (i.e., to the flue gas region of the power plant), and the bromine then "enhances mercury removal in downstream pollution control systems such as wet and SDA FGD systems, and PAC injection systems."[383]

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[383] EX1007 (Downs-Boiler-Provisional) ¶[0018]; see also EX1006 (Downs-Boiler) ¶[0015].

c. Element 1(c): "promoting the oxidation of elemental mercury with the bromine containing reagent;"

226. Downs-Boiler-Provisional discloses this limitation. In describing the two primary benefits realized by employing the bromine-containing reagent, Downs-Boiler-Provisional discloses:

> The removal of <u>elemental mercury</u> from coal combustion gases generated by electric utility plants through the application of a conventional PAC injection process is very expensive. The current invention promises to significantly reduce the cost of mercury removal at coal-fired electric plants in two ways. First, <u>increasing the fraction of mercury appearing in the oxidized and</u> particulate-bound <u>forms enhances the removal of mercury in</u> conventional pollution control systems such as particulate collectors and wet and SDA FGD systems. This reduces, or may eliminate entirely, the need for PAC injection <u>to remove elemental mercury.</u> Second, the <u>increased fraction of oxidized mercury</u> also enhances the removal of mercury across a PAC injection process, due to the higher reactivity of oxidized mercury with PAC.[384]

227. Downs-Boiler-Provisional makes clear that the effect of the bromine-containing reagent is a promotion of the oxidation of elemental mercury, describing that power plants with a selective catalytic reduction (SCR) system "have been

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[384] EX1007 (Downs-Boiler-Provisional) ¶[0019]; see also EX1006 (Downs-Boiler) ¶[0016].

shown to <u>promote the oxidation of elemental mercury</u> if the correct species (in this case bromine species) are present in the flue gases."[385]

d. Element 1(d): "creating an oxidized form of mercury from the elemental mercury; and"

228. Downs-Boiler-Provisional discloses this claim element. Downs-Boiler-Provisional explains that vapor-phase mercury from the combustion of coal come in two forms, "as elemental mercury (elemental, metallic mercury vapor) or as oxidized mercury (vapor-phase species of various compounds of mercury). Speciation, the form of mercury present, is a key factor in the development of mercury emissions control strategies."[386]

229. As described above with respect to Claim Element 1(c) of Downs-Boiler, Downs-Boiler-Provisional teaches converting the elemental mercury to its oxidized form, thereby increasing the fraction of oxidized mercury in the flue gas (as compared to elemental mercury).[387] Thus, Downs-Broiler-Provision teaches to create oxidized forms of mercury from the elemental mercury by oxidizing the

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[385] EX1007 (Downs-Boiler-Provisional) ¶[0027]; see also EX1006 (Downs-Boiler) ¶[0024].

[386] EX1007 (Downs-Boiler-Provisional) ¶[003]; see also EX1006 (Downs-Boiler) ¶[0002].

[387] EX1007 (Downs-Boiler-Provisional) ¶[003]; see also EX1006 (Downs-Boiler) ¶[0002].

available elemental mercury.[388] As explained by Downs-Boiler-Provisional, this is achieved by adding the bromine-containing reagent to the boiler such that "[b]romine species released during the combustion process enhance the oxidation of mercury as the combustion gases pass through the furnace" which is inexorably from the "removal of [the] elemental mercury from [the] coal combustion gases."[389]

e. Element 1(e): "removing the oxidized mercury from the flue gas."

230. Downs-Boiler-Provisional provisional discloses this claim element. Once more, the title of the disclosure is "Bromine Addition for the Improved Removal of Mercury from Flue Gas."[390]

231. Downs-Boiler-Provisional explicitly acknowledges that it is known in the art that mercury—especially mercury appearing in its oxidized form—is readily removed from the flue gas by conventional pollution control systems, such as "PAC injection [which] removes both oxidized and elemental mercury species, although

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[388] EX1007 (Downs-Boiler-Provisional) ¶¶[0018-19]; see also EX1006 (Downs-Boiler) ¶[0015-16].

[389] EX1007 (Downs-Boiler-Provisional) ¶¶[0018-19]; see also EX1006 (Downs-Boiler) ¶[0015-16].

[390] EX1007 (Downs-Boiler-Provisional) at Title; see also EX1007 (Downs-Boiler-Provisional) at Claim 1 ("1. A method of reducing the mercury concentration of a flue gas comprising; adding a bromine containing agent to the combustion chamber."); EX1006 (Downs-Boiler) at Title.

removal efficiencies are higher for the oxidized form."[391] Downs-Boiler-Provisional further states that "the <u>increased fraction of oxidized mercury also enhances the removal of mercury across a PAC injection process, due to the higher reactivity of oxidized mercury with PAC.</u>"[392] The mercury-sorbent composition can be removed with "electrostatic precipitators (ESP) or fabric filters (FF), sometimes called baghouses," as well as in "wet and spray dryer absorber (SDA) flue gas desulfurization (FGD) systems."[393]

C. AWMA CONFERENCE (2002) – STARNS [EX1008]

232. The Air & Waste Management Association ("AWMA") Conference has been held annually since 1907.[394] The primary purpose of AWMA is to provide training, information, and networking opportunities to thousands of environmental

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[391] EX1007 (Downs-Boiler-Provisional) ¶[005]; see also EX1006 (Downs-Boiler) ¶[0004].

[392] EX1007 (Downs-Boiler-Provisional) ¶[0019]; see also EX1006 (Downs-Boiler) ¶[0016].

[393] EX1007 (Downs-Boiler-Provisional) ¶[0004]; see also EX1006 (Downs-Boiler) ¶[0003].

[394] EX1078 (AWMA Overview), available at https://web.archive.org/web/20020613041559/http://www.awma.org/about/overview.htm; EX1079 (AWMA Homepage), available at https://web.archive.org/web/20020527005933/http://www.awma.org/.

professionals in 65 countries across the world.[395] I personally attended the AWMA Conferences in 1997, 1998, 1999, 2000, 2001, 2002, 2003, and 2005. During these years, AWMA focused on strengthening the environmental profession, expanding scientific and technological responses to environmental concerns, and assisting professionals in critical environmental decision making to benefit society.[396] I delivered presentations at the 94th conference in 2001 entitled, "Interpreting Laboratory Test Data on Homogeneous Mercury Oxidation in Coal-Derived Exhausts," and at the 96th conference in 2003 entitled, "Predicting Mercury Speciation in Coal-Derived Flue Gases." Both presentations described our progress in interpreting measured Hg speciation from lab- and full-scale testing with my company's reaction mechanism for Hg chemistry in coal-derived flue gas. My first-hand impressions are confined to the presentations and exhibits I attended in 1997, 1998, 1999, 2000, 2001, 2002, 2003, and 2005.

233. As an attendee of the 2002 AWMA Conference, I received a CD that included, among other items, a PDF copy of an article from the conference titled

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[395] EX1080 (AWMA About Page), available at https://web.archive.org/web/20020604012426/http://www.awma.org:80/about/.

[396] EX1078 (AWMA Overview), available at https://web.archive.org/web/20020613041559/http://www.awma.org/about/overview.htm.

"Full-Scale Test of Mercury Control with Sorbent Injection and an ESP at Wisconsin Electric's Pleasant Prairie Power Plant," whose lead author was Travis Starns. The PDF copy was saved on the CD with filename 43249.pdf. Exhibit 1008 is a true and correct copy of that file. Starns was presented during the AE-1c Panel "Results from Full-Scale Mercury Control Testing: Overview and Panel Discussion" at 1:30pm on June 24, 2002.[397] Exhibit 1077 is a true and correct copy of the label and jacket of the CD that was mailed to me from the 2002 AWMA Conference. ("AWMA CD Scan").[398]

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[397] EX1081 (AWMA Technical Program Schedule for Monday 24, 2002), available at https://web.archive.org/web/20020601173851/http://www.awma.org/ACE2002/tech-program/MondayPM.asp#AE-1c.

[398] EX1077 (AWMA CD Photo).

234. In the years I attended, including 2002, other AWMA attendees included business, sales, and project managers from the vendors, and engineers, compliance specialists, technical staff, and environmental control managers from the utilities. There was also a sizeable representation of consultants and academic, government, and commercial researchers plying their services regarding

environmental control and cleanup to both vendors and utility representatives, as well as project managers for government R&D programs.[399]

235. The population of speakers at the 2002 AWMA Conference was largely drawn from the technical experts who actually performed field tests, and some vendors also gave presentations that described their technology. Representatives from the U.S. funding agencies (such as DOE and EPA) occasionally delivered overview presentations on the general status of a single control technology, or performance comparisons among two or more control technologies.[400]

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[399] EX1082 (AWMA 2002 Conference list of exhibitors), available at https://web.archive.org/web/20020616091740/http://www.awma.org/ACE2002/exhibition/list.asp;

EX1081 (AWMA Technical Program Schedule for Monday 24, 2002), available at https://web.archive.org/web/20020601173851/http://www.awma.org/ACE2002/tech-program/MondayPM.asp#AE-1c;

EX1083 (AWMA 2002 Conference Top Ten Reasons), available at https://web.archive.org/web/20020601121532/http://www.awma.org/ACE2002/top10list.asp.

[400] EX1081 (AWMA Technical Program Schedule for Monday 24, 2002), available at https://web.archive.org/web/20020601173851/http://www.awma.org/ACE2002/tech-program/MondayPM.asp#AE-1c.

1. Prior Art Status of Starns

236. The 2002 AWMA Conference took place on June 23-27, 2002 at the Baltimore Convention Center, in Baltimore, Maryland:[401]

Welcome to the Proceedings of the Air & Waste Management's Association's 95th Annual Conference & Exhibition

Includes the complete 2002 Critical Review "Visibility: Science and Regulation," By Dr. John Watson

Baltimore Convention Center Baltimore, Maryland June 23-27, 2002

Each presenter prepared a presentation and/or accompanying article for the conference. The conference compiled the presentations and any accompanying articles, and within a few weeks of the completion of the conference, mailed a CD to all attendees that included the conference materials. The CD contained every paper presented at the 2002 AWMA Conference in PDF format. The CD was

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[401] EX1073 (AWMA CD Scan), Welcome Page;

EX1084 (AWMA 95th Annual Conference and Exhibition), available at https://web.archive.org/web/20020610093515/http://www.awma.org/ACE2002/welcome.asp.

indexed and fully navigable, including being organized by Session Listing, Paper by Session, and Author Index. This organization structure can be seen from the screenshot of the main menu of the conference CD, shown below:[402]

I received the CD from the 2002 AWMA Conference in summer 2002 ("AWMA CD Scan"), and photographs of the physical CD from which the Starns reference (EX1008) was copied, are shown below:[403]

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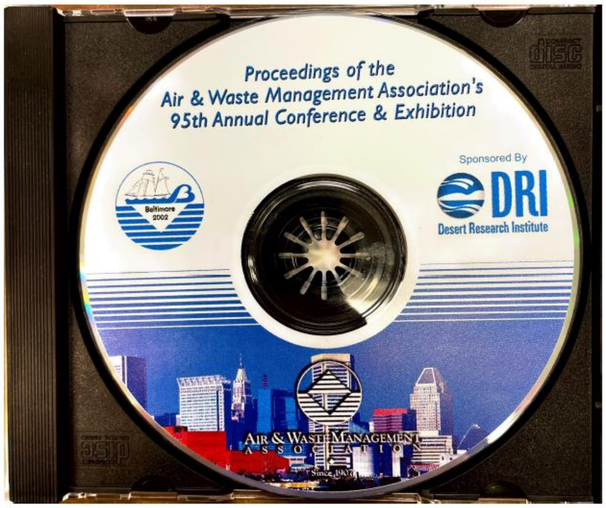
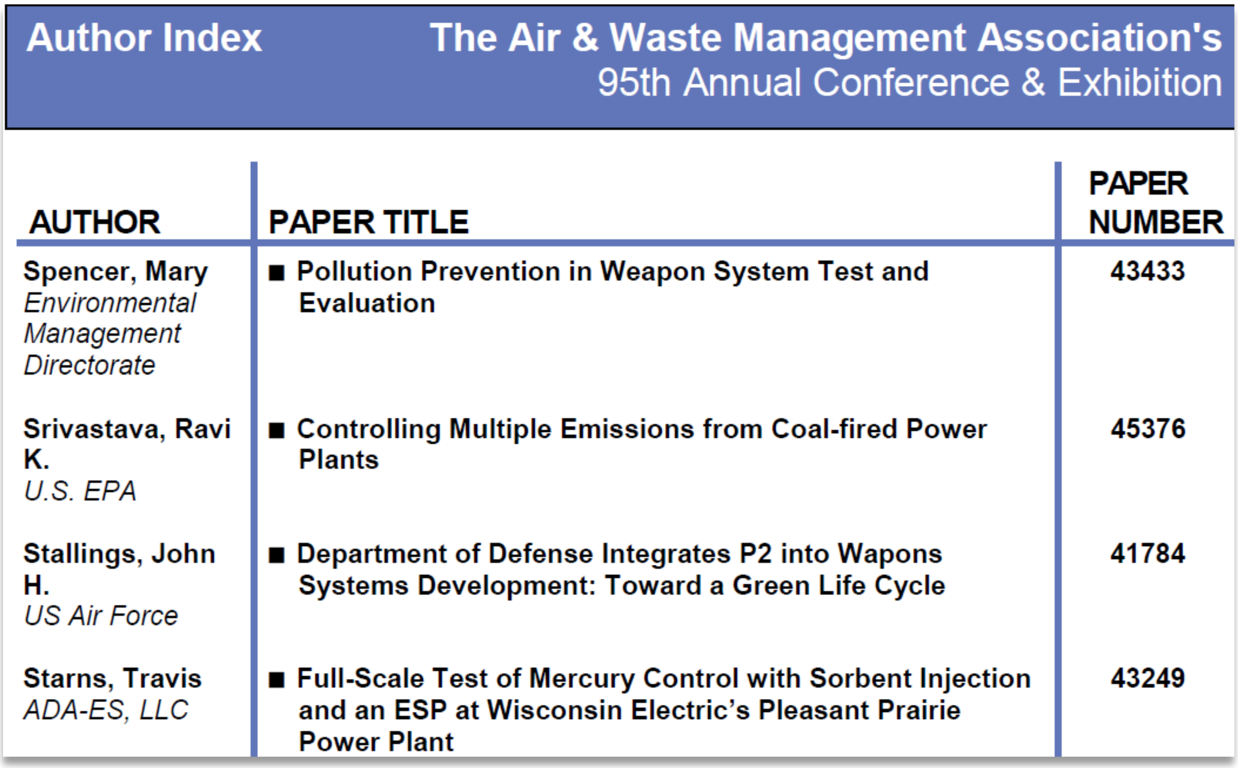
[402] EX1073-EX1074 (AWMA Welcome Page and Main Menu).

[403] EX1077 (photo of jacket and CD).



The author listing for the Starns paper is shown below, which is on a file from the physical CD:[404]



Author Index **The Air & Waste Management Association's**
95th Annual Conference & Exhibition

AUTHOR	PAPER TITLE	PAPER NUMBER
Spencer, Mary *Environmental Management Directorate*	■ **Pollution Prevention in Weapon System Test and Evaluation**	**43433**
Srivastava, Ravi K. *U.S. EPA*	■ **Controlling Multiple Emissions from Coal-fired Power Plants**	**45376**
Stallings, John H. *US Air Force*	■ **Department of Defense Integrates P2 into Wapons Systems Development: Toward a Green Life Cycle**	**41784**
Starns, Travis *ADA-ES, LLC*	■ **Full-Scale Test of Mercury Control with Sorbent Injection and an ESP at Wisconsin Electric's Pleasant Prairie Power Plant**	**43249**

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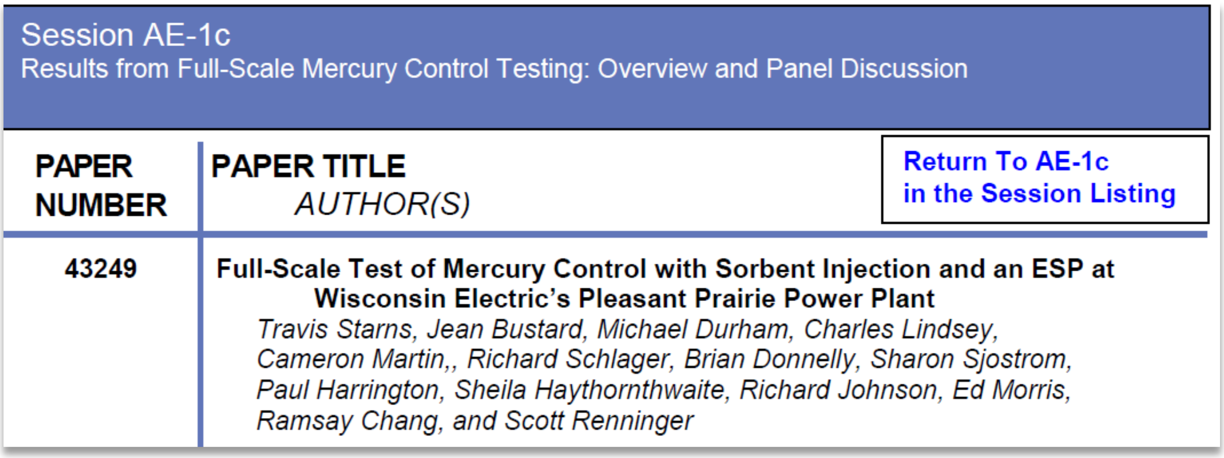
[404] EX1075 (AWMA CD Scan, Author Index) at 171.

The session listing, showing the Starns paper, is below[405]:



Session AE-1c
Results from Full-Scale Mercury Control Testing: Overview and Panel Discussion

Return To AE-1c in the Session Listing

PAPER NUMBER	PAPER TITLE *AUTHOR(S)*
43249	**Full-Scale Test of Mercury Control with Sorbent Injection and an ESP at Wisconsin Electric's Pleasant Prairie Power Plant** *Travis Starns, Jean Bustard, Michael Durham, Charles Lindsey, Cameron Martin,, Richard Schlager, Brian Donnelly, Sharon Sjostrom, Paul Harrington, Sheila Haythornthwaite, Richard Johnson, Ed Morris, Ramsay Chang, and Scott Renninger*

237. Additionally, the AWMA website had a store that allowed for the purchase of the conference CDs by AWMA members and the general public, including the CD containing the presentations from the 2002 AWMA Conference:[406]

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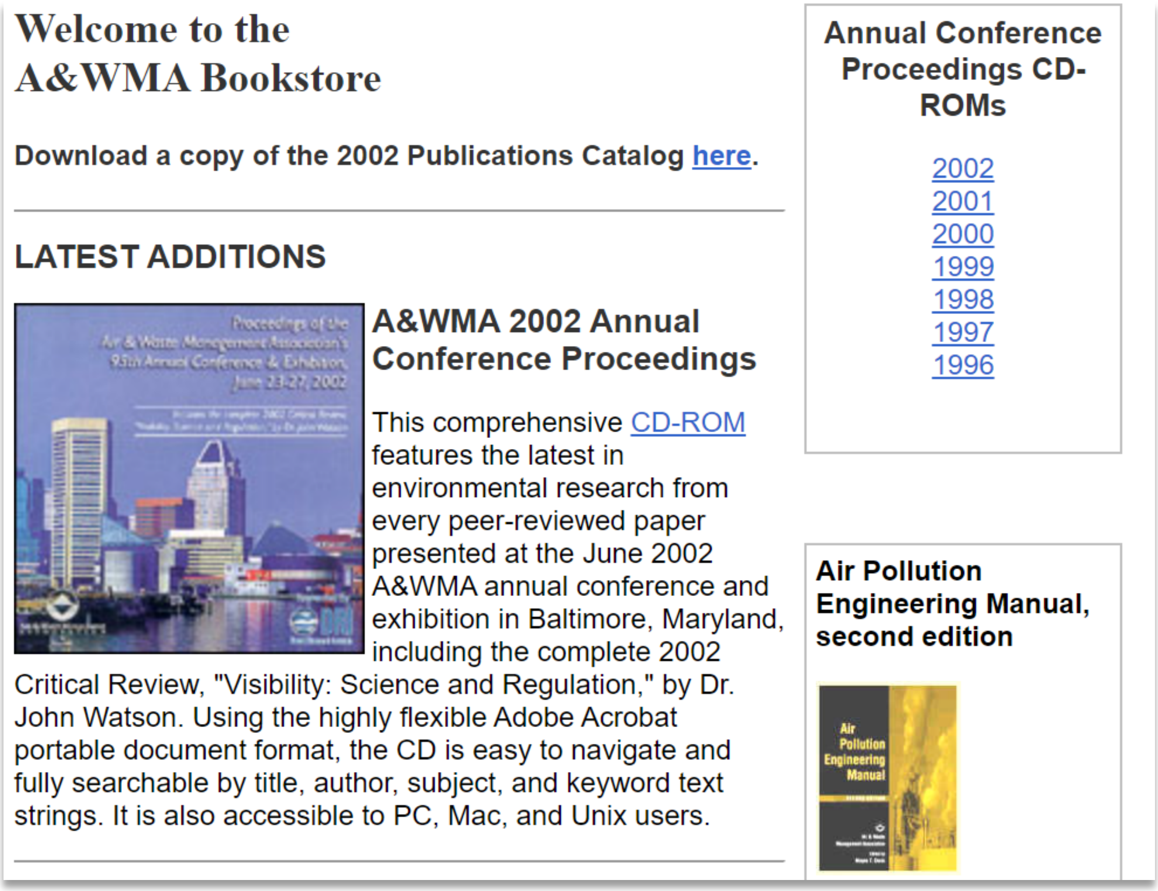
[405] EX1076 (AWMA CD Scan, Papers by Session) at 19.

[406] EX1086 (AWMA Bookstore Homepage), available at https://web.archive.org/web/20020806041256/http://www.awma.org:80/pubs/bookstore/.



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Annual Conference Proceedings CD-ROMs

2002
2001
2000
1999
1998
1997
1996

Air Pollution Engineering Manual, second edition

238. The CD from the 2002 AWMA Conference, which includes the Starns article (EX1008), was publicly available for purchase on the AWMA website at least as early as August 6, 2002 (the date set forth in the Internet Archive link ("20020806")):[407]

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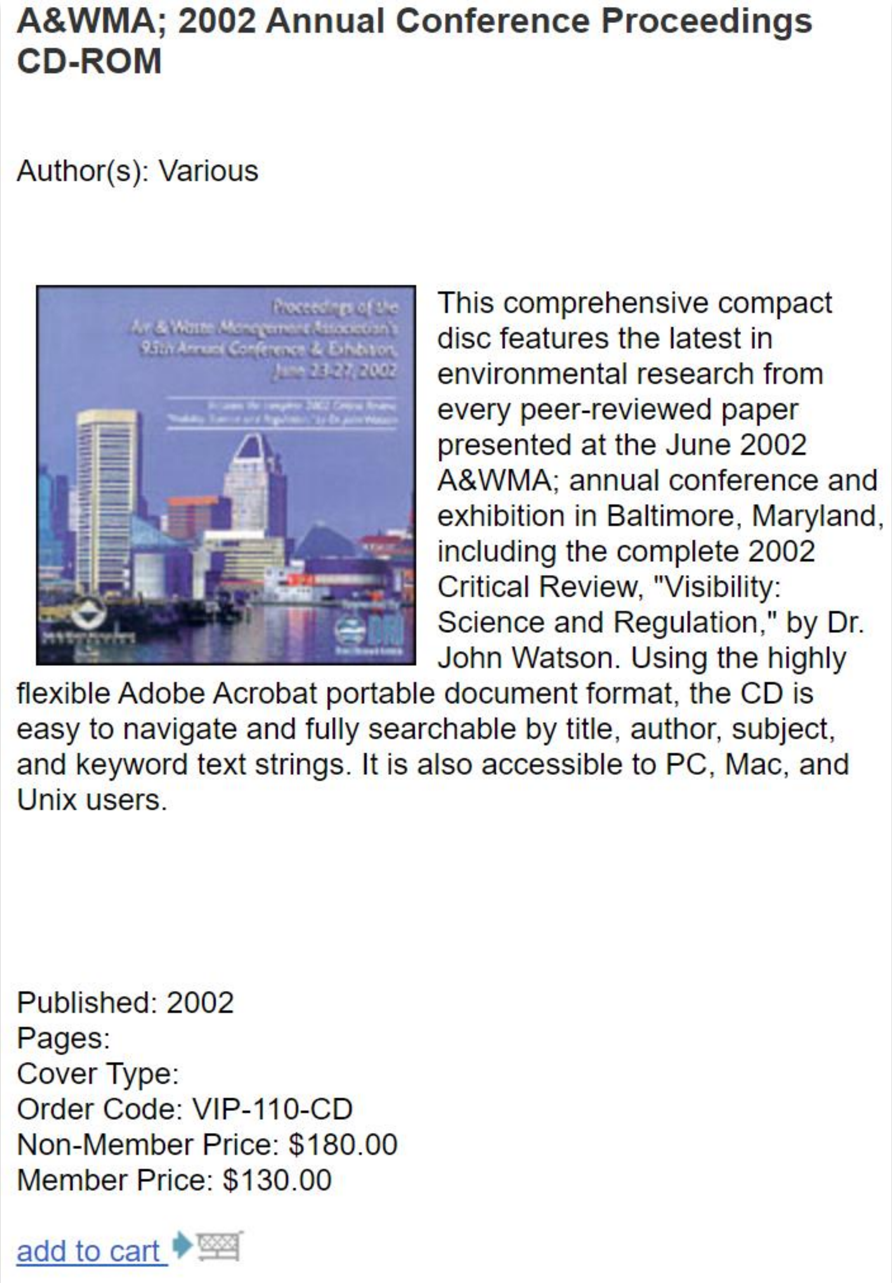
[407] EX1085 (AWMA Bookstore Page for 2002 AWMA Conference CD), available at https://web.archive.org/web/20020806044928/http://www.awma.org/pubs/bookstore/ItemInfo.asp?OrderCode_s=VIP-110-CD;

EX1091 explains how the hyperlinks correlate to a date, available at https://archive.org/legal/affidavit.php.



A&WMA; 2002 Annual Conference Proceedings CD-ROM

Author(s): Various

This comprehensive compact disc features the latest in environmental research from every peer-reviewed paper presented at the June 2002 A&WMA; annual conference and exhibition in Baltimore, Maryland, including the complete 2002 Critical Review, "Visibility: Science and Regulation," by Dr. John Watson. Using the highly flexible Adobe Acrobat portable document format, the CD is easy to navigate and fully searchable by title, author, subject, and keyword text strings. It is also accessible to PC, Mac, and Unix users.

Published: 2002
Pages:
Cover Type:
Order Code: VIP-110-CD
Non-Member Price: $180.00
Member Price: $130.00

add to cart

239. In addition to myself, hundreds of people attended the 2002 AWMA Conference, including engineers, regulatory compliance specialists, and project managers from utilities; engineers and technicians from labs and testing organizations; technical staff from R&D organizations; and sales managers and

representatives from technology vendors.[408] As with other AWMA conferences, many people who would qualify as a person of skill in the art attended the 2002 AWMA Conference, including from such notable organizations as U.S. Environmental Protection Agency, U.S. Department of Energy, ADA-ES, EPRI, URS Corporation, Southern Company, ALSTOM Power, and many others.[409]

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[408] EX1082 (AWMA 2002 Conference list of exhibitors), available at https://web.archive.org/web/20020616091740/http://www.awma.org/ACE2002/exhibition/list.asp;

EX1081 (AWMA Technical Program Schedule for Monday 24, 2002), available at https://web.archive.org/web/20020601173851/http://www.awma.org/ACE2002/tech-program/MondayPM.asp#AE-1c;

EX1083 (AWMA 2002 Conference Top Ten Reasons), available at https://web.archive.org/web/20020601121532/http://www.awma.org/ACE2002/top10list.asp.

[409] EX1082 (AWMA 2002 Conference list of exhibitors), available at https://web.archive.org/web/20020616091740/http://www.awma.org/ACE2002/exhibition/list.asp;

EX1081 (AWMA Technical Program Schedule for Monday 24, 2002), available at https://web.archive.org/web/20020601173851/http://www.awma.org/ACE2002/tech-program/MondayPM.asp#AE-1c;

EX1083 (AWMA 2002 Conference Top Ten Reasons), available at https://web.archive.org/web/20020601121532/http://www.awma.org/ACE2002/top10list.asp.

2. Starns Is Analogous Art and Overview of the Disclosure

240. Starns is analogous art to the Challenged Patent, as it is in both the same field of endeavor and reasonably pertinent to the problems faced by the inventors of the Challenged Patent. For example, the field of endeavor of the Challenged Patent is "removal of pollutants from flue gas or product gas from a gasification system," and more specifically removal of "mercury . . . from gas streams generated during the burning or gasification of fossil fuels."[410] The specific problem faced by the inventors of the Challenged Patent was "a need for more economical and effective mercury removal technology."[411] So too, the field of endeavor of Starns is "mercury control technology for coal-fired utility plants," and the problem addressed was a need for "mercury control technologies [] to be proven at full scale" "with mercury regulations imminent."[412] Both references address the problem through using activated carbon sorbents.[413] Starns provides details as to how to inject activated carbon at a coal-fired power plant. Starns teaches specific ACI equipment, which

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[410] EX1001 ('114 Patent) at 1:28-31.

[411] EX1001 ('114 Patent) at 3:22-23.

[412] EX1008 (Starns) at 2 (Abstract and Introduction).

[413] EX1008 (Starns) at 2 (Abstract and Introduction).

types of activated carbon to use, and where in the process to inject the activated carbon.

D. MASS-EPA [EX1009]

1. Prior Art Status of Mass-EPA

241. Mass-EPA was published by the Massachusetts Department of Environmental Protection, which is an administrative agency of the Commonwealth of Massachusetts with the established goal of protecting and enhancing the quality of Massachusetts' natural resources to provide for the health, safety, and welfare of its citizens.[414] Within the Massachusetts Department of Environmental Protection is the Bureau of Waste Prevention, which administers air, water, and land protection programs:[415]

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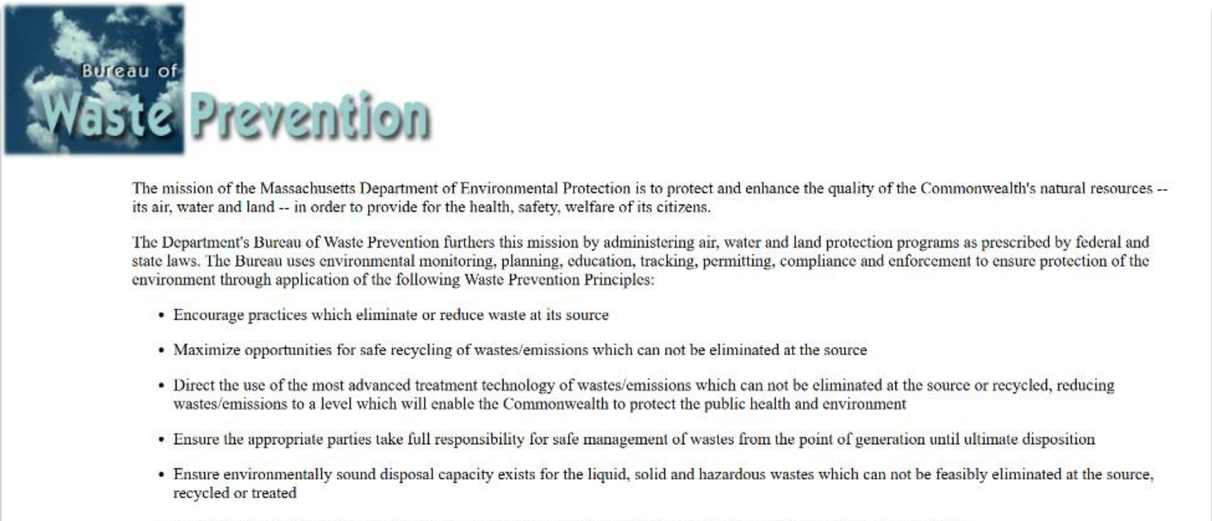
[414] EX1087 (Mass-EPA Internet Archive) (dated Jan. 6, 2003), available at https://web.archive.org/web/20030106044457/http://www.state.ma.us/dep/bwp/about.htm.

[415] EX1087 (Mass-EPA Internet Archive) (dated Jan. 6, 2003), available at https://web.archive.org/web/20030106044457/http://www.state.ma.us/dep/bwp/about.htm.



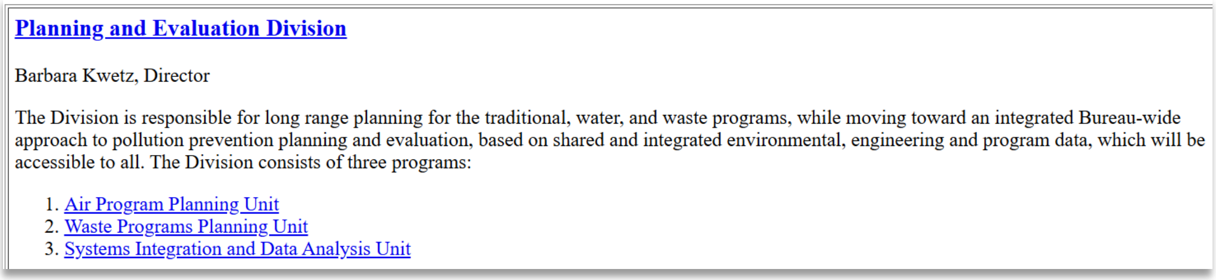
Bureau of Waste Prevention

The mission of the Massachusetts Department of Environmental Protection is to protect and enhance the quality of the Commonwealth's natural resources -- its air, water and land -- in order to provide for the health, safety, welfare of its citizens.

The Department's Bureau of Waste Prevention furthers this mission by administering air, water and land protection programs as prescribed by federal and state laws. The Bureau uses environmental monitoring, planning, education, tracking, permitting, compliance and enforcement to ensure protection of the environment through application of the following Waste Prevention Principles:

- Encourage practices which eliminate or reduce waste at its source
- Maximize opportunities for safe recycling of wastes/emissions which can not be eliminated at the source
- Direct the use of the most advanced treatment technology of wastes/emissions which can not be eliminated at the source or recycled, reducing wastes/emissions to a level which will enable the Commonwealth to protect the public health and environment
- Ensure the appropriate parties take full responsibility for safe management of wastes from the point of generation until ultimate disposition
- Ensure environmentally sound disposal capacity exists for the liquid, solid and hazardous wastes which can not be feasibly eliminated at the source, recycled or treated
- Coordinate programs to achieve a coherent, effective, consistent and beneficial impact on affected facilities and persons

The Bureau of Waste Prevention was comprised of four Divisions: Planning and Evaluation, Business Compliance, Consumer and Transportation, and Program Support.[416] The tasks of the Planning and Evaluation Division were as follows:[417]



Planning and Evaluation Division

Barbara Kwetz, Director

The Division is responsible for long range planning for the traditional, water, and waste programs, while moving toward an integrated Bureau-wide approach to pollution prevention planning and evaluation, based on shared and integrated environmental, engineering and program data, which will be accessible to all. The Division consists of three programs:

1. Air Program Planning Unit
2. Waste Programs Planning Unit
3. Systems Integration and Data Analysis Unit

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[416] EX1088 (Mass-EPA Internet Archive) (dated Dec. 21, 2002), available at https://web.archive.org/web/20021221040816/http://www.state.ma.us/dep/bwp/bwpprogs.htm.

[417] EX1088 (Mass-EPA Internet Archive) (dated Dec. 21, 2002), available at https://web.archive.org/web/20021221040816/http://www.state.ma.us/dep/bwp/bwpprogs.htm.

A POSITA would have looked to the Massachusetts EPA, including the Planning and Evaluation Division, as a repository for pollution mitigation, particularly since the goal of it was to provide "shared and integrated environmental, engineering and program data, which will be accessible to all."[418] Within the Planning and Evaluation Division is the Air Program Planning Unit.[419] Pursuant to the goal of the Planning and Evaluation Division, the Air Program Planning Unit made its data "accessible to all" in that it made publicly available a host of publications, along with an index at the front of the page. The publications of the Air Program Planning Unit were provided on the Massachusetts Department of Environmental Protection website, were organized by subject, and with descriptive titles that are text-searchable:[420]

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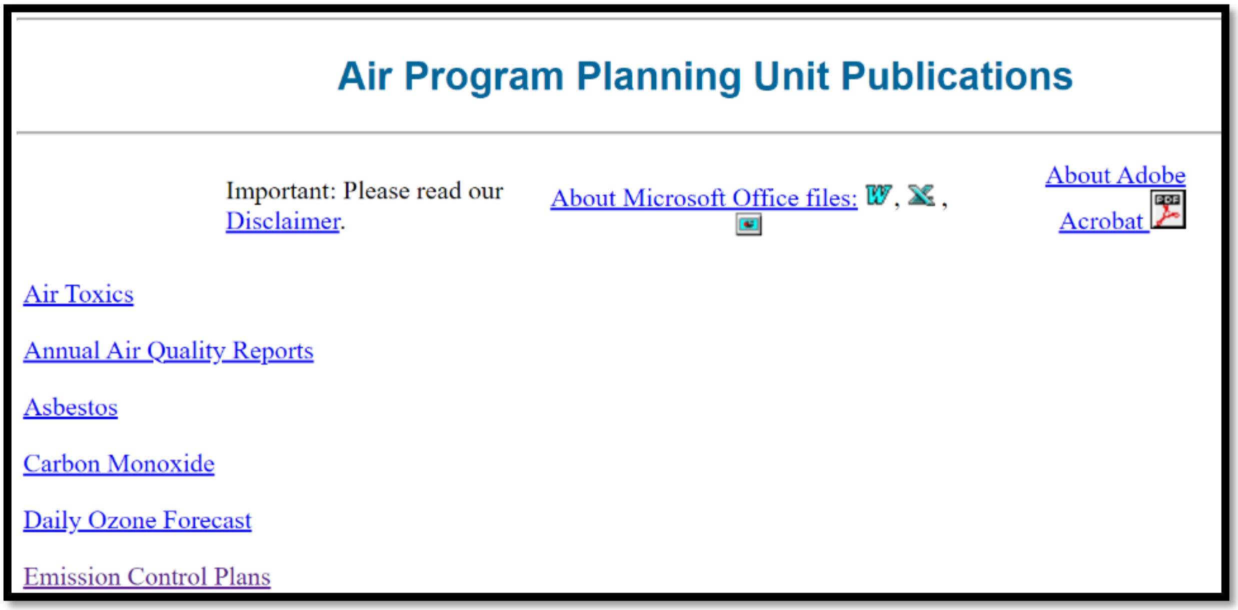
[418] EX1088 (Mass-EPA Internet Archive) (dated Dec. 21, 2002), available at https://web.archive.org/web/20021221040816/http://www.state.ma.us/dep/bwp/bwpprogs.htm.

[419] EX1088 (Mass-EPA Internet Archive) (dated Dec. 21, 2002), available at https://web.archive.org/web/20021221040816/http://www.state.ma.us/dep/bwp/bwpprogs.htm.

EX1089 (Mass-EPA Internet Archive) (dated Jan. 6, 2003), available at https://web.archive.org/web/20030106024342/http://www.state.ma.us/dep/bwp/bwppubs.htm.

[420] EX1090 (Mass-EPA Internet Archive) (dated Dec. 20, 2002), available at https://web.archive.org/web/20021220143210/http://www.state.ma.us/dep/bwp/daqc/daqcpubs.htm#ecp.



Air Program Planning Unit Publications

Important: Please read our Disclaimer.

About Microsoft Office files: W, X,

About Adobe Acrobat

Air Toxics

Annual Air Quality Reports

Asbestos

Carbon Monoxide

Daily Ozone Forecast

Emission Control Plans

As shown above, the Massachusetts EPA also provided a link to "Adobe Acrobat" so that the interested public could readily download and read the publications. In a section devoted to "Other Air Quality Publications," the Massachusetts EPA made the following available for download as a "mercfeas.pdf" file.[421]

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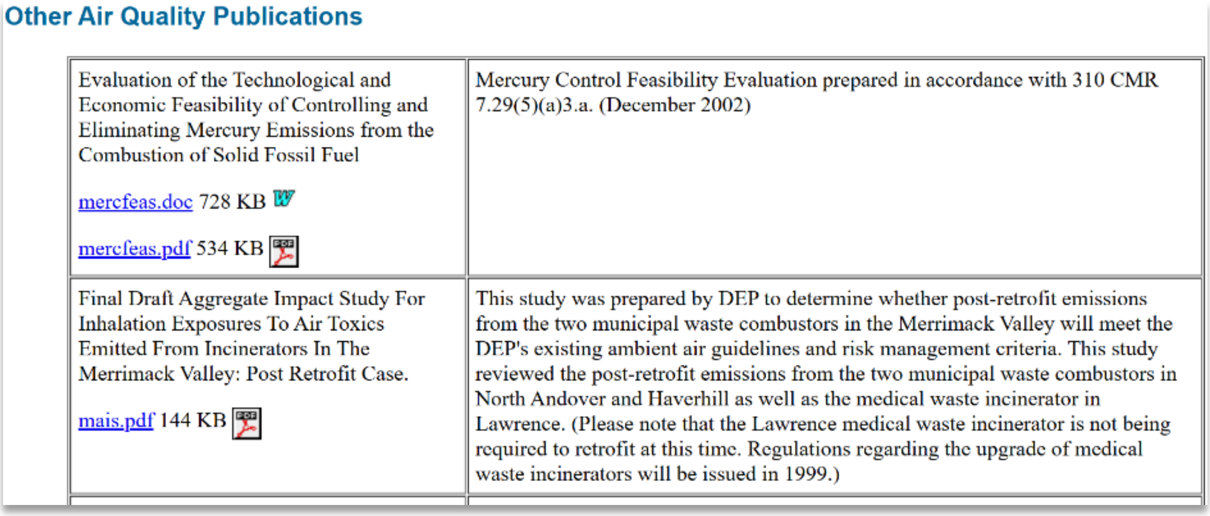
[421] EX1090 (Mass-EPA Internet Archive) (dated Dec. 20, 2002), available at https://web.archive.org/web/20021220143210/http://www.state.ma.us/dep/bwp/daqc/daqcpubs.htm#ecp.



Other Air Quality Publications

Evaluation of the Technological and Economic Feasibility of Controlling and Eliminating Mercury Emissions from the Combustion of Solid Fossil Fuel mercfeas.doc 728 KB mercfeas.pdf 534 KB	Mercury Control Feasibility Evaluation prepared in accordance with 310 CMR 7.29(5)(a)3.a. (December 2002)
Final Draft Aggregate Impact Study For Inhalation Exposures To Air Toxics Emitted From Incinerators In The Merrimack Valley: Post Retrofit Case. mais.pdf 144 KB	This study was prepared by DEP to determine whether post-retrofit emissions from the two municipal waste combustors in the Merrimack Valley will meet the DEP's existing ambient air guidelines and risk management criteria. This study reviewed the post-retrofit emissions from the two municipal waste combustors in North Andover and Haverhill as well as the medical waste incinerator in Lawrence. (Please note that the Lawrence medical waste incinerator is not being required to retrofit at this time. Regulations regarding the upgrade of medical waste incinerators will be issued in 1999.)

A POSITA searching for the word "mercury" would have arrived at the Mass-EPA (EX1009) document, as shown in the above screenshot. In fact, the only two hits on the page for "mercury" were regarding this document. A POSITA would have been motivated to look for the Mass-EPA document, and readily able to navigate the website to find it, because creation of the Mass-EPA document was commissioned pursuant to a regulation from the State of Massachusetts that went into effect May 2001, which mandated the Department of Environmental Protection to complete its report by December 1, 2002:[422]

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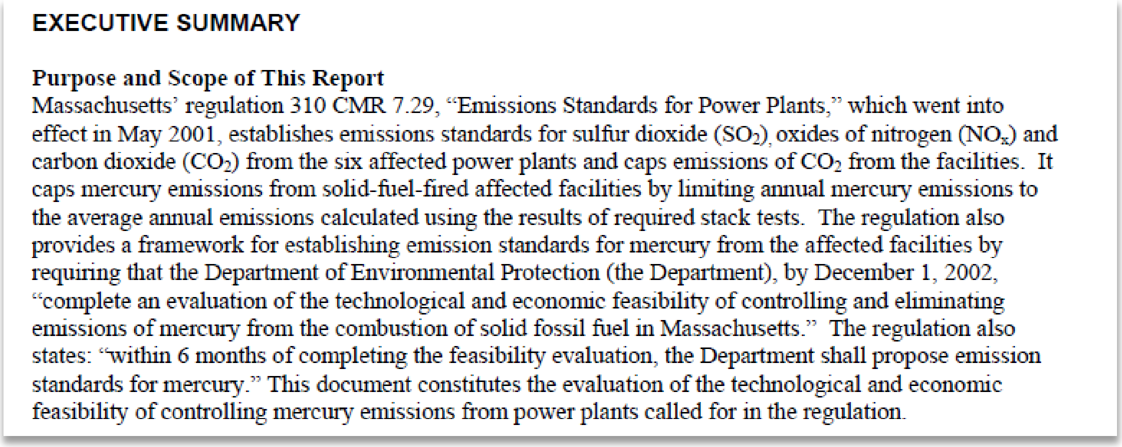
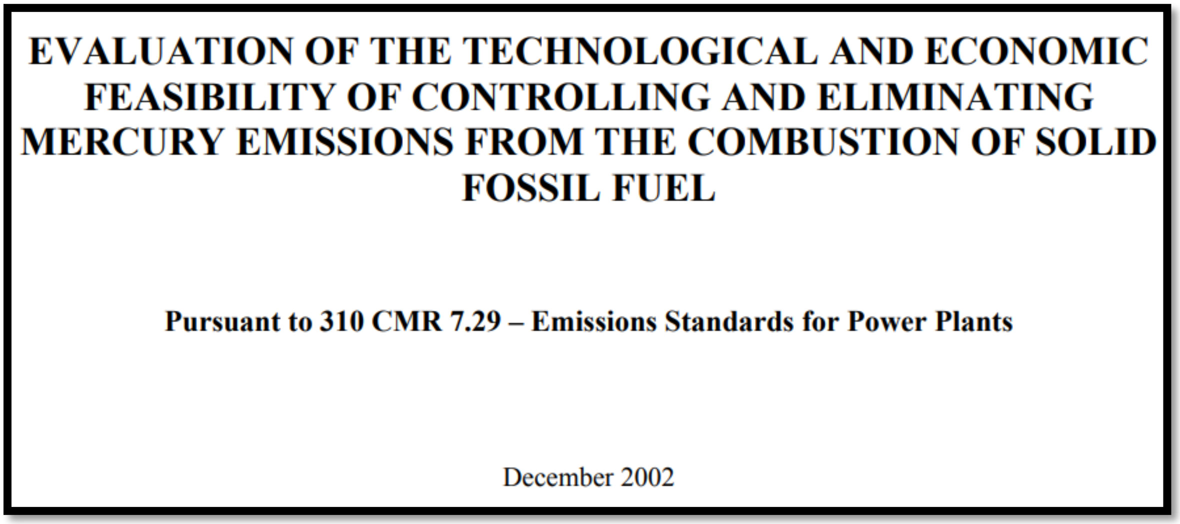
[422] EX1009 (Mass-EPA) at 1 (Executive Summary).



EXECUTIVE SUMMARY

Purpose and Scope of This Report
Massachusetts' regulation 310 CMR 7.29, "Emissions Standards for Power Plants," which went into effect in May 2001, establishes emissions standards for sulfur dioxide (SO_2), oxides of nitrogen (NO_x) and carbon dioxide (CO_2) from the six affected power plants and caps emissions of CO_2 from the facilities. It caps mercury emissions from solid-fuel-fired affected facilities by limiting annual mercury emissions to the average annual emissions calculated using the results of required stack tests. The regulation also provides a framework for establishing emission standards for mercury from the affected facilities by requiring that the Department of Environmental Protection (the Department), by December 1, 2002, "complete an evaluation of the technological and economic feasibility of controlling and eliminating emissions of mercury from the combustion of solid fossil fuel in Massachusetts." The regulation also states: "within 6 months of completing the feasibility evaluation, the Department shall propose emission standards for mercury." This document constitutes the evaluation of the technological and economic feasibility of controlling mercury emissions from power plants called for in the regulation.

242. As shown in the screenshot above, in December 2002, the Air Program Planning Unit of the Planning and Evaluation Division of the Bureau of Waste Prevention published a report titled "Evaluation of the Technological and Economic Feasibility of Controlling and Eliminating Mercury Emissions from the Combustion of Solid Fossil Fuel":[423]



EVALUATION OF THE TECHNOLOGICAL AND ECONOMIC FEASIBILITY OF CONTROLLING AND ELIMINATING MERCURY EMISSIONS FROM THE COMBUSTION OF SOLID FOSSIL FUEL

Pursuant to 310 CMR 7.29 – Emissions Standards for Power Plants

December 2002

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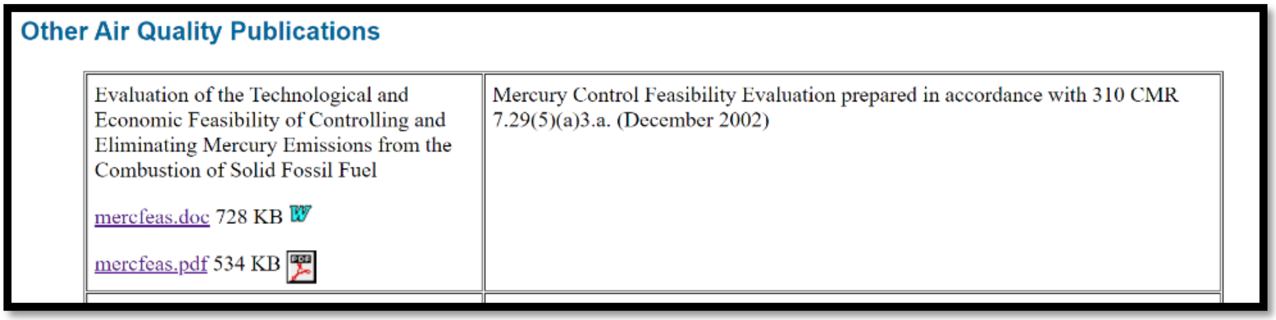
[423] EX1009 (Mass-EPA) at 1.

243. While the link hosting the PDF of Mass-EPA was archived on April 11, 2003 according to the Wayback Machine (as indicated by the "20030411" in the URL), the article was publicly available for download on the Massachusetts Department of Environmental Protection website at least by December 20, 2002 (as indicated by the "20021220" in the URL):[424]



Other Air Quality Publications

Evaluation of the Technological and Economic Feasibility of Controlling and Eliminating Mercury Emissions from the Combustion of Solid Fossil Fuel mercfeas.doc 728 KB mercfeas.pdf 534 KB	Mercury Control Feasibility Evaluation prepared in accordance with 310 CMR 7.29(5)(a)3.a. (December 2002)

The "mercfeas.pdf" article referenced above is Exhibit 1009, the Mass-EPA document. The Mass-EPA document is also available for download today from the State of Massachusetts government website.[425]

244. A POSITA would have been motivated to follow information repositories on mercury removal like Mass-EPA because, in the early 2000s, states were adopting Hg emissions regulations much faster than the federal government.

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[424] EX1090 (Mass-EPA Internet Archive), available at https://web.archive.org/web/20021220143210/http://www.state.ma.us/dep/bwp/daqc/daqcpubs.htm#ecp.

[425] https://www.mass.gov/doc/evaluation-of-technological-economic-feasibility-of-controlling-eliminating-mercury-emissions/download

For example, the State of Massachusetts passed an "Emissions Standards for Power Plants" regulation that went into effect in May 2001 to regulate emissions of SOx, NOx, and carbon dioxide. But at the same time, the regulation required that the Massachusetts Department of Environmental Protection would "complete an evaluation of the technological and economic feasibility of controlling and eliminating emissions from mercury from the combustion of solid fuel in Massachusetts."[426] The Mass-EPA document (EX1009) describes the results of that study, and based on the study, the Massachusetts Department of Environmental Protection would propose emissions standards within six months.[427] Thus, a POSITA would have followed these regulatory developments—not only to be able to operate power plans within the State of Massachusetts—but also to understand and prepare for the likely federal regulations to come in the short term, as Mass-EPA served as a harbinger of future federal regulations. The feasibility assessment by Mass-EPA is a sterling description of the regulatory landscape in this period.

2. <u>Mass-EPA Is Analogous Art and Overview of the Disclosure</u>

245. Mass-EPA is analogous art to the Challenged Patent, as it is in both the same field of endeavor and reasonably pertinent to the problems faced by the

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[426] EX1009 (Mass-EPA) at 1.

[427] EX1009 (Mass-EPA) at 1.

inventors of the Challenged Patent. For example, the field of endeavor of the Challenged Patent is “removal of pollutants from flue gas or product gas from a gasification system,” and more specifically removal of “mercury . . . from gas streams generated during the burning or gasification of fossil fuels.”[428] The specific problem faced by the inventors of the Challenged Patent was “a need for more economical and effective mercury removal technology.”[429] So too, the field of endeavor of Mass-EPA, as reflected in its title, is “Controlling and Eliminating Mercury Emissions from the Combustion of Solid Fossil Fuel,” and the problem faced was a need to control mercury emissions in view of “number of initiatives underway that are aimed at reducing mercury emissions from power plants.”[430] Both references address the problem through using activated carbon sorbents, as Mass-EPA states: “Activated carbon (AC) has been the most extensively studied sorbent for mercury adsorption. Currently, AC seems to be the most likely candidate to reach commercialization for mercury removal in the near future.”[431] Mass-EPA provides details as to how to inject activated carbon at a coal-fired power plant.

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[428] EX1001 (’114 Patent) at 1:28-31.

[429] EX1001 (’114 Patent) at 3:22-23.

[430] EX1009 (Mass-EPA) at Abstract, 4.

[431] EX1009 (Mass-EPA) at 32.

Mass-EPA teaches specific ACI equipment, which types of activated carbon to use, and where in the process to inject the activated carbon.

E. EUEC CONFERENCE (2005) – SJOSTROM [EX1010] AND ECKBERG [EX1011]

246. The Electric Utilities Environment Conference ("EUEC") has been held annually since 1998. The primary purpose of EUEC was to facilitate information exchange, and to foster cooperation between industry, government, and regulatory stakeholders regarding environmental controls for electric utilities.[432] I personally attended the EUEC in 2005, 2006, 2007, 2009, 2010 and 2013. During these years, the EUEC included a focus on bringing together vendors and developers of mercury control technology with people who implemented that technology in utility companies. I delivered presentations at the 2005, 2006, 2007 and 2013 EUEC. The earliest three presentations were on Niksa Energy Associates' work on mercury emissions control, and the latest one was on catalyst poisoning in SCR units for NO_x control. My first-hand impressions are confined to the presentations and exhibits on mercury emissions control and related multipollutant control strategies in the years that I attended.

247. As an attendee of the 2005 EUEC, I received a CD that included, among other items discussed in greater detail below, a PDF copy of a handout from the

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[432] EX1061 (EUEC 2005 Home Page).

conference. Exhibit 1030 is a true and correct copy of that handout ("EUEC Handout"). The EUEC Handout included a searchable index of presenters—organized by subject matter to include a schedule (including both time and conference room) for their presentations—as well as the titles of their presentations, and an abstract summarizing their presentations. Exhibit 1030 was obtained from CD that was mailed to me from the 2005 EUEC, as described further below. Exhibit 1031 is a true and correct copy of the label of the CD that was mailed to me from the 2005 EUEC. ("EUEC CD Scan").[433]

248. In the years I attended, including 2005, other EUEC attendees included business, sales, and project managers from the vendors, and engineers, compliance specialists, technical staff, and environmental control managers from the utilities. There was also a sizeable representation of consultants and academic, government, and commercial researchers plying their services regarding environmental control and cleanup to both vendors and utility representatives, as well as project managers for government R&D programs.

249. Most presentations at EUEC were collaborations among a vendor, a utility, a field test team, and a funding agency. The population of speakers was largely drawn from the technical experts who actually performed mercury field tests,

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[433] EX1031 (EUEC CD).

and some vendors also gave presentations that described their technology. Representatives from the U.S. funding agencies (such as DOE and EPA) occasionally delivered overview presentations on the general status of a single control technology, or performance comparisons among two or more control technologies.

250. The annual EUEC had two primary components: a very large selection of technical presentations in several distinct tracks, and a massive exhibition of technology vendors. The EUEC placed an emphasis on commercial applications of mercury control technology. This emphasis was evident in the presentations which, for the most part, were made by technology vendors, consulting companies, and teams of utility staff with technology vendors. Most presenters emphasized performance of mercury control technology in field tests instead of laboratory or theoretical data. Thus, the EUEC was particularly valuable as a direct link from vendors of technologies and services for mercury emissions control and the engineers and technical staff at utilities who would ultimately implement and maintain these technologies and services.

251. My presentations on behalf of Niksa Energy Associates LLC related to mercury emissions control in 2005, 2006, and 2007. Those in 2005 and 2006 pertained to our latest calculations to estimate how FGD scrubbing and SCR units for NO_x control affected mercury emissions at the stack. Both topics were aspects

of Niksa Energy Associates' ("NEA's") larger program to develop a predictive capability for mercury speciation as a component of complete gas cleaning systems for any coal type and furnace operating conditions. NEA's presentation in 2007 validated predicted mercury emissions with measured emissions for an assortment of complete utility gas cleaning configurations.

1. **Prior Art Status of the 2005 EUEC Presentations**

252. The 2005 EUEC took place on January 24-25, 2005 at the Westin La Paloma Resort, in Tucson, Arizona.[434] The conference included four separate presentation tracks: Track A – Air quality; Track B – Global Climate Change; Track C – Renewable Energy; and Track D – Other.[435] Each presenter prepared a PowerPoint presentation that was presented at the conference. The conference compiled the presentations, and within a few weeks of the completion of the conference, mailed a CD to all attendees that included all the presentations that were presented at the conference. I received the CD from the 2005 EUEC via mail in February 2005 ("EUEC CD Scan").[436]

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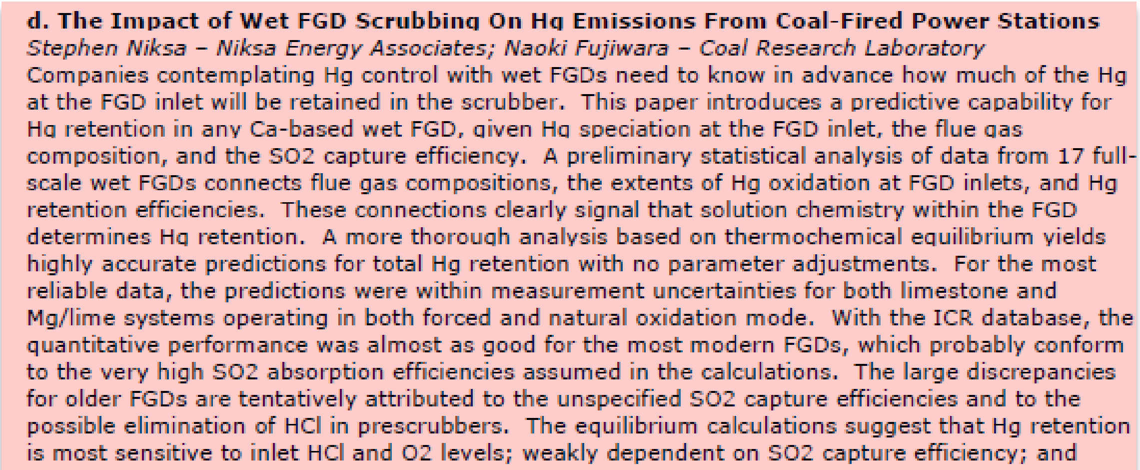
[434] EX1030 (EUEC Handout) at 2; EX1061 (EUEC 2005 Home Page).

[435] EX1030 (EUEC Handout) at 2.

[436] EX1031 (EUEC CD Scan).

253. I personally presented at the 2005 EUEC in Track A – Air Quality proceedings and attended most presentations for Track A – Air Quality proceedings.[437] An excerpt of the program schedule discussing my presentation is shown below:[438]



d. The Impact of Wet FGD Scrubbing On Hg Emissions From Coal-Fired Power Stations
Stephen Niksa – Niksa Energy Associates; Naoki Fujiwara – Coal Research Laboratory
Companies contemplating Hg control with wet FGDs need to know in advance how much of the Hg at the FGD inlet will be retained in the scrubber. This paper introduces a predictive capability for Hg retention in any Ca-based wet FGD, given Hg speciation at the FGD inlet, the flue gas composition, and the SO2 capture efficiency. A preliminary statistical analysis of data from 17 full-scale wet FGDs connects flue gas compositions, the extents of Hg oxidation at FGD inlets, and Hg retention efficiencies. These connections clearly signal that solution chemistry within the FGD determines Hg retention. A more thorough analysis based on thermochemical equilibrium yields highly accurate predictions for total Hg retention with no parameter adjustments. For the most reliable data, the predictions were within measurement uncertainties for both limestone and Mg/lime systems operating in both forced and natural oxidation mode. With the ICR database, the quantitative performance was almost as good for the most modern FGDs, which probably conform to the very high SO2 absorption efficiencies assumed in the calculations. The large discrepancies for older FGDs are tentatively attributed to the unspecified SO2 capture efficiencies and to the possible elimination of HCl in prescrubbers. The equilibrium calculations suggest that Hg retention is most sensitive to inlet HCl and O2 levels; weakly dependent on SO2 capture efficiency; and insensitive to HgCl2, NO, Ca/S ratio, and slurry dilution level in limestone FGDs, and to MgSO3 levels in Mg/lime systems. Consequently, systems with prescrubbers to eliminate HCl probably retain less Hg than fully integrated FGDs. The analysis also predicts re-emission of Hg0, but only for wide variations in the inlet O2 to levels that are much lower than those in full-scale FGDs.

As a result of my attendance, as noted above, I received a CD including PDFs of all presentations and other program materials. A scan of the front of that CD from my personal files is attached to this declaration.[439]

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[437] EX1030 (EUEC Handout) at 3.

[438] EX1030 (EUEC Handout) at 32.

[439] EX1031 (EUEC CD Scan).

254. In addition to myself, over 800 people attended the 2005 EUEC, as described in the attendee list included in the EUEC Handout.[440] As with other EUEC conferences, many people who would qualify as a person of skill in the art attended the 2005 EUEC, including from such notable organizations as U.S. Department of Energy, EPRI, ADA-ES Inc., URS Corporation, Southern Company, ALSTOM Power, and many others. In particular, I recall that approximately 250 to 300 people attended the Track A meetings, and the attendees of Track A included engineers, regulatory compliance specialists, and project managers from utilities; engineers and technicians from labs and testing organizations; technical staff from R&D organizations; and sales managers and representatives from technology vendors.

255. During the Track A – Air Quality proceedings of the 2005 EUEC, two presentations were given that are discussed in greater detail below. The first presentation was "Full-Scale Evaluations of Mercury Control Technologies with PRB Coals" presented by employees at ADA-ES Inc. and naming Sharon Sjostrom as the lead researcher.[441] A copy of that presentation, as provided to me in the CD I received from EUEC, and has been provided as Exhibit 1010 (hereinafter "Sjostrom"). The subject matter of the presentation from the CD mailed to me and

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[440] EX1030 (EUEC Handout) at 106-118.

[441] EX1030 (EUEC Handout) at 23.

the other conference attendees, as reflected in Sjostrom, correlates with the presentation I attended at the 2005 EUEC.[442]

256. The second presentation delivered during the Track A — Air Quality proceedings of the 2005 EUEC was "Mercury Control Evaluation of Halogen Injection into a Texas Lignite-Fired Boiler," presented by employees of Texas Genco and naming Craig Eckberg as the lead researcher.[443] A copy of that presentation, as provided to me in the CD I received from EUEC, has been provided as Exhibit 1011 (hereinafter "Eckberg"). The subject matter of the presentation from the CD mailed to me and the other conference attendees, as reflected in Sjostrom, correlates with the presentation I attended at the 2005 EUEC.[444]

257. Both Eckberg and Sjostrom were delivered during the A3 session—a particular subset of Track A that was devoted to "Mercury – Control"—which was scheduled for 7:30-9:30 am on January 25, 2005.[445] The attendees for the A3 session were generally the same as those described above with regards to Track A as a

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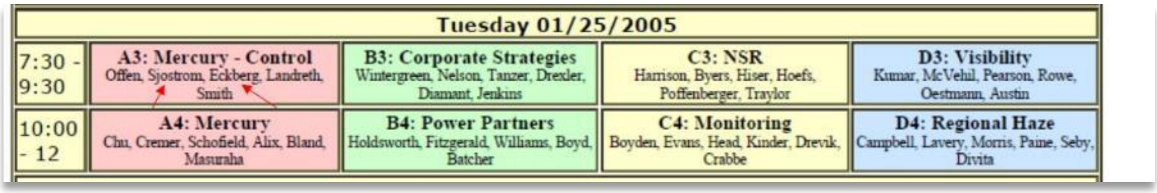
[442] EX1010 (Sjostrom).

[443] EX1030 (EUEC Handout) at 23.

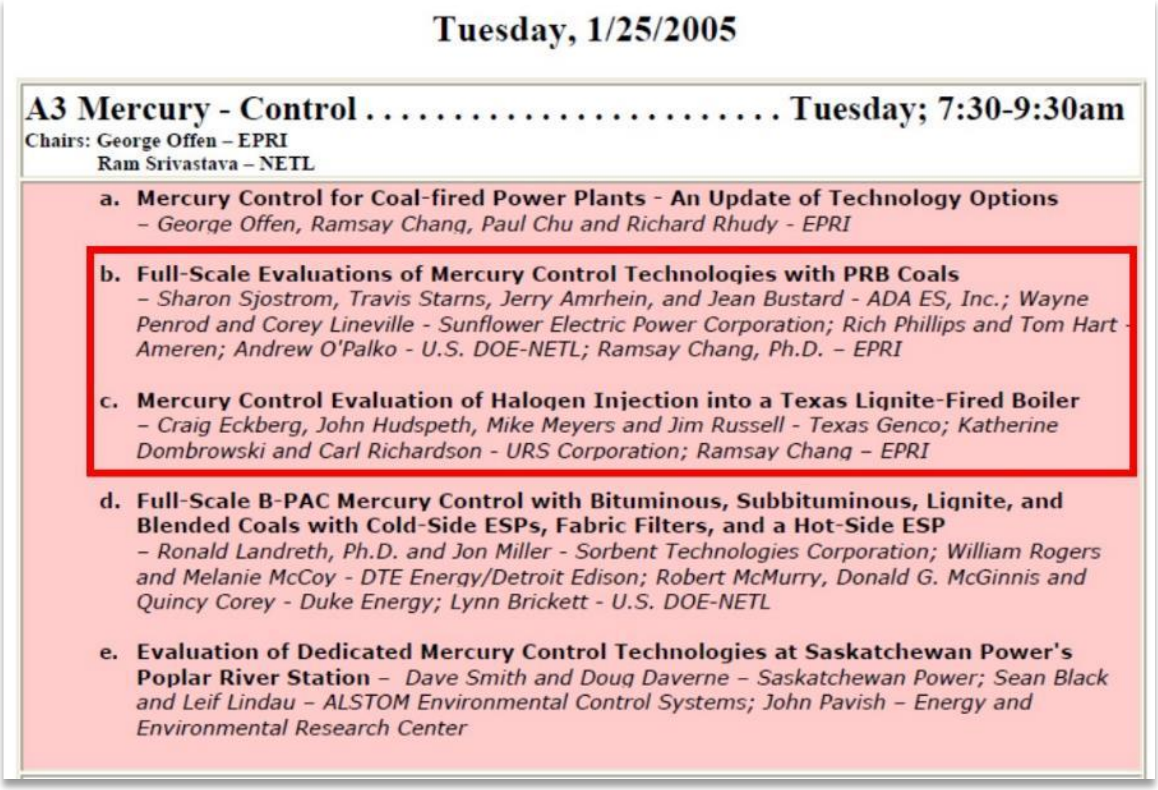
[444] EX1011 (Eckberg).

[445] EX1030 (EUEC Handout) at 23.

whole. In fact, Sjostrom and Eckberg were presented consecutively, in the same room.[446]



Tuesday 01/25/2005				
7:30 - 9:30	**A3: Mercury - Control** Offen, Sjostrom, Eckberg, Landreth, Smith	**B3: Corporate Strategies** Wintergreen, Nelson, Tanzer, Drexler, Diamant, Jenkins	**C3: NSR** Harrison, Byers, Hiser, Hoefs, Poffenberger, Traylor	**D3: Visibility** Kumar, McVehil, Pearson, Rowe, Oestmann, Austin
10:00 - 12	**A4: Mercury** Chu, Cremer, Schofield, Alix, Bland, Masuraha	**B4: Power Partners** Holdsworth, Fitzgerald, Williams, Boyd, Batcher	**C4: Monitoring** Boyden, Evans, Head, Kinder, Drevik, Crabbe	**D4: Regional Haze** Campbell, Lavery, Morris, Paine, Seby, Divita



Tuesday, 1/25/2005

A3 Mercury - Control . . . . Tuesday; 7:30-9:30am
Chairs: George Offen – EPRI
Ram Srivastava – NETL

a. **Mercury Control for Coal-fired Power Plants - An Update of Technology Options**
– George Offen, Ramsay Chang, Paul Chu and Richard Rhudy - EPRI

b. **Full-Scale Evaluations of Mercury Control Technologies with PRB Coals**
– Sharon Sjostrom, Travis Starns, Jerry Amrhein, and Jean Bustard - ADA ES, Inc.; Wayne Penrod and Corey Lineville - Sunflower Electric Power Corporation; Rich Phillips and Tom Hart - Ameren; Andrew O'Palko - U.S. DOE-NETL; Ramsay Chang, Ph.D. – EPRI

c. **Mercury Control Evaluation of Halogen Injection into a Texas Lignite-Fired Boiler**
– Craig Eckberg, John Hudspeth, Mike Meyers and Jim Russell - Texas Genco; Katherine Dombrowski and Carl Richardson - URS Corporation; Ramsay Chang – EPRI

d. **Full-Scale B-PAC Mercury Control with Bituminous, Subbituminous, Lignite, and Blended Coals with Cold-Side ESPs, Fabric Filters, and a Hot-Side ESP**
– Ronald Landreth, Ph.D. and Jon Miller - Sorbent Technologies Corporation; William Rogers and Melanie McCoy - DTE Energy/Detroit Edison; Robert McMurry, Donald G. McGinnis and Quincy Corey - Duke Energy; Lynn Brickett - U.S. DOE-NETL

e. **Evaluation of Dedicated Mercury Control Technologies at Saskatchewan Power's Poplar River Station –** *Dave Smith and Doug Daverne – Saskatchewan Power; Sean Black and Leif Lindau – ALSTOM Environmental Control Systems; John Pavish – Energy and Environmental Research Center*

The Sjostrom EUEC presentation was slotted as presentation number A3b, and the Eckberg EUEC presentation was slotted as presentation number A3c.[447]

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[446] EX1030 (EUEC Handout) at 5, 23, 30.

[447] EX1030 (EUEC Handout) at 5, 23, 30.

2. Sjostrom Is Analogous Art and Overview of the Disclosure

258. Sjostrom is analogous art to the Challenged Patent, as it is in both the same field of endeavor and reasonably pertinent to the problems faced by the inventors of the Challenged Patent. For example, the field of endeavor of the Challenged Patent is "removal of pollutants from flue gas or product gas from a gasification system," and more specifically removal of "mercury . . . from gas streams generated during the burning or gasification of fossil fuels."[448] The specific problem faced by the inventors of the Challenged Patent was "a need for more economical and effective mercury removal technology."[449] So too, the field of endeavor of Sjostrom, as reflected in its title, is "Mercury Control Technologies with PRB Coals," and the problem faced was a need to "enhanc[e] mercury removal for western coals."[450]

259. Sjostrom discussed the results of full-scale testing that was focused on increasing the halogen concentration, including bromine and iodine, in coal-fired power-plant flue gas for the purpose of mercury removal from the flue gas. Sjostrom disclosed multiple methods of introducing the halogens, and discussed "the effect

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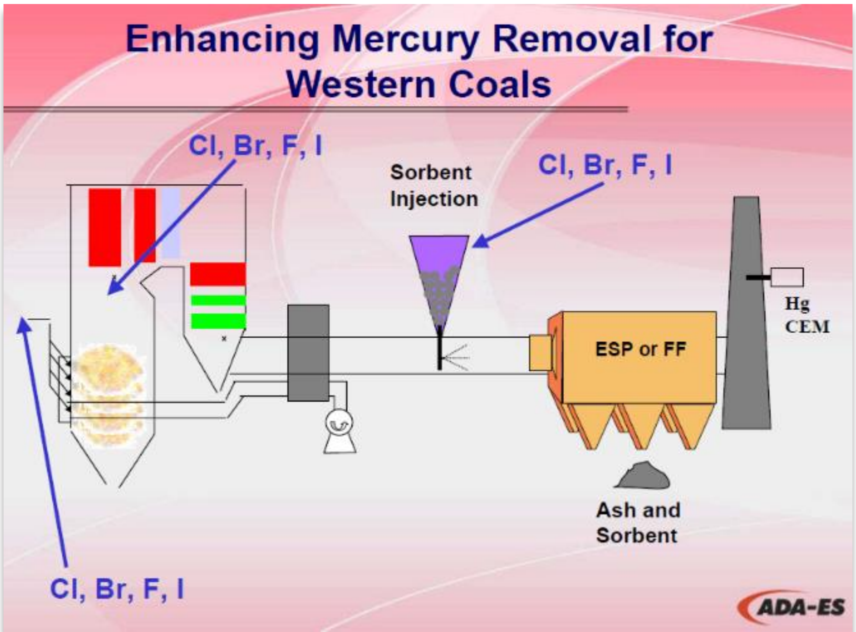
[448] EX1001 ('114 Patent) at 1:28-31.

[449] EX1001 ('114 Patent) at 3:22-23.

[450] EX1010 (Sjostrom) at 1, 4.

on mercury emissions of 1) blending PRB [(Powder River Basin coal)] with bituminous coal, 2) injecting alternative sorbents specifically designed to operate in a halogen deficient flue gas, and 3) injecting chemical additives onto the coal."[451] Sjostrom described testing mercury removal from flue gas of coal-fired power plants involving sorbent injection, halogen injection, and both sorbent and halogen injection as detailed below.[452]



Enhancing Mercury Removal for Western Coals

In the figure above, the following abbreviations are used:

- Cl, Br, F, I: chemicals containing chlorine, bromine, fluorine, and iodine
- ESP or FF: electrostatic precipitator or fabric filter

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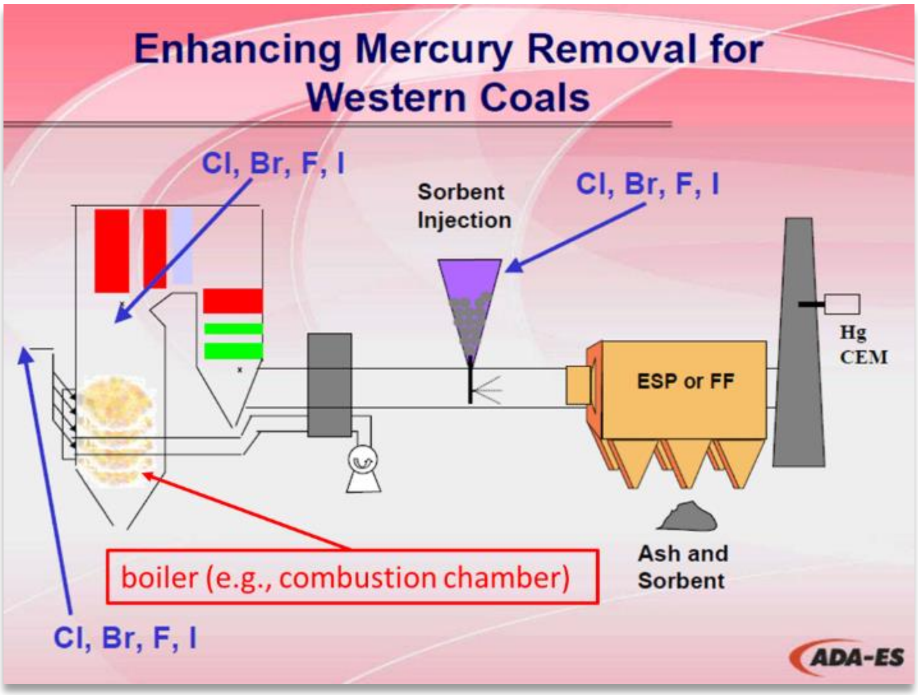
[451] EX1030 (EUEC Handout) at 23.

[452] EX1010 (Sjostrom) at 4.

- Hg CEM: mercury (Hg) continuous emissions monitor

260. Sjostrom described various mercury control tests conducted at coal-fired power plants.[453] The plants involve combustion of coal in a coal-fired boiler (e.g., combustion chamber), as shown in the annotated version of the same figure below.[454]



Enhancing Mercury Removal for Western Coals

A POSITA would have understood that this unit was a boiler based on the image used to represent the unit in the drawing, which was a common and routine way to

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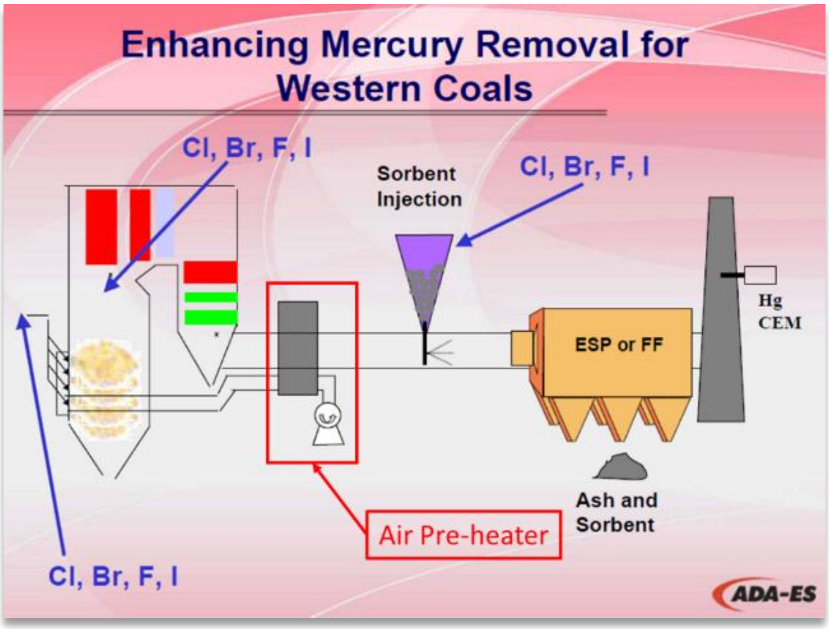
[453] EX1010 (Sjostrom) at 12, 18.

[454] EX1010 (Sjostrom) at 4 (annotations in red).

draw a coal-combustion boiler. Sjostrom later explains that the halogens are added specifically to the coal, as she refers to "Coal Additives" at Meramec.[455]

261. Sjostrom discloses testing at coal-fired power plants that also include an air pre-heater as shown in the annotated version of the same figure below.[456]



Enhancing Mercury Removal for Western Coals

A POSITA would have understood that the labeled component is an air pre-heater based on the image used to portray the unit on the schematic of Sjostrom. For example, the image includes a fan connected to a flow-path loop going into the inlet of the boiler to mix preheated air and coal. The gray box indicates the heat-transfer

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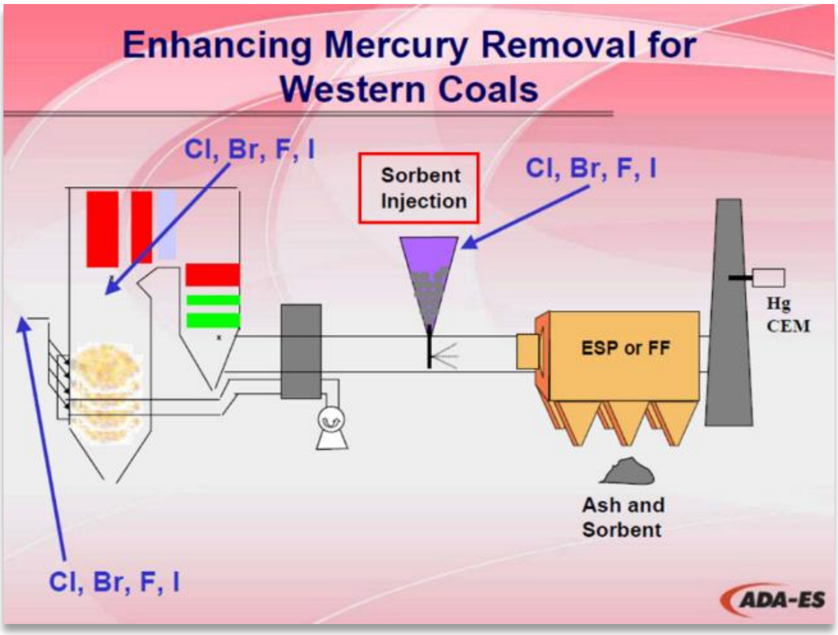
[455] EX1010 (Sjostrom) at 23, 25.

[456] EX1010 (Sjostrom) at 4 (annotations in red).

zone where the air pre-heater transfers heat to the air from the flue gas leaving the boiler.

262. The system of Sjostrom also includes a sorbent injection unit downstream of the boiler (labeled "Sorbent Injection"), as shown in the annotated version of the same figure below.[457]



The sorbent used by Sjostrom is "activated carbon injection."[458]

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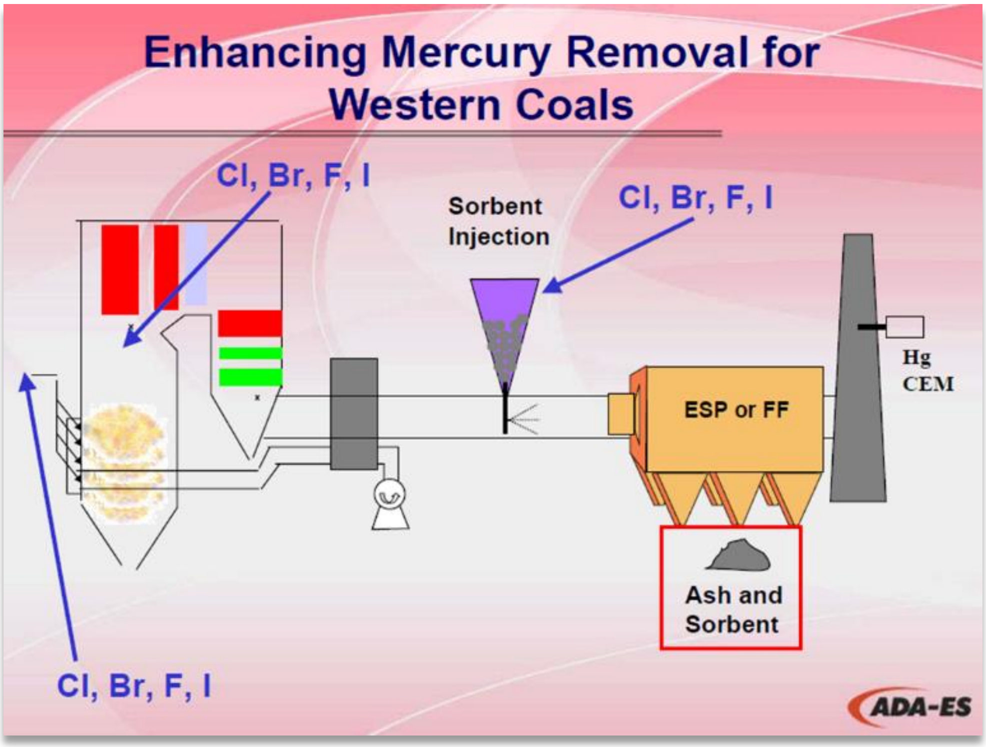
[457] EX1010 (Sjostrom) at 4 (annotations in red).

[458] EX1010 (Sjostrom) at 10, 34.

263. As shown in the annotated version of the figure below, Sjostrom describes passing the flue gas through an electrostatic precipitator ("ESP") or fabric filter ("FF").[459]



Enhancing Mercury Removal for Western Coals

This annotated figure from Sjostrom specifically shows that particulate matter, including the mercury-sorbent composition, would have been separated from the flue gas by the ESP (electrostatic precipitator) or FF (fabric filter), because a

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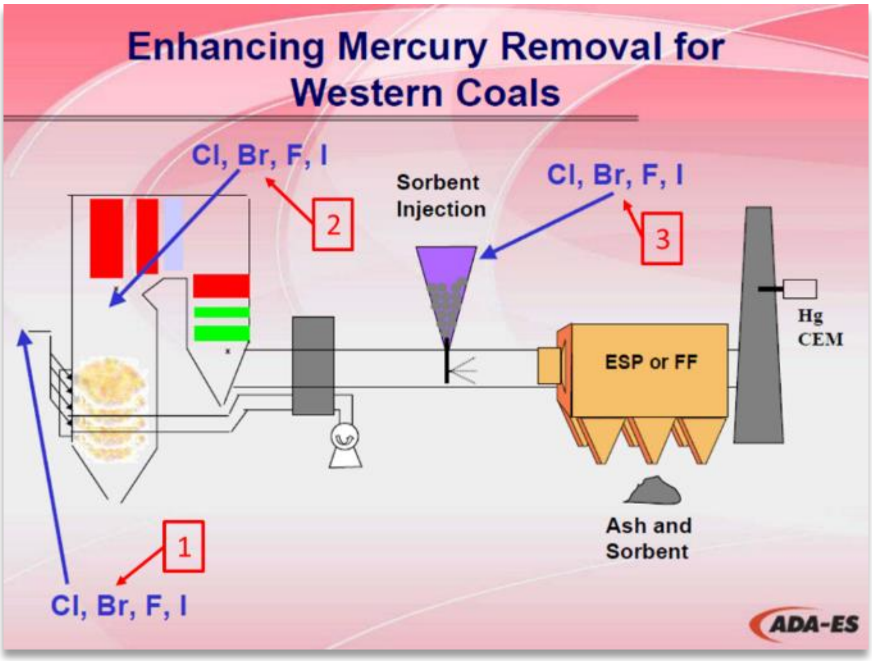
[459] EX1010 (Sjostrom) at 4 (annotations in red).

POSITA would have understood that it was the well-known purpose of an ESP or FF to separate such solid materials from the flue gas.[460]

264. Sjostrom demonstrates that activated-carbon sorbent injection was a well-known way of treating mercury emissions in flue gas.[461] Sjostrom also teaches injecting halogens (e.g., "Cl, Br, F, I") at multiple locations (those locations are annotated and numbered in red in the same figure being discussed here).[462]



Enhancing Mercury Removal for Western Coals

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[460] Technology Background and State of the Art ("Particulate Matter Emissions Controls"), IX.B.5.a.

[461] EX1010 (Sjostrom) at 10-11, 34.

[462] EX1010 (Sjostrom) at 4 (annotations in red). She also refers to "coal additives" on pages 23, 25, and 34.

Location 1 of Sjostrom teaches adding bromine upstream of the combustion chamber, such as by adding it to the coal entering the boiler.[463] The figure should be read within the larger context of the paper, which specifically refers to "Coal Additives" at Meramec.[464] With this context in mind, the schematic shows an arrow at Location 1 indicating the addition of bromine to pulverized coal in the primary air lines.[465] For example, the schematic of Sjostrom shows the stream splitting into four burner injection lines.[466] The schematic further shows a combustion plume corresponding to Location 1 of each of these four burner injection lines.[467] Thus, a POSITA would have understood that this was the primary air injection stream that included pulverized coal. Location 2 of Sjostrom teaches injecting bromine into the

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[463] EX1010 (Sjostrom) at 4 (annotations in red).

[464] EX1010 (Sjostrom) at 23, 25.

[465] EX1010 (Sjostrom) at 4 (annotations in red).

[466] EX1010 (Sjostrom) at 4 (annotations in red).

[467] EX1010 (Sjostrom) at 4 (annotations in red).

combustion chamber.[468,469] Location 3 of Sjostrom teaches adding bromine to the activated-carbon sorbent that is injected into the flue gas.[470]

3. Eckberg Is Analogous Art and Overview of the Disclosure

265. Eckberg is analogous art to the Challenged Patent, as it is in both the same field of endeavor and reasonably pertinent to the problems faced by the inventors of the Challenged Patent. For example, the field of endeavor of the Challenged Patent is "removal of pollutants from flue gas or product gas from a gasification system," and more specifically removal of "mercury . . . from gas streams generated during the burning or gasification of fossil fuels."[471] The specific problem faced by the inventors of the Challenged Patent was "a need for more economical and effective mercury removal technology."[472] So too, the field of endeavor of Eckberg, as reflected in its title, is "Mercury Control Evaluation of

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[468] EX1010 (Sjostrom) at 4 (annotations in red).

[469] Patent Owner's expert agrees with this understanding of Sjostrom. EX1094 (O'Keefe), 246:21-247:6, 249:6-252:9 (describing Locations 1-3 of Sjostrom).

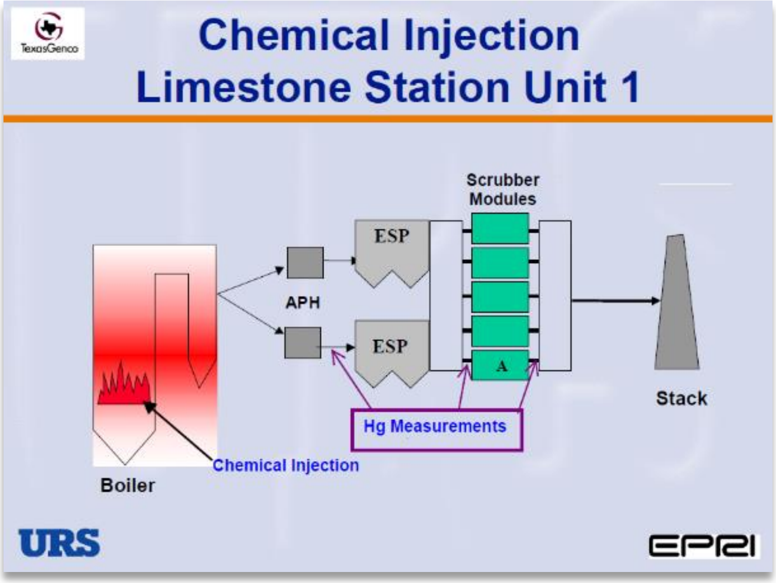
[470] EX1010 (Sjostrom) at 4 (annotations in red).

[471] EX1001 ('114 Patent) at 1:28-31.

[472] EX1001 ('114 Patent) at 3:22-23.

Halogen Injection into a Texas Lignite-Fired Boiler," and the problem faced was a need to "enhance mercury removal."[473]

266. Eckberg, which was presented immediately after Sjostrom at the 2005 EUEC, also disclosed the use of halogens to remove mercury from coal-fired plants. Eckberg provided data that showed "how halogen injection technology affects mercury removal and oxidation across an ESP in Texas Lignite flue gas."[474] As shown in the figure below, Eckberg describes testing the mercury removal effects of "Chemical Injection" of a halogen directly into a coal-fired combustion chamber (labeled "boiler").[475]



Chemical Injection
Limestone Station Unit 1

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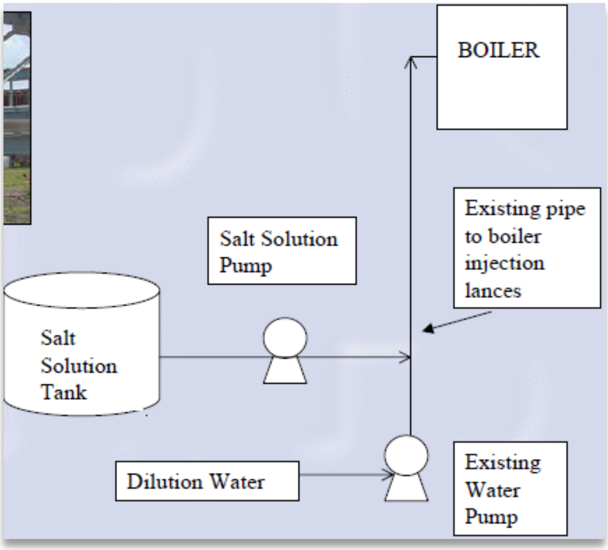
[473] EX1011 (Eckberg) at 1, 3.

[474] EX1030 (EUEC Handout) at 24.

[475] EX1011 (Eckberg) at 5.

267. Eckberg also includes a schematic showing the injection equipment used for the chemical injection.[476]



The halogens were maintained in an aqueous solution (labeled "Salt Solution Tank"), then pumped into a transport line where they were diluted with additional water ("Dilution Water"), followed by injection directly into the combustion chamber ("Boiler"). Eckberg explains that the "salt solution" injected into the boiler was either "$CaCl_2$ (25 wt%)" or "$CaBr_2$ (52 wt%)."[477] $CaBr_2$ refers to calcium bromide, and the 52 wt% means that of the solution, 52% by weight was calcium bromide, and 48% was water. Eckberg further discloses the ratio of bromine to coal,

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[476] EX1011 (Eckberg) at 8.

[477] EX1011 (Eckberg) at 9.

the feed rate of the aqueous salt solution (in gallons per minute), and the estimated gas-phase concentration (in ppm) of HBr in the mercury-containing flue gas.[478]

F. THE OLSON-646 REFERENCE [EX1012]

268. Exhibit 1012 ("Olson-646") is U.S. Patent Application Publication No. 2006/0048646, which names Edwin S. Olson, Michael J. Holmes, and John H. Pavlish as co-inventors. Olson-646 is entitled "Sorbents for the Oxidation and Removal of Mercury."[479]

1. Prior-Art Status of the Olson-646 Reference

269. I have been informed that Olson-646 was published by the USPTO on March 9, 2006 as U.S. Patent Pub. No. 2006/0048646. As described above, the Challenged Claims of the Challenged Patent do not have priority support to the earlier-filed applications. Accordingly, I understand that Olson-646 qualifies as prior art, as it was published more than one year before the earliest priority date of the Challenged Patent.

2. Olson-646 Is Analogous Art

270. Olson-646 is analogous art to the Challenged Patent, as it is in both the same field of endeavor and reasonably pertinent to the problems faced by the

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[478] EX1011 (Eckberg) at 9.

[479] EX1012 (Olson-646).

inventors of the Challenged Patent. For example, the field of endeavor of the Challenged Patent is "removal of pollutants from flue gas or product gas from a gasification system," and more specifically removal of "mercury . . . from gas streams generated during the burning or gasification of fossil fuels."[480] The specific problem faced by the inventors of the Challenged Patent was "a need for more economical and effective mercury removal technology."[481] So too, the field of endeavor of Olson-646 is removal of "mercury . . . from gas streams generated during the burning or gasification of fossil fuels," and the problem faced was a need to "provide new and economical methods for the removal of mercury from the gases produced in the utilizations of fossil fuels."[482]

3. Overview of the Disclosure of Olson-646

271. Figure 2 of Olson-646, reproduced below, shows "a theory developed from scientific evidence to explain the nature of the promoting compounds."[483]

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[480] EX1001 ('114 Patent) at 1:28-31.

[481] EX1001 ('114 Patent) at 3:22-23.

[482] EX1012 (Olson-646) ¶¶[0004], [0010].

[483] EX1012 (Olson-646) ¶[0054], Figure 2.

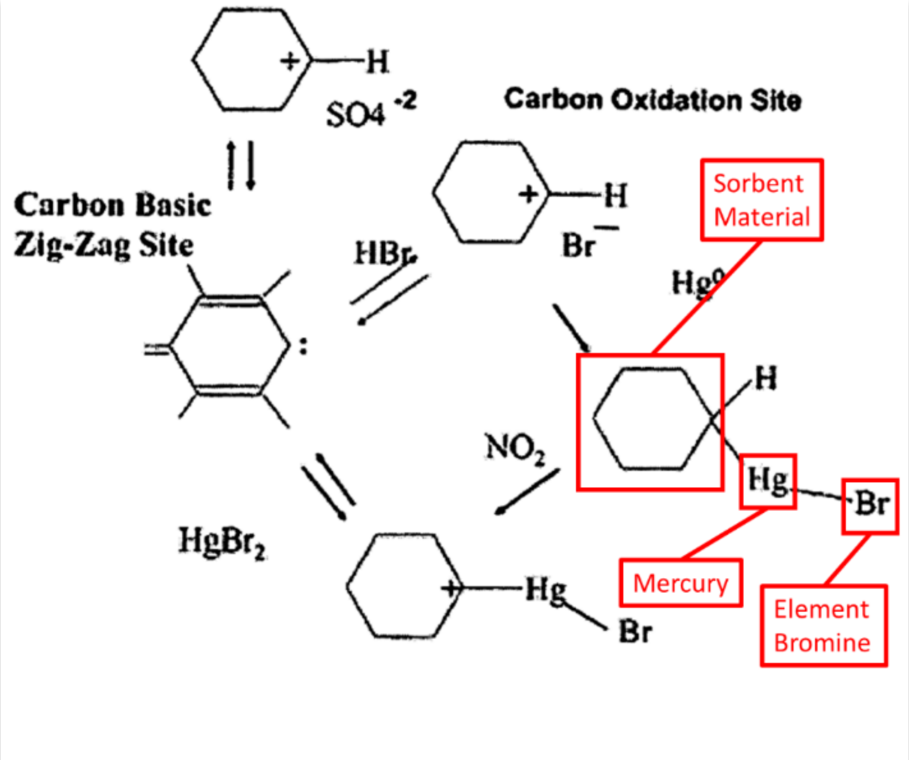

FIG. 2

The text in red was added above. Olson-646 explains that "hydrogen bromide reacts with the unsaturated structure of the activated carbon."[484] Olson-646 teaches that the reaction may take place at "a carbene species on the edge of the graphene sheet structures of the carbon."[485] Further, Olson-646 explains that "[m]olecular bromine or a bromine compound reacts to form a similar structure, with a positive carbon that is active for oxidizing the mercury with subsequent capture by the sorbent."[486]

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[484] EX1012 (Olson-646) ¶[0054].

[485] EX1012 (Olson-646) ¶[0054].

[486] EX1012 (Olson-646) ¶[0054].

Figure 2 of Olson-646, reproduced above, shows that the complex includes the activated-carbon sorbent, the element bromine, and the element mercury.[487] Though more expensive, iodine can also be used.[488]

272. Olson-646 provides implementation details regarding promoting activated carbon with a bromine-containing reagent to form promoted activated carbon, and then injecting the promoted activated carbon in the mercury-containing (flue) gas stream in Figure 3, reproduced below.[489]

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[487] EX1012 (Olson-646) at Figure 2.

[488] EX1012 (Olson-646) ¶[0093].

[489] EX1012 (Olson-646) at Figure 3.

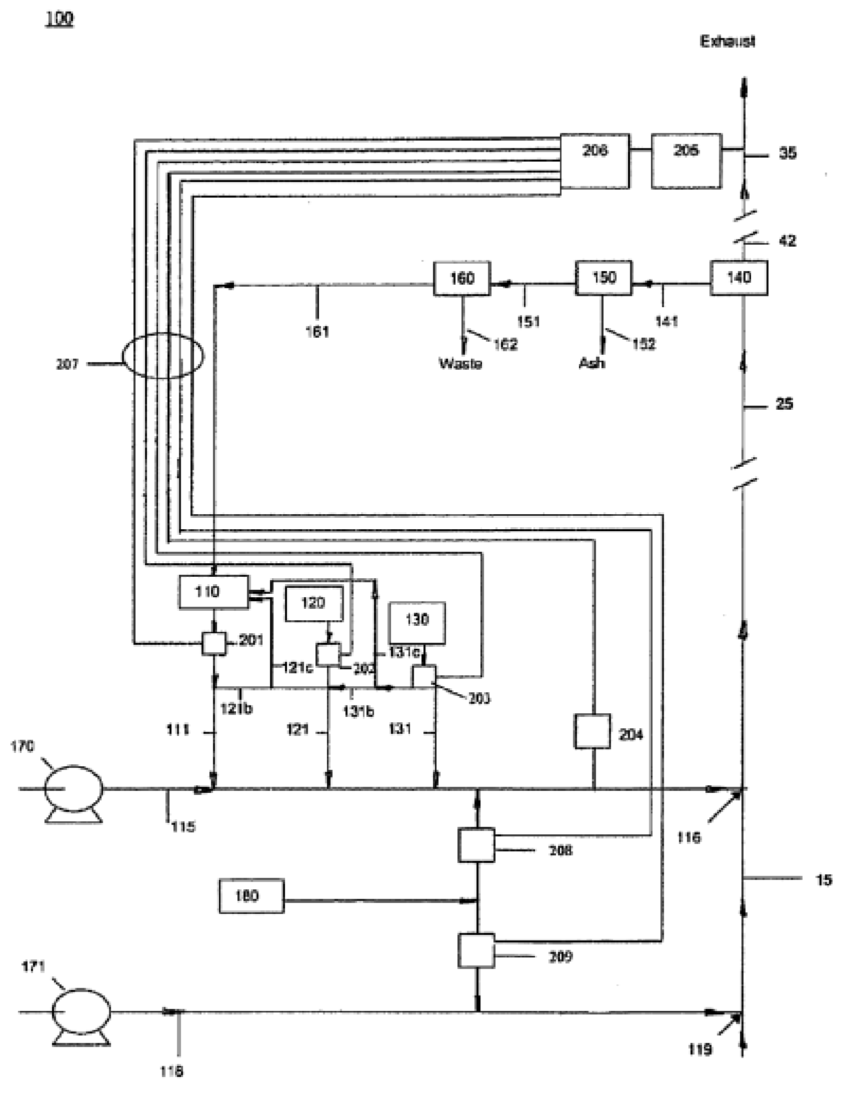

FIG. 3

Figure 3 of Olson-646 shows a schematic of "mercury control system 100 comprising preparation of promoted carbon sorbents, and flue gas mercury reduction, in accordance with preferred embodiments of the present invention."[490]

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[490] EX1012 (Olson-646) ¶[0056].

273. Olson-646 explains that Figure 3 shows a "base activated carbon reservoir 110, an optional halogen/halide promoter reservoir 120, an optional secondary component reservoir 130, and an optional alkali component reservoir 180, each of which with corresponding flow control device(s) 201, 202, 203, and 208/209, respectively."[491] Olson-646 explains that a "promoted carbon sorbent and/or an optional alkali component is injected into contaminated flue gas stream 15."[492]

G. THE OLSON-235 REFERENCE [EX1018]

274. Exhibit 1018 ("Olson-235") is U.S. Patent No. 8,652,235, which names Edwin S. Olson, Michael J. Holmes, and John H. Pavlish as co-inventors. Olson-235 is entitled "Sorbents for the Oxidation and Removal of Mercury."[493]

1. Prior-Art Status of the Olson-235 Reference

275. I have been informed that Olson-235 was issued by the USPTO on February 18, 2014. As described above, the Challenged Claims of the Challenged Patent do not have priority support to the earlier-filed applications. Accordingly, I understand that Olson-235 qualifies as prior art, as it issued more than one year before the earliest priority date of the Challenged Patent.

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[491] EX1012 (Olson-646) ¶[0056].

[492] EX1012 (Olson-646) ¶[0061].

[493] EX1018 (Olson-235).

2. Overview of the Disclosure of the Olson-235 Reference

276. Figure 2 of Olson-235, reproduced below, shows "a proposed mechanistic model of the chemical reactions results in the oxidation and capture of mercury."[494]

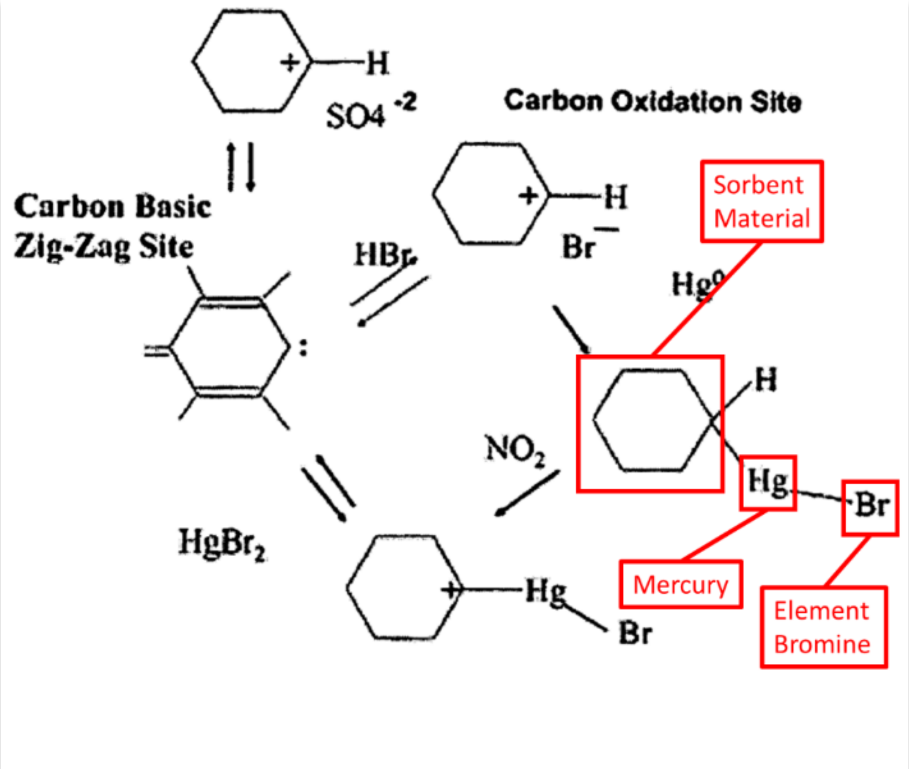

FIG. 2

The text in red was added above. Olson-235 explains that "the reactive carbon form can preferably be generated by the addition of bromine, hydrogen bromide, or combinations of bromine and other elements, as described herein."[495] Further,

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[494] EX1018 (Olson-235) at 8:63-65, Figure 2.

[495] EX1018 (Olson-235) at 16: 61-65.

Olson-235 explains that "[h]alogen treatment resulted in higher-activity carbons because the halide anions (especially bromide and iodide) were effective in promoting oxidation by stabilizing the developing positive charge on the mercury in the transition state for oxidation."[496] Figure 2 of Olson-646, reproduced above, shows that the complex includes the activated-carbon sorbent, the element bromine, and the element mercury.[497]

277. Olson-235 provides implementation details regarding promoting activated carbon with a bromine-containing reagent to form promoted activated carbon, and then injecting the promoted activated carbon in the mercury-containing (flue) gas stream in Figure 3, reproduced below.[498]

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[496] EX1018 (Olson-235) at 16:65-67, 17: 1-2.

[497] EX1018 (Olson-235) at Figure 2.

[498] EX1018 (Olson-235) at Figure 3.

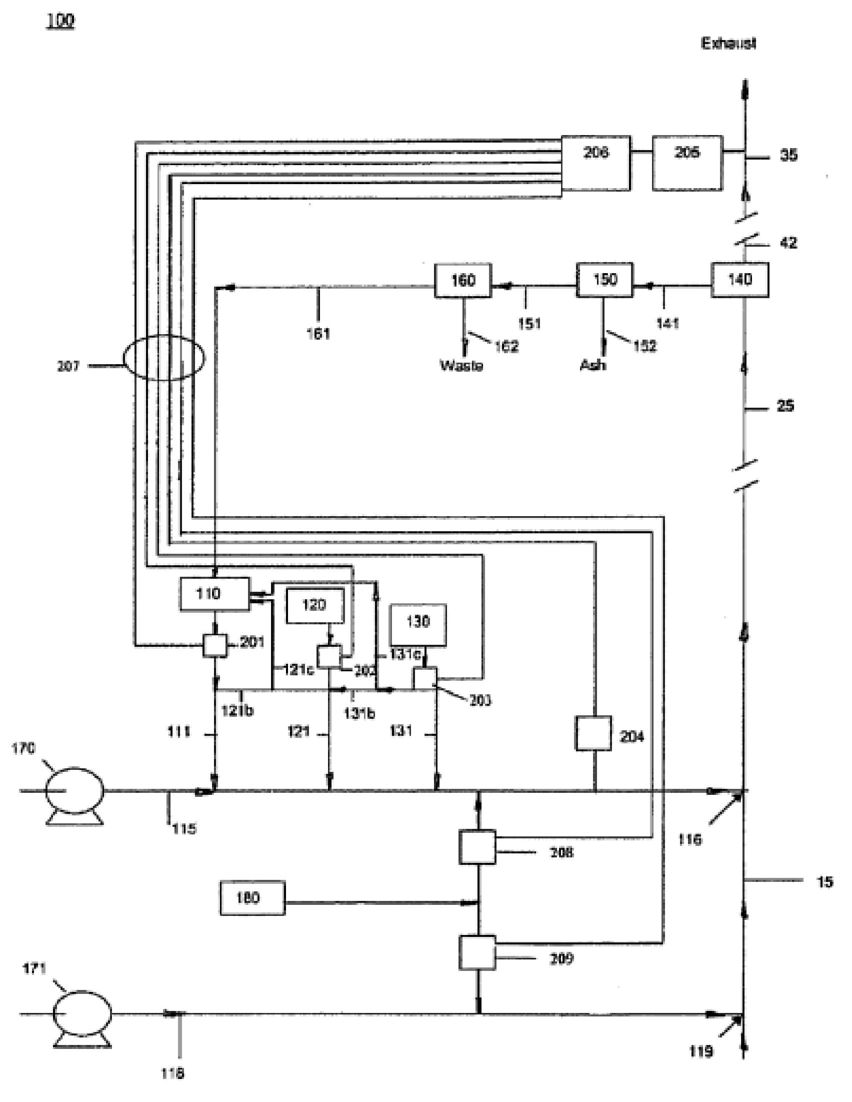

FIG. 3

Figure 3 of Olson-235 shows a schematic of “mercury control system 100 comprising preparation of promoted base sorbents, and flue gas mercury reduction, in accordance with preferred embodiments of the present invention.”[499]

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[499] EX1018 (Olson-235) at 13:10-15.

278. Olson-235 explains that Figure 3 shows "a base sorbent reservoir 110, a halogen/halide promoter reservoir 120, a secondary component reservoir 130, and an alkali component reservoir 180, each of which with corresponding flow control device(s) 201, 202, 203, and 208/209, respectively."[500] Olson-235 explains that a "promoted sorbent and/or an optional alkali component is injected into contaminated flue gas stream 15."[501]

XIII. GROUND A1 AND GROUND A2: OBVIOUSNESS OVER VOSTEEN589 IN VIEW OF STARNS [GROUND A1] AND VOSTEEN589 IN VIEW OF MASS-EPA [GROUND A2]

279. It is my opinion that claims 1-30 would have been obvious over the combination of Vosteen589 and Starns (Ground A1). Claims 1-30 would have been obvious over the combination of Vosteen589 and Mass-EPA (Ground A2). Ground A1 and Ground A2 largely rely on the common disclosure of Vosteen589, with certain claim limitations disclosed by Starns (Ground A1) and by Mass-EPA (Ground A2) (in some cases, in addition to the disclosure of those limitations already present in Vosteen589). In the subsections below, I discuss the reasons to combine Vosteen589 with each reference, followed by the disclosure of Vosteen589 and each reference.

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[500] EX1018 (Olson-235) at 13:15-19.

[501] EX1018 (Olson-235) at 14:30-32.

A. REASONS TO COMBINE

280. A person of ordinary skill in the art would have been motivated to combine Vosteen589 with Starns (Ground A1) and Vosteen589 with Mass-EPA (Ground A2), and with reasonable expectation of success, because all three references are directed towards the same goal (removing mercury from coal-combustion flue gas) and are interoperable with one another.

281. As described more fully below, Vosteen589 explains that a sorbent system is used to remove mercury from the flue gas, and gives activated carbon as a specific example. For example, Vosteen589 discloses a "dry emission control system" as part of the "flue gas emission control system," and that the dry emission control system works "based on the adsorption of ionic mercury compounds."[502] Vosteen589 uses halogen-containing species (such as HBr) to oxidize mercury "since the ionic [oxidized] mercury is readily water soluble . . . and is readily adsorbable to a range of adsorbents."[503] Vosteen589 discloses that his invention is particularly suited "for those high-temperature plants which do not have a wet flue gas emission control system, but solely have a dry emission control system having a

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[502] EX1005 (Vosteen589) ¶¶[0018]-[0019].

[503] EX1005 (Vosteen589) ¶[0007].

mercury <u>sorption stage</u>."[504] The process that Vosteen589 repeatedly describes as being performed by the dry-emission control system—"adsorption"—refers to a process by which adsorbate (e.g., atoms, ions, or molecules) in a fluid (typically a gas) are bound to the surface of a sorbent. Vosteen589 discloses that an example of the sorbent is "finely pulverulent slaked lime/activated carbon."[505] In such adsorption processes, the adsorbate (e.g., mercury) is adhering to the sorbent (e.g., activated carbon), and the activated carbon is thus contacting mercury in the mercury-containing gas. Vosteen589 discloses that an example of the sorbent is "finely pulverulent slaked lime/activated carbon."[506] For the coal-fired power plants, Vosteen589 discloses that a "dry electrostatic precipitator (ESP) is used."[507]

282. Vosteen589 thus discloses that its invention is an improvement to the dry-emission control systems in particular, the very system that is the subject of Starns and Mass-EPA. Vosteen589 however does not fully disclose certain details about how to implement the dry-emission control system, although it does provide an exemplary sorbent (finely pulverulent slaked lime/activated

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[504] EX1005 (Vosteen589) ¶[0019].

[505] EX1005 (Vosteen589) ¶[0019].

[506] EX1005 (Vosteen589) ¶[0019].

[507] EX1005 (Vosteen589) ¶[0034].

carbon) and also exemplary particulate control devices (e.g., fabric filter and ESP). Also, although Vosteen589 does disclose use of activated carbon-sorbent, it does not fully disclose all the details, such as injection rates, the type of activated-carbon to use, or how to use the activated-carbon sorbent with an ESP. Each of these details were known in the art to a POSITA, and Starns and Mass-EPA also supply those details. A POSITA would have been motivated to use activated-carbon injection (as disclosed in each of Starns and Mass-EPA) with Vosteen589, and would have a reasonable expectation of success, because activated-carbon injection was well-known in the art, as admitted by the '114 Patent.[508] As explained above regarding Technology Background and State of the Art,[509] that a POSITA would have readily understood how to add the activated-carbon sorbent to the system, namely by injection into the mercury-containing flue gas between the combustion chamber and the PCD (such as the ESP or fabric filter). Starns and Mass-EPA each provides these details of ACI to purify mercury-containing flue gas, including how sorbent injection rate affects mercury-removal rate, where to inject the sorbent, and how to remove it with an ESP. A POSITA

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[508] EX1001 ('114 Patent) at 1:59-65, 11:8-16, 25:35-48.

[509] State of the Art ("Sorbents/Activated Carbon"), §IX.C.

would have been motivated to combine Vosteen589 with Starns (Ground A1) and Vosteen589 with Mass-EPA (Ground A2).

1. Ground A1 (Combination of Vosteen589 with Starns)

283. Like Vosteen589, Starns also pertains to systems for collecting and removing mercury from the flue gas of coal-combustion plants. The title of Starns is, "Full-Scale Test of Mercury Control with Sorbent Injection and an ESP at Wisconsin Electric's Pleasant Prairie Power Plant."[510] Like Vosteen589, Starns touts a dry emission system using sorbent, particularly activated carbon injection (ACI), to collect and remove the mercury. Starns touts this as "mature" and readily available technology:

> The most mature, retrofit technology available today is the injection of sorbents such as powdered activated carbon (PAC) into the flue gas upstream of the particle control equipment. The gas-phase mercury in the flue gas contacts the sorbent and attaches to its surface.[511]

284. Starns provides details as to how to supply activated carbon to the system and processes of Vosteen589:

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[510] EX1008 (Starns) at 1.

[511] EX1008 (Starns) at 2.

- **Injection of the activated carbon:** "injection equipment" that includes a "bulk-storage silo and twin blower/feeder trains ...."[512] The injection equipment at a full-scale coal-fired power plant is shown below, in Figure 2 of Starns:

- **Control of activated carbon injection (ACI):** "A PLC [programmable logic controller] is used to control system operation and adjust injection rates."[513] One of the "[p]rimary variables" to control how much mercury is removed is "injection concentration" of the sorbent.[514]

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[512] EX1008 (Starns) at 7; *see also* EX1008 (Starns) at Fig. 2.

[513] EX1008 (Starns) at 7; *see also* EX1008 (Starns) at Fig. 2.

[514] EX1008 (Starns) at 10; *see also* EX1008 (Starns) at 13-16, Figs. 4, 5 (achieving up to 70% mercury removal by increasing the sorbent concentration).

- **Type of activated carbon:** Starns describes that powdered activated carbon (PAC) should be used: "Four sorbents were selected for full-scale evaluation in the parametric test series. All four sorbents were PACs …."[515]

285. Starns provides the details of ACI—what Starns describes as the "most mature retrofit technology available today"[516]—to purify the mercury-containing flue gas, including how the sorbent concentration affects the mercury-removal rate. A POSITA would have been motivated, with a reasonable expectation of success, to use the activated carbon injection (ACI) system and control scheme of Starns with the halogenation and coal-combustion system of Vosteen589, in particular the embodiments of Vosteen589 using an ESP in the dry emission system.

286. A POSITA would have looked to Starns for practical applications of the discovery disclosed in Vosteen589 relating to the use of halogen species added to the coal or to the combustor to improve the collection of mercury on activated carbon sorbents. A POSITA would have used "injection" (as described by Starns) as the method for introducing activated-carbon sorbent (as described by both Vosteen589 and Starns) into the mercury-containing flue gas of Vosteen589, particularly in those embodiments of Vosteen589 using an ESP in the dry

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[515] EX1008 (Starns) at 9.

[516] EX1008 (Starns) at 2.

emission system (as used in Starns). As ACI was already a "mature" technology by the time of Starns, the combination of Vosteen589 and Starns represents no more than combining prior art elements according to known methods to yield predictable results of removing mercury. Moreover, the activated carbon injection of Starns was a "known technique" and introducing the halogens (as described in Vosteen589) would yield the predictable results in the form of improved mercury removal, allowing lower amounts of activated carbon to be used and thus lower costs.

287. A POSITA would have a reasonable expectation of success in combining Vosteen589 with Starns because, as Starns explains, "The most mature, retrofit technology available today is the injection of sorbents such as powdered activated carbon (PAC) into the flue gas upstream of the particle control equipment."[517] The particle control equipment in Starns is an electrostatic precipitator (ESP), and Starns recommends "using activated carbon injection upstream of an ESP."[518] A POSITA would have been motivated, as Starns suggests, to use activated carbon injection between the combustion chamber (furnace) and the

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[517] EX1008 (Starns) at 2.

[518] EX1008 (Starns) at 20. Starns also discloses that a fabric filter can be used. EX1008 (Starns) at 19 (Fig. 8).

ESP in Vosteen589.[519] The mercury-sorbent composition is eventually removed by standard and well-known particulate control devices, such as the electrostatic precipitators (ESPs) in Vosteen589 and in Starns.

2. Ground A2 (Combination of Vosteen589 with Mass-EPA)

288. Like Vosteen589, Mass-EPA also pertains to systems for collecting and removing mercury from the flue gas of coal-combustion plants. The title of Mass-EPA is, "Evaluation of the Technological and Economic Feasibility of Controlling and Eliminating Mercury Emissions from the Combustion of Solid Fossil Fuel."[520] And like Vosteen589, Mass-EPA discusses the use of sorbents with dry emission particulate management (PM) control systems, such as ESPs:

> A number of technologies have been under development specifically to address mercury control and are in various stages of research, development, and testing. They include use of sorbents (processes that use injection and fixed-bed configurations), mercury oxidation materials, and mercury oxidation catalysts. A number of these technologies can be used in plants equipped with a PM control device (ESP and/or FF).[521]
>
> Mercury can be captured and removed from gas by injection of a sorbent into the exhaust system and subsequent collection of the particulates in a PM control device. Availability of low-cost

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[519] EX1005 (Vosteen589) ¶¶[0019], [0033], [0037], [0039], [0042], [0047]-[0049], claim 8 (discussing use of an ESP).

[520] EX1009 (Mass-EPA) at 1.

[521] EX1009 (Mass-EPA) at 31 (section entitled, "Mercury-Specific Control Technologies").

> and efficient sorbents and effective particulate collection are key in implementation of this type of mercury control.[522]

289. In particular, Mass-EPA touts a dry emission system using sorbent, particularly activated carbon injection (ACI), including by co-injection of activated carbon with lime:

> In the near term, activated carbon seems the most likely technology to be commercialized for mercury control because there have been full-scale tests of this technology that have generated promising results.[523]
>
> Increased removal of mercury from gas has been demonstrated by co-injection of activated carbon and calcium-based sorbents in spray dryer adsorber systems in full-scale coal-fired power plants. [524]

Vosteen589 also discloses activated carbon, including with lime.[525] Mass-EPA discloses "activated carbon <u>injection</u>" in numerous other places.[526]

290. Mass-EPA concludes that the "estimated costs for <u>powdered activated carbon injection</u>-based technology, which most likely will reach commercialization for mercury control before other technologies, is within the current control costs for

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[522] EX1009 (Mass-EPA) at 32 (subsection entitled, "Sorbent Injection").

[523] EX1009 (Mass-EPA) at 32.

[524] EX1009 (Mass-EPA) at 32.

[525] EX1005 (Vosteen589) ¶[0019].

[526] EX1009 (Mass-EPA) at 31, 35, 36, 49, 52, 56.

NOx."[527] Thus, a POSITA would have been motivated, with a reasonable expectation of success, to use the activated carbon injection (ACI) system and control scheme of Mass-EPA with the halogenation and coal-combustion system of Vosteen589.

291. A POSITA would have looked to Mass-EPA for practical applications of the discovery disclosed in Vosteen589 relating to the use of halogen species added to the coal or to the combustor to improve the uptake of mercury on activated carbon sorbents. A POSITA would have used "injection" (as described by Mass-EPA) as the method for introducing activated-carbon sorbent (as described by both Vosteen589 and Mass-EPA) into the mercury-containing flue gas of Vosteen589. As ACI was already "the most likely technology to be commercialized for mercury control"[528] by the time the Massachusetts EPA released its report in December 2002, the combination of Vosteen589 and Mass-EPA represents no more than combining prior art elements according to known methods to yield predictable results of removing mercury. The activated carbon injection of Mass-EPA was a "known technique" and introducing the halogens (as described in Vosteen589) would yield the predictable results in the form of improved mercury removal.

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[527] EX1009 (Mass-EPA) at 58.

[528] EX1009 (Mass-EPA) at 32.

292. A POSITA would have a reasonable expectation of success in combining Vosteen589 with Mass-EPA because, as Mass-EPA described, activated carbon injection was the "most extensively studied sorbent for mercury adsorption" and the "most likely candidate to reach commercialization for mercury removal in the near future."[529] The technology was mature, because "[e]xtensive tests have been performed at the bench, laboratory, pilot, and full scale for application of AC in the coal-fired utility boiler gas."[530] Mass-EPA concludes that the "estimated costs for <u>powdered activated carbon injection</u>-based technology, which most likely will reach commercialization for mercury control before other technologies, is within the current control costs for NOx."[531]

293. Mass-EPA further emphasizes that "research in understanding and improving mercury adsorption efficiency of activated carbons has been ongoing with the goal of improving carbon to mercury injection rates and reducing control costs."[532] Introducing the halogens (as described in Vosteen589), along with the activated carbons, would yield the predictable results in the form of improved

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[529] EX1009 (Mass-EPA) at 32.

[530] EX1009 (Mass-EPA) at 33.

[531] EX1009 (Mass-EPA) at 56.

[532] EX1009 (Mass-EPA) at 39.

mercury adsorption efficiency of activated carbons. This would allow lower amounts of activated carbon to be used for mercury collection and removal and thus lower costs.

B. DISCLOSURE AND TEACHINGS OF THE COMBINATIONS

294. It is my opinion that the combination of Vosteen589 in view of Starns (Ground A1) and the combination of Vosteen589 in view of Mass-EPA (Ground A2) each renders obvious the claims below of the Challenged Patent. I start with analyzing claim 25, because it has the fewest limitations. I then discuss claims depending from claim 25, and follow that with the remaining claims, which repeat many of the limitations of claim 25.

1. Independent Claim 25

a. Claim 25: Preamble—"A method of separating mercury from a mercury-containing gas, the method comprising:"

295. Vosteen589 discloses the preamble. The title of Vosteen589 is, "Process for removing mercury from flue gases."[533] Flue gas is an example of mercury-containing gas, and "removing mercury" refers to separating the mercury from a mercury-containing gas in order to reduce the mercury emissions. Vosteen589 describes "removal of mercury from the flue gases in a flue gas emission

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[533] EX1005 (Vosteen589) at Title.

control system downstream of the combustion," in plants such as "power stations, for example bituminous coal-fired or lignite-fired power stations.[534] Claim 1 of Vosteen589 also discloses the preamble, as shown in the highlighting below:[535]

> 1. Process for removing mercury from flue gases of high-temperature plants, in particular from power stations and waste incineration plants, characterized in that
>
> bromine and/or a bromine compound and/or a mixture of various bromine compounds is fed to the if appropriate multistage furnace and/or to the flue gas in a plant section downstream of the furnace, the temperature during the contact of the bromine compound with the flue gas being at least 500º C., preferably at least 800º C.,
>
> the combustion taking place in the presence of a sulphur compound, in particular sulphur dioxide, with or without the addition of sulphur and/or a sulphur compound and/or of a mixture of various sulphur compounds,
>
> and then the flue gas being subjected to an if appropriate multistage cleanup for removing mercury from the flue gas, which cleanup comprises a wet scrubber and/or a dry cleanup.[536]

Thus, Vosteen589 itself discloses the preamble for both Ground A1 and Ground A2.

296. In the combination of Vosteen589 with Starns (Ground A1), the combination still discloses the preamble, as the purpose of Starns is to help "coal-

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[534] EX1005 (Vosteen589) ¶¶[0007]-[0008]; see also Abstract (similar language).

[535] EX1005 (Vosteen589) at Claim 1.

[536] EX1005 (Vosteen589) at Claim 1.

fired power plants" comply with draft "mercury regulations" from the EPA and "to remove mercury."[537]

297. In the combination of Vosteen589 with Mass-EPA (Ground A2), the combination still discloses the preamble, as the purpose of Mass-EPA is to explain how controlling "mercury emissions from solid-fossil-fuel fired facilities" is indeed feasible. The Department plans, therefore, to proceed with the development of a proposed mercury emissions standard for power plants within six months of the date of this report."[538]

b. Claim 25: Element 25(a)—"combusting coal in a combustion chamber, to provide the mercury-containing gas, wherein"

298. Vosteen589 discloses this claim element. Vosteen589 discloses that one of the applications for his process is in removing mercury from a mercury-containing gas generated from the combustion of coal in a combustion chamber. For example, Vosteen589 describes experiments conducted on "a <u>coal-fired power station</u> of Bayer AG in Uerdingen, which essentially consists of a <u>slag-tap fired boiler</u> …."[539] Vosteen589 later refers to the "<u>coal-fired</u> power station of Bayer AG

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[537] EX1008 (Starns) at 2 (Abstract and Introduction).

[538] EX1009 (Mass-EPA) at 3.

[539] EX1005 (Vosteen589) ¶[0034].

in Uerdingen (see FIG. 9)" with "two parallel slag-tap fired boilers 91, 91' having temperatures in the combustion chamber around 1450ºC."[540] Vosteen589 describes his results in Figures 7 and 8 regarding the experiments conducted on "coal combustion (bituminous coal)."[541] This limitation is also disclosed in claim 1 of Vosteen589, highlighted below:[542]

> 1. Process for removing mercury from flue gases of high-temperature plants, in particular from power stations and waste incineration plants, characterized in that
>
> bromine and/or a bromine compound and/or a mixture of various bromine compounds is fed to the if appropriate multistage furnace and/or to the flue gas in a plant section downstream of the furnace, the temperature during the contact of the bromine compound with the flue gas being at least 500º C., preferably at least 800º C.,
>
> the combustion taking place in the presence of a sulphur compound, in particular sulphur dioxide, with or without the addition of sulphur and/or a sulphur compound and/or of a mixture of various sulphur compounds,
>
> and then the flue gas being subjected to an if appropriate multistage cleanup for removing mercury from the flue gas, which cleanup comprises a wet scrubber and/or a dry cleanup.

Thus, Vosteen589 itself discloses this claim element for Ground A1 and Ground A2.

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[540] EX1005 (Vosteen589) ¶¶[0046]-[0047], Fig. 9; *see also* ¶[0005] ("coal-fired power stations").

[541] EX1005 (Vosteen589) ¶[0048], Figs. 7-8.

[542] EX1005 (Vosteen589) at Claim 1.

299. Upon combination with Starns (Ground A1), the combination still discloses the claim, as the activated carbon injection (ACI) of Starns was implemented to help "coal-fired power plants" comply with draft "mercury regulations" from the EPA and "to remove mercury."[543]

300. Upon combination of Vosteen589 with Mass-EPA (Ground A2), the combination still discloses the preamble, as the purpose of Mass-EPA is to explain how controlling "mercury emissions from solid-fossil-fuel fired facilities" is indeed feasible. The Department plans, therefore, to proceed with the development of a proposed mercury emissions standard for power plants within six months of the date of this report."[544]

c. Claim 25: Element 25(b)—"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 combination thereof,"

301. Vosteen589 discloses this claim element. Vosteen589 describes adding HBr (hydrogen bromide), bromine (Br_2), and bromide compounds (such as sodium bromide, NaBr) to the coal, to the combustion chamber, or to both. Vosteen589

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[543] EX1008 (Starns) at 2 (Abstract and Introduction).

[544] EX1009 (Mass-EPA) at 1.

describes that bromine-containing ingredients are added to the combustion chamber (also referred to by Vosteen589 as a "furnace"):

> The invention relates to a process for removing mercury from flue gases of high-temperature plants, in particular from power stations and waste incineration plants, in which bromine and/or a bromine compound and/or a mixture of various bromine compounds is fed to the if appropriate multistage furnace ….[545]
>
> Particularly preferably, an aqueous solution of hydrogen bromide [HBr] or an alkali metal bromide, in particular sodium bromide [NaBr], or an aqueous solution of the alkali metal bromide is used.[546]
>
> The addition of a bromine compound and if appropriate a sulphur compound is made according to the invention to the furnace and/or to the flue gas in a plant section downstream of the furnace, the temperature during contact of the bromine compound with the flue gas being at least 500º C., preferably at least 800º C.[547]
>
> In a further embodiment of the inventive process, it is also possible to feed the bromine compound, for example an aqueous solution of hydrogen bromide or sodium bromide, at a fine dispersion to the combustion air and/or if appropriate to a recirculated substream, in particular recirculated flue gas, recirculated ash and recirculated fly ash.[548]

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[545] EX1005 (Vosteen589) ¶[0006].

[546] EX1005 (Vosteen589) ¶[0009].

[547] EX1005 (Vosteen589) ¶[0013].

[548] EX1005 (Vosteen589) ¶[0014].

Vosteen589 also describes that the bromine-containing ingredients (including a "bromine compound" and hydrogen bromide) can be added either through injection into the pre-combustion air (upstream of the furnace) or by addition to the coal itself:

> The bromine compound, for example, sodium bromide, can be added in solid form, for example as salt, or liquid form, for example as aqueous solution, to the waste mixture, coal or the like to be burnt, upstream of the furnace. [549]
>
> [I]t is also possible to feed the bromine compound, for example an aqueous solution of hydrogen bromide or sodium bromide, at a fine dispersion to the combustion air and/or if appropriate to a recirculated substream, in particular recirculated flue gas, recirculated ash and recirculated fly ash. [550]

302. This claim element is also disclosed by claims 1 and 2 of Vosteen589, highlighted below, which recite adding a bromine compound or mixture of compounds (including hydrogen bromide) to the combustion chamber (furnace): [551]

> 1. Process for removing mercury from flue gases of high-temperature plants, in particular from power stations and waste incineration plants, characterized in that
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> bromine and/or a bromine compound and/or a mixture of various bromine compounds is fed to the if appropriate multistage furnace and/or to the flue gas in a plant section downstream of the furnace, the temperature during the contact of the bromine

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[549] EX1005 (Vosteen589) ¶[0013].

[550] EX1005 (Vosteen589) ¶[0014].

[551] EX1005 (Vosteen589) at claims 1-2.

> compound with the flue gas being at least 500º C., preferably at least 800º C.,
>
> the combustion taking place in the presence of a sulphur compound, in particular sulphur dioxide, with or without the addition of sulphur and/or a sulphur compound and/or of a mixture of various sulphur compounds,
>
> and then the flue gas being subjected to an if appropriate multistage cleanup for removing mercury from the flue gas, which cleanup comprises a wet scrubber and/or a dry cleanup.
>
> 2. Process according to claim 1, characterized in that the bromine compound is an aqueous solution of hydrogen bromide and/or an alkali metal bromide, in particular sodium bromide, and/or an aqueous solution of alkali metal bromide.

Thus, Vosteen589 discloses this claim element for both Ground A1 and Ground A2.

d. Claim 25: Element 25(c)—"injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber; contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition; and"

303. This claim element is disclosed by the combination of Vosteen589 with Starns (Ground A1) and Vosteen589 with Mass-EPA (Ground A2). Vosteen589 explains that a sorbent system (dry emission system) is used to contact the mercury to form a mercury/sorbent composition and thus remove mercury from the flue gas, and even gives activated carbon as a specific example. Starns and Mass-EPA each provide additional details as to how that sorbent is introduced to a system like those of Vosteen589 and Starns, namely, activated carbon injection (ACI).

i. "injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber"

304. Vosteen589 discloses a "dry emission control system" as part of the "flue gas emission control system," which he also refers to as "cleanup of the flue gas" or as "dry cleanup."[552] Vosteen589 describes that the sorbent is introduced to the mercury-containing flue gas, downstream of the combustion chamber, and even states: "removal of mercury from the flue gases in a flue gas emission control system <u>downstream of the combustion</u> . . . ."[553] The flue gas was formed as a result of combustion of coal in the combustion chamber.

305. Vosteen589 describes that a sorbent is used for the dry emission control system, namely that the system works "based on the <u>adsorption of</u> ionic mercury compounds."[554] The halogen-containing species are used to oxidize mercury from its metallic (Hg) into its ionic form (such as $HgBr_2$),[555] because "the ionic mercury … is readily <u>adsorbable to</u> a range of adsorbents."[556] In another passage, Vosteen589

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[552] EX1005 (Vosteen589) ¶¶[0017]-[0019].

[553] EX1005 (Vosteen589) ¶[0007].

[554] EX1005 (Vosteen589) ¶[0019].

[555] EX1005 (Vosteen589) ¶[0019].

[556] EX1005 (Vosteen589) ¶[0007].

refers to using the invention in plants "which do not have a wet flue gas emission control system, but solely have a dry emission control system having a mercury <u>sorption stage</u>."[557] The processes that Vosteen589 repeatedly describes as being performed by the dry-emission control system—"adsorption" or "sorption"—are ones in which an adsorbate (e.g., atoms, ions, or molecules) in a fluid (typically a gas) become bound to the surface of the sorbent. Specific to Vosteen589, the adsorbate (e.g., mercury) in the mercury-containing flue gas is being adhered to the sorbent (e.g., activated carbon), and the activated carbon is thus contacting mercury in the mercury-containing gas to form a mercury/sorbent composition, which can then be separated from the gas stream before it is released to the atmosphere. Vosteen589 repeatedly refers to binding mercury to "adsorbents," another term for "sorbents,"[558] and provides as an exemplary sorbent "finely pulverulent slaked lime/<u>activated carbon</u>."[559]

306. Thus, Vosteen589 discloses the need for a dry-emission control system that works using sorbent including activated carbon to bind the mercury. However, Vosteen589 is not concerned with the specific details of how to implement that dry-

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[557] EX1005 (Vosteen589) ¶[0019].

[558] EX1005 (Vosteen589) ¶¶[0003], [0007], [0019].

[559] EX1005 (Vosteen589) ¶[0019].

emission control system and how to add the sorbent to the system. As explained above regarding Technology Background and State of the Art,[560] a POSITA would have readily understood how to add the activated-carbon sorbent to the system, namely by injection into the mercury-containing flue gas between the combustion chamber and the PCD (such as the ESP or fabric filter). Starns and Mass-EPA each provides these details, and a POSITA would have been motivated to combine Vosteen589 with Starns (Ground A1) and Vosteen589 with Starns (Ground A2), as discussed in the Reasons to Combine section.

(1) Ground A1 (Combination of Vosteen589 with Starns)

307. Starns describes injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber: "the overall objective of this project is to determine the capabilities of <u>injecting activated carbon</u> ahead of particle control devices (PCD) to remove mercury and to determine the cost and impacts of this technology."[561] Starns provides "injection

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[560] State of the Art, §IX.C.

[561] EX1008 (Starns) at 2 (Abstract).

equipment" that includes a "bulk-storage silo and twin blower/feeder trains ...."[562] The silo is shown below:[563]

Starns provides the details of ACI—what Starns describes as "mature" technology—to purify the mercury-containing flue gas, including how the sorbent concentration affects the mercury-removal rate. Starns describes that the type of sorbent to use is powdered activated carbon (PAC): "Four sorbents were selected for full-scale evaluation in the parametric test series. All four sorbents were PACs…."[564]

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[562] EX1008 (Starns) at 7; *see also* EX1008 (Starns) at Fig. 2.

[563] EX1008 (Starns) at 7; *see also* EX1008 (Starns) at Fig. 2.

[564] EX1008 (Starns) at 9.

(2) Ground A2 (Combination of Vosteen589 with Mass-EPA)

308. Mass-EPA describes injecting a sorbent material comprising activated carbon into the mercury-containing gas:

> In the near term, activated carbon seems the most likely technology to be commercialized for mercury control because there have been full-scale tests of this technology that have generated promising results.[565]
>
> Increased removal of mercury from gas has been demonstrated by co-injection of activated carbon and calcium-based sorbents in spray dryer adsorber systems in full-scale coal-fired power plants.[566]
>
> <u>Activated carbon (AC) has been the most extensively studied sorbent for mercury adsorption</u>. Currently, AC seems to be the most likely candidate to reach commercialization for mercury removal in the near future.[567]

Mass-EPA describes that the activated-carbon sorbent is injected downstream of the combustion chamber, in that it repeatedly refers to the activated-carbon injection as "post combustion pollution control."[568] For example, Mass-EPA states:

> <u>Post-combustion</u>, flue gas technologies employ three basic methods to capture mercury:

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[565] EX1009 (Mass-EPA) at 32.

[566] EX1009 (Mass-EPA) at 32.

[567] EX1009 (Mass-EPA) at 32.

[568] EX1009 (Mass-EPA) at 6, 21, 22, 23.

> 1) capture of particulate-bound mercury in particulate matter control devices;
>
> 2) adsorption of elemental and oxidized mercury onto sorbents for subsequent capture in particulate matter control devices; and
>
> 3) removal of soluble oxidized mercury in wet scrubbers (including processes to convert elemental to oxidized mercury for subsequent capture in wet scrubbers).[569]

Mass-EPA explains that the activated carbon is "injected." Mass-EPA discloses "activated carbon injection" in numerous other places.[570]

ii. "contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition"

309. The mercury in the flue gas is adsorbed, and thus contacted, with the sorbent to form a mercury/sorbent composition. As described above, the system works "based on the adsorption of ionic mercury compounds."[571] The halogen-containing species are used to oxidize mercury from its metallic (Hg) into its ionic form (such as $HgBr_2$),[572] because "the ionic mercury … is readily adsorbable to a

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[569] EX1009 (Mass-EPA) at 6-7.

[570] EX1009 (Mass-EPA) at 31, 35, 36, 49, 52, 56.

[571] EX1005 (Vosteen589) ¶[0019].

[572] EX1005 (Vosteen589) ¶[0019].

range of adsorbents."[573] Vosteen589 also refers to this as the "mercury sorption stage."[574] In order to be adsorbed onto the activated-carbon sorbent, the mercury must contact the sorbent.

310. Vosteen589 explains that the mercury forms a mercury/sorbent composition that comprises mercury, bromine, and activated carbon. Vosteen589 states regarding the dry emission control system, "Mercury bromide $HgBr_2$ <u>adsorbs more strongly to dry sorbents</u> than mercury chloride $HgCl_2$."[575] A person of skill in the art would have understood that the scope of a "mercury/sorbent composition" is broad enough to encompass a "mercury/sorbent/bromine" composition, because, for example, independent claim 25 of the '114 Patent recites a "mercury/sorbent composition" and its dependent claim 30 recites that "the mercury/sorbent composition comprises the element bromine, the sorbent material, and mercury."[576] Also, the title of Vosteen589 is "Process for Removing Mercury from Flue Gases," and the way mercury gets removed from a flue gas, in a dry-sorbent system, is by forming a composition with the sorbent (activated carbon) that is then removed.

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[573] EX1005 (Vosteen589) ¶[0007].

[574] EX1005 (Vosteen589) ¶[0019].

[575] EX1005 (Vosteen589) ¶[0019].

[576] EX1001 ('114 Patent) at Claims 25, 30.

311. This is also confirmed by Starns (Ground A1): through "the injection of sorbents such as powdered activated carbon (PAC) into the flue gas upstream of the particle control equipment," the "gas-phase mercury in the flue gas <u>contacts the sorbent</u> and attaches to its surface."[577]

312. This is further confirmed by Mass-EPA (Ground A2), in that "[m]ass transfer refers to the ability of the sorbent particles to contact the Hg in the flue gas."[578]

e. Claim 25: Element 25(d)—"separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas."

313. This claim element is disclosed by Vosteen589. Vosteen589 discloses "removing mercury … from flue gases."[579] Vosteen589 repeatedly refers to a flue gas <u>cleaning system</u>. In Claim 1 of Vosteen589, for example, "the flue gas being subjected to an if appropriate multistage <u>cleanup</u> for removing mercury from the flue gas, which cleanup comprises a wet scrubber and/or a dry cleanup."[580] Vosteen589 refers to "clean gas downstream of the wet and/or dry flue gas emission control

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[577] EX1008 (Starns) at 2 (Introduction).

[578] EX1009 (Mass-EPA) p. 21 n.25; see also EX1009 (Mass-EPA) p. 33 ("time available for the mercury to contact the AC [activated carbon] particle").

[579] EX1005 (Vosteen589) ¶[0005].

[580] EX1005 (Vosteen589) at Claim 1; *see also* EX1005 (Vosteen589) ¶[0006].

system."[581] This is because, as Vosteen589 discloses, an "object of the invention [is] to provide a process for removing mercury, in particular for the substantially complete removal of mercury (Hg), from flue gases of high-temperature processes."[582] The "dry cleanup stage" and "dry sorbent" includes, for example, the activated-carbon sorbent that is separated by the ESP or other PCD devices, such as a fabric filter. For the coal-fired power plants, Vosteen589 discloses that a "dry electrostatic precipitator (ESP) is used."[583] The "cleanup" and "removal" referred to by Vosteen589 in the passages above refer to separating the mercury/sorbent composition from the mercury-containing flue gas, such as with the ESP. As described for Element 25(c), a POSITA would have known, or at least found it obvious that the sorbent is a mercury/sorbent composition after it is introduced into the mercury-containing gas.

314. This limitation is also disclosed by the combination of Vosteen589 with Starns (Ground A1): The particle control devices (PCD) in Starns includes an electrostatic precipitator (ESP), and Starns recommends "using activated carbon

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[581] EX1005 (Vosteen589) ¶[0022].

[582] EX1005 (Vosteen589) ¶[0005].

[583] EX1005 (Vosteen589) ¶[0034].

injection upstream of an ESP."[584] It is a mercury/sorbent composition that is removed, because through the "injection of sorbents such as powdered activated carbon (PAC) into the flue gas upstream of the particle control equipment," the "gas-phase mercury in the flue gas contacts the sorbent and attaches to its surface."[585] A POSITA would have been motivated, as Starns suggests, to use activated carbon injection between the combustion chamber (furnace) and the ESP or fabric filter in Vosteen589, which are amongst the dry-emission control system listed in Vosteen589.[586] Each of these were well-known components in coal-fired power plants to remove particulate matter (such as the mercury/sorbent composition in Vosteen589 and Starns), as I describe above in the Technology Background and State of the Art section ("Particulate Matter Emissions Controls"). Further, to be effective, the injection must happen after the combustion zone (where the mercury-containing flue gas is generated) and before the separation system (where the sorbent is removed). The mercury-sorbent composition is separated from the mercury-containing gas by particulate control devices, such as the electrostatic precipitators (ESPs) in Vosteen589 and in Starns, to form a cleaned gas.

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[584] EX1008 (Starns) at 20.

[585] EX1008 (Starns) at 2.

[586] EX1005 (Vosteen589) ¶¶[0019], [0033], [0037], [0039], [0042], [0047]-[0049], claim 8 (discussing use of an ESP).

315. This limitation is also disclosed by the combination of Vosteen589 with Mass-EPA (Ground A2): "The particulate-bound form of mercury can be readily captured in the particulate matter (PM) control devices, i.e., electrostatic precipitators (ESPs) and fabric filters (FFs)."[587] The "particulate-bound form of mercury" refers to the mercury adsorbed onto the activated-carbon sorbent, i.e., a mercury/sorbent composition. Mass-EPA continues, "An ESP or a FF is always installed downstream of a semi-dry scrubber or dry injection point to remove the sorbent from the flue gas."[588] A POSITA would have been motivated, as Mass-EPA suggests, to use activated carbon injection between the combustion chamber (furnace) and the ESP or fabric filter in Vosteen589, which are amongst the dry-emission control system listed in Vosteen589.[589] Each of these were well-known components in coal-fired power plants to remove particulate matter (such as the mercury/sorbent composition in Vosteen589 and Mass-EPA), as I describe above in the Technology Background and State of the Art section ("Particulate Matter Emissions Controls"). Further, to be effective, the injection must happen after the combustion zone (where the mercury-containing flue gas is generated) and before

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[587] EX1009 (Mass-EPA) at 20.

[588] EX1009 (Mass-EPA) at 27.

[589] EX1005 (Vosteen589) ¶¶[0019], [0033], [0037], [0039], [0042], [0047]-[0049], claim 8 (discussing use of an ESP).

the separation system (where the sorbent is removed). The mercury-sorbent composition is separated from the mercury-containing gas by particulate control devices, such as the electrostatic precipitators (ESPs) and fabric filters in Vosteen589 and in Mass-EPA, to form a cleaned gas.

2. Claims Depending from Claim 25 (Claims 26-30)

a. Claim 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."

316. Vosteen589 discloses this claim in Ground A1 and in Ground A2. As I explain regarding Claim Element 25(b), Vosteen589 describes that bromine-containing ingredients are added to the coal, upstream of the combustion chamber.

> The bromine compound, for example, sodium bromide, can be added in solid form, for example as salt, or liquid form, for example as aqueous solution, to the waste mixture, coal or the like to be burnt, upstream of the furnace. [590]

Vosteen589 includes "bromine and/or a bromine compound and/or a mixture of various bromine compounds."[591] The "bromine" refers to molecular bromine, Br_2. Vosteen589 also discloses that the bromine compound, such as sodium bromide (NaBr) is be added to the coal:

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[590] EX1005 (Vosteen589) ¶[0013].

[591] EX1005 (Vosteen589) ¶[0006].

> The bromine compound, for example, sodium bromide, can be added in solid form, for example as salt, or liquid form, for example as aqueous solution, to the waste mixture, coal or the like to be burnt, upstream of the furnace. [592]

Aqueous hydrogen bromide HBr (aq) can also be added to the coal.[593]

b. Claim 27: "The method of claim 25, wherein the combustion chamber comprises the added Br_2, HBr, the bromide compound, or a combination thereof."

317. Vosteen589 discloses this claim in Ground A1 and Ground A2. As I explain regarding Claim Element 25(b) and claim 26, Vosteen589 describes that the combustion chamber (sometimes referred to as "furnace" or "boiler" in Vosteen589) comprises added aqueous hydrogen bromide (HBr), molecular bromine (Br_2), and bromine compounds such as sodium bromide (NaBr). And as described for claim 25(b) and claim 26, these compounds can be added to the coal (in which case they are fed to the combustion chamber), or they can be directly added to the combustion chamber.

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[592] EX1005 (Vosteen589) ¶[0013].

[593] EX1005 (Vosteen589) ¶¶[0009], [0014], [0044], claim 2.

c. Claim 28: "The method of claim 25, further comprising monitoring the mercury content of the cleaned gas; and 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 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."

318. This claim is disclosed by Vosteen589 alone (Ground A1 and Ground A2), and also by the combination of Vosteen589 with Starns (Ground A1) and the combination of Vosteen589 with Mass-EPA (Ground A2). All three references disclose the continuous monitoring of mercury concentration. Vosteen589 achieves desired mercury removal by controlling the halogen injection rate, and Starns and Mass-EPA each achieves desired mercury removal by controlling the sorbent injection rate. Both control schemes meet the limitations of Claim 28.

i. Claim Element 28(a)—"monitoring the mercury content of the cleaned gas; and 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 bromide compound, or a combination thereof, or a combination thereof"

319. Vosteen589 discloses this claim element. Vosteen589 describes monitoring mercury content of the cleaned gas (i.e., downstream of the mercury

removal system) and, in response, controlling the injection rate of halogens (Br_2, HBr, or the bromide compound).

> Preferably, in the inventive process, the mercury content of the flue gas, in particular the content of metallic mercury [i.e., elemental mercury], is measured continuously downstream of the flue gas emission control system and on the basis of the measured mercury content the amount of bromine fed and/or bromine compounds and/or the mixture of bromine compounds and if appropriate sulphur and/or sulphur substances and/or the mixture of sulphur substances is controlled. A relatively high content of metallic mercury in the flue gas is an indicator for the fact that the oxidation of mercury is proceeding incompletely and thus the mercury is being removed incompletely in the flue gas emission control system. In order to oxidize mercury as completely as possible, in such a case more bromine compound must be fed. In addition, the content of ionic mercury downstream of the flue gas emission control system can be measured and the degree of removal of ionic mercury in the flue gas emission control system can be determined therefrom.[594]

That is, if the content of mercury (either elemental and/or ionic) is too high, Vosteen589 discloses increasing the rate of addition of bromine-containing additives to the coal and combustion chamber. Vosteen589 discloses not only measuring elemental (“metallic”) mercury and using that to control halogen addition, but also total mercury content: “Continuous measurement of metallic mercury, and if appropriate also of total mercury in the clean gas downstream of the wet and/or dry

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[594] EX1005 (Vosteen589) ¶[0022].

flue gas emission control system is performed….”[595] Measurements of the mercury content are depicted in Figures 2–8 of Vosteen589,[596] and are also recited in claim 10, copied below.

> 10. Process according to one of claims 1 to 9, characterized in that the mercury content of the flue gas, in particular the content of metallic mercury, is measured continuously downstream of the flue gas emission control system and on the basis of the measured mercury content the amount of bromine fed and/or bromine compounds fed and any sulphur and/or sulphur compounds fed is controlled.[597]

Measuring mercury content of the cleaned gas is a form of monitoring the mercury.

(1) Ground A1 (Combination of Vosteen589 with Starns)

320. In addition to this element being disclosed by Vosteen589 alone, this element is also disclosed by the combination of Vosteen589 with Starns (Ground A1). It would have been obvious to implement the control scheme of Starns with Vosteen589, to give Vosteen589 the flexibility of adjusting another input (e.g., sorbent injection rate) based on the measured output (mercury content). Starns discloses a control scheme interoperable with that of Vosteen589, which is controlling the sorbent concentration in the flue gas based on mercury

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[595] EX1005 (Vosteen589) ¶[0022].

[596] EX1005 (Vosteen589) at Figs. 2-8.

[597] EX1005 (Vosteen589) at Claim 10.

measurements. A POSITA would have used such a control scheme either in place of the control scheme of Vosteen589, or in addition to that control scheme (e.g., control both sorbent concentration and halogen concentration in response to mercury measurements).

321. Starns discloses measuring "vapor phase mercury concentrations" in the flue gas using a "Semi-Continuous Emissions Monitor (S-CEM)," which was "operate[d] continuously."[598] The S-CEM was used to adjust sorbent concentration (activated carbon injection) and determine its effects on mercury removal:

> Mercury removal was monitored as a function of the sorbent injection concentration. In addition, the impact of sorbent injection on the performance of the ESP was monitored. An example of the data from the S-CEMs during the first week of parametric testing is presented in Figure 3…. Reduction and recovery of outlet mercury concentration can be seen to correlate with periods of sorbent injection.[599]

Starns plots the percentage of mercury removal against the concentration of activated carbon injected into the flue gas (in units of pounds activated carbon per million actual cubic feet of flue gas), both for the parametric testing and the long-

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[598] EX1008 (Starns) at 8.

[599] EX1008 (Starns) at 11.

term testing in Figures 3-6.[600] Exemplary Figure 4 is shown below, which shows the direct connection between mercury emissions and sorbent concentration:[601]

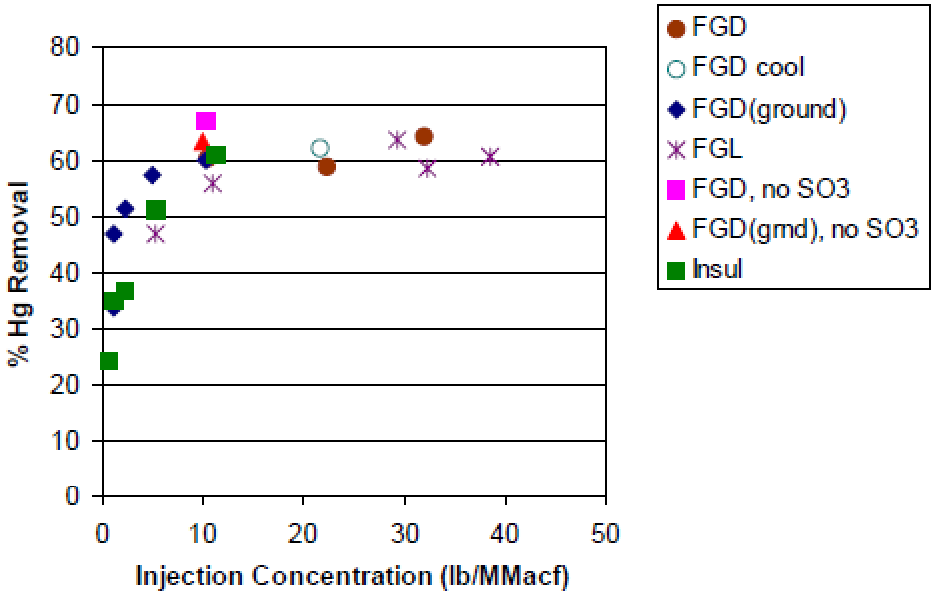
Figure 4. Mercury Removal Trends Across ESP as a Function of PAC Injection Concentrations. Measurements Made During Parametric Tests, Sept-Oct 2001.

Thus, Starns discloses continuously monitoring the mercury content of the gas in response to the sorbent concentration. Controlling the rate of addition of the sorbent <u>in response to the mercury content of</u> the cleaned gas is also obvious over Starns. A POSITA reviewing the monitoring data, as presented by Figures 3-6 of Starns, would have understood that the monitored mercury content (dependent variable in the graphs) is the information that would be used to adjust a rate of addition of the

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[600] EX1008 (Starns) at Figs. 3-6; *see also* EX1008 (Starns) at 20.

[601] EX1008 (Starns) at 13.

sorbent (the independent variable in the graphs) by either selecting a given rate or by interpolating an intermediate value in response to the monitored mercury content of the cleaned gas. Adding more sorbent than required to remove the necessary amount of mercury would be wasteful, and adding less sorbent would not achieve target limits. In operating a dry-emission control system, as in Vosteen589, a person of skill in the art would have been motivated to continuously adjust an injection concentration of the sorbent into the mercury-containing gas, in response to the monitoring of the mercury content of that gas, to provide the necessary amount of sorbent needed to remove a targeted amount of mercury. This control scheme is all the more obvious in view of the hardware disclosed by Starns: "A PLC [programmable logic controller] is used to control system operation and adjust injection rates."[602]

322. The normal desire of a POSITA to improve on a given process would have been to adjust the result-effective variable of the injection rate of the sorbent so as not to wastefully inject excessive sorbent once sufficient mercury removal was demonstrated, in order to minimize costs associated with operating the sorbent injection system. Furthermore, due to the variability of the composition of coal as a fuel source (including for example, native mercury and halogen content), as

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[602] EX1008 (Starns) at 7.

described in the State of the Art,[603] it would have been obvious that some amount of adjustment to the rate of injection of the sorbent into the flue gas would be performed as part of routine process control and optimization to account for variances in the coal.

(2) Ground A2 (Combination of Vosteen589 with Mass-EPA)

323. In addition to this element being disclosed by Vosteen589 alone, this element is also disclosed by the combination of Vosteen589 with Mass-EPA (Ground A2). It would have been obvious to implement the control scheme of Mass-EPA with Vosteen589, to give Vosteen589 the benefit of adjusting the input (e.g., sorbent injection rate) based on the measured output (mercury content). Mass-EPA discloses a control scheme interoperable with Vosteen589, controlling the sorbent concentration in the flue gas based on mercury measurements. A POSITA would have used such a control scheme either in place of the control scheme of Vosteen589, or in addition to that control scheme (e.g., control both sorbent concentration and halogen concentration in response to mercury measurements).

324. Mass-EPA discloses using a "continuous emissions monitoring systems (CEMS) to monitor stack-level Hg emissions, averaging the data over a time period

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[603] See Technology Background and State of the Art, IX.B.1.

to be specified in the standard."[604] Mass-EPA recognized that a reason to monitor mercury was to understand the sorbent injection rate to use:

> [A] fraction of a pound increase in carbon injection rate increase[es] mercury removal from the gas by [as] much as 30%.[605]
>
> With respect to both the removal trend and the sorbent costs, preliminary results for Brayton Point indicate that the higher the amount of sorbent injected, the more mercury removed, with the highest removal values during long term tests ranging from 90-93% at the highest sorbent injection rate of 20 lb/MMacf. In contrast to the other two facilities for which data are available, Brayton Point does not exhibit a sorbent injection level at which further injection of sorbent provides no further mercury removal; instead, addition of more sorbent results in additional mercury reductions over the range of sorbent injection levels tested, with an approximately linear trend. [606]

The direct connection between mercury concentration and activated-carbon injection (ACI) rate is clearly seen in Chart 2, which shows mercury removals for various ACI rates measured at three coal-fired plants, in which the X-axis is sorbent-injection rate:[607]

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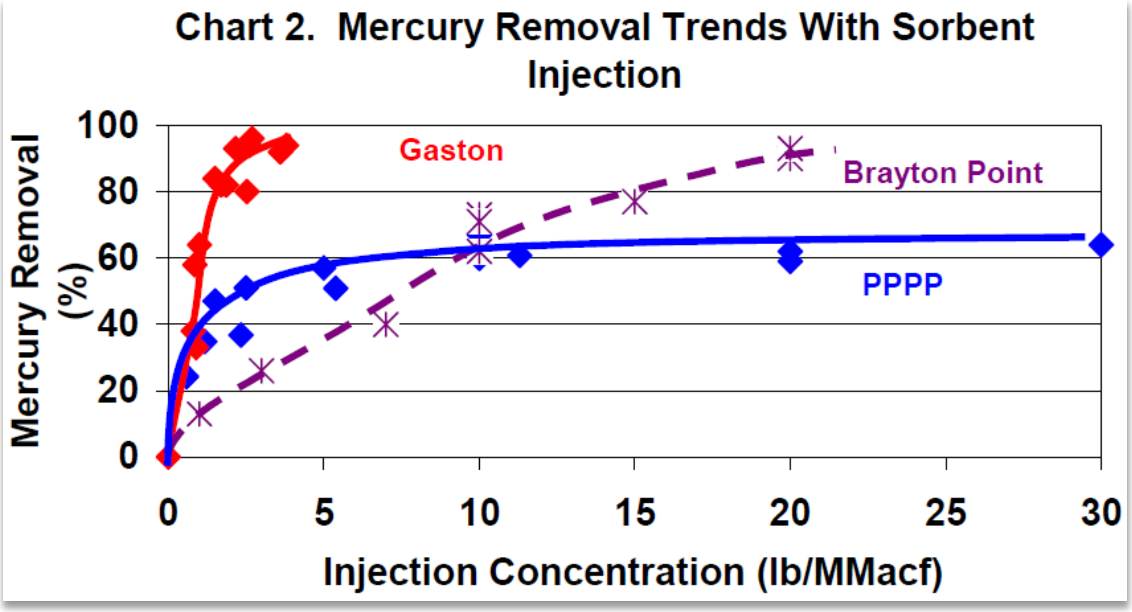
[604] EX1009 (Mass-EPA) at 60.

[605] EX1009 (Mass-EPA) at 33; *see also* p. 50 ("PAC injection rate requirements increase nonlinearly with increases in Hg removal efficiency."); p. 73 ("mercury removal as a function of [sorbent] injection rate").

[606] EX1009 (Mass-EPA) at 11.

[607] EX1009 (Mass-EPA) at 12.



Mass-EPA discusses the parametric testing as being "conducted at different sorbent, feed rate and operating conditions and were performed at full load. The areas of interest included <u>mercury removal as a function of [sorbent] injection rate</u>."[608]

325. At each plant, as shown in Chart 2, the mercury removal percentage increased (mercury concentration decreased) as the injection concentration increased, until either they approached the upper limit of 100% removal or plateau at some lower removal. The Massachusetts EPA noted that this behavior closely resembled the performance of ACI in municipal waste combustors (MWCs), which ultimately became the basis for regulating MWC operators to reduce Hg emissions by implementing ACI: "The MWCs were required to optimize the level of carbon

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[608] EX1009 (Mass-EPA) at 73.

injection by selecting a carbon injection rate above which additional amounts of carbon injection would achieve limited additional mercury control."[609] In other words, monitor mercury content and, based on that measurement, control the rate of injecting the sorbent into the mercury-containing gas.

326. Accordingly, in operating a dry-emission control system, as in Vosteen589 in combination with Mass-EPA, a person of skill in the art would have been motivated to continuously control an injection rate of the sorbent (the independent variable) into the mercury-containing gas, in response to the monitoring of the mercury content of that gas (the dependent variable), to provide the desired amount of sorbent needed to remove a targeted amount of mercury. A POSITA reviewing the monitoring data, such as the data presented by Chart 2 of Mass-EPA, would have understood that the monitored mercury content is the information that would be used to adjust a rate of addition of the sorbent by either selecting a given rate or by interpolating an intermediate value in response to the monitored mercury content of the cleaned gas. Adding more sorbent than required to remove the necessary amount of mercury would be wasteful, and adding less sorbent would not achieve target limits.

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[609] EX1009 (Mass-EPA) at 13.

327. The normal desire of a POSITA to improve on a given process would have been to adjust the result-effective variable of the injection rate of the sorbent so as not to wastefully inject excessive sorbent once sufficient mercury removal was demonstrated, in order to minimize costs associated with operating the sorbent injection system. Furthermore, due to the variability of the composition of coal as a fuel source (including for example, native mercury and halogen content), as described in the State of the Art,[610] it would have been obvious that some amount of adjustment to the rate of injection of the sorbent into the flue gas would be performed as part of routine process control and optimization to account for variances in the coal.

ii. Claim Element 28(b)—"so that the mercury content of the cleaned gas is maintained at or below a desired level."

328. Vosteen589 and the secondary references each disclose controlling the halogen addition (Vosteen589) and activated carbon injection rate (Starns and Mass-EPA) so that the mercury content of the cleaned gas is maintained at or below a desired level.

329. As discussed for Claim Element 28(a), Vosteen589 describes measuring the mercury content and then, in response to that measurement,

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[610] See Technology Background and State of the Art, § IX.B.1.

controlling process parameters (e.g., rates of addition of bromine-containing components) to achieve those limits. Measurements of the mercury content are depicted in Figures 2–8 of Vosteen589, and also in Claim 10.[611] Vosteen589 further describes maintaining mercury content of the cleaned gas below desired levels, including those imposed by regulatory authorities. For example, Vosteen589 mentions that "strict limiting values exist for the legally permissible emission of mercury, for example from incineration plants and power stations."[612] Vosteen589 discusses the need that his invention provided a solution for "further reduction of the currently permitted limiting values" of mercury emissions.[613] Limiting values and legally required limits for mercury are each examples of a "desired level."

(1) Ground A1 (Combination of Vosteen589 with Starns)

330. In addition to this element being disclosed by Vosteen589 alone, this element is also disclosed by the combination of Vosteen589 with Starns (Ground A1). Starns also discusses maintaining mercury content of the cleaned gas below a desired level based on activated carbon injection rate:

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[611] EX1005 (Vosteen589) at Figs. 2-8, Claim 10.

[612] EX1005 (Vosteen589) ¶[0002].

[613] EX1005 (Vosteen589) ¶[0002].

> Effective mercury removal between 40 – 50% was obtained at 1 lb/MMacf.
>
> Effective mercury removal between 50 – 60% was obtained at 3 lb/MMacf.
>
> Effective mercury removal between 60 – 70% was obtained at 10 lb/MMacf.[614]

The units above refer to pounds sorbent (activated carbon) per 1 million actual cubic feet of flue gas.

331. As I discuss in the State of the Art, the EPA and other regulatory bodies proposed rules that, upon implementation, would have required mercury emissions reductions by 70% (which was achieved by Starns and surpassed by Vosteen589). In trying to ensure their plants were compliant upon eventual implementation and promulgation of the EPA rules, a person of skill in the art would have been motivated, and it would have been obvious, to keep mercury emissions below the desired levels proposed by regulatory authorities in order to avoid paying regulatory fines and other penalties that would incur upon rule implementation.

(2) Ground A2 (Combination of Vosteen589 with Mass-EPA)

332. In addition to this element being disclosed by Vosteen589 alone, this element is also disclosed by the combination of Vosteen589 with Mass-EPA

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[614] EX1008 (Starns) at 20; *see also* Figs. 4-5 (graphing mercury removal vs. sorbent injection rate).

(Ground A2). The Massachusetts EPA surveyed several proposed rules at the federal level in various stages of development, but also concluded that, "In the face of these uncertain federal requirements,…the Department plans to propose emission standards for mercury within six months of completing this feasibility evaluation, notwithstanding the federal MACT process."[615] The Conference of New England Governors and Eastern Canadian Premiers (NEG/ECP), which MA belongs to, adopted a Mercury Action Plan in 1998.[616] The goals of this Plan were explicit: "In 2001, after an evaluation of the interim goal, the NEG/ECP adopted another interim goal of an overall reduction of 75% or greater by 2010, with an evaluation in 2005 to allow for new information to be taken into account and to revise the target if necessary."[617] A person of ordinary skill in the art would have been motivated to target at least this "overall reduction of 75% or greater mercury removal, which is keeping the mercury content at or below a desired level. In trying to ensure their plants were compliant upon eventual implementation and promulgation of the EPA rules (including Mass-EPA rules), a person of skill in the art would have been motivated, and it would have been obvious, to keep mercury emissions below the

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[615] EX1009 (Mass-EPA) at 5.

[616] EX1009 (Mass-EPA) at 5.

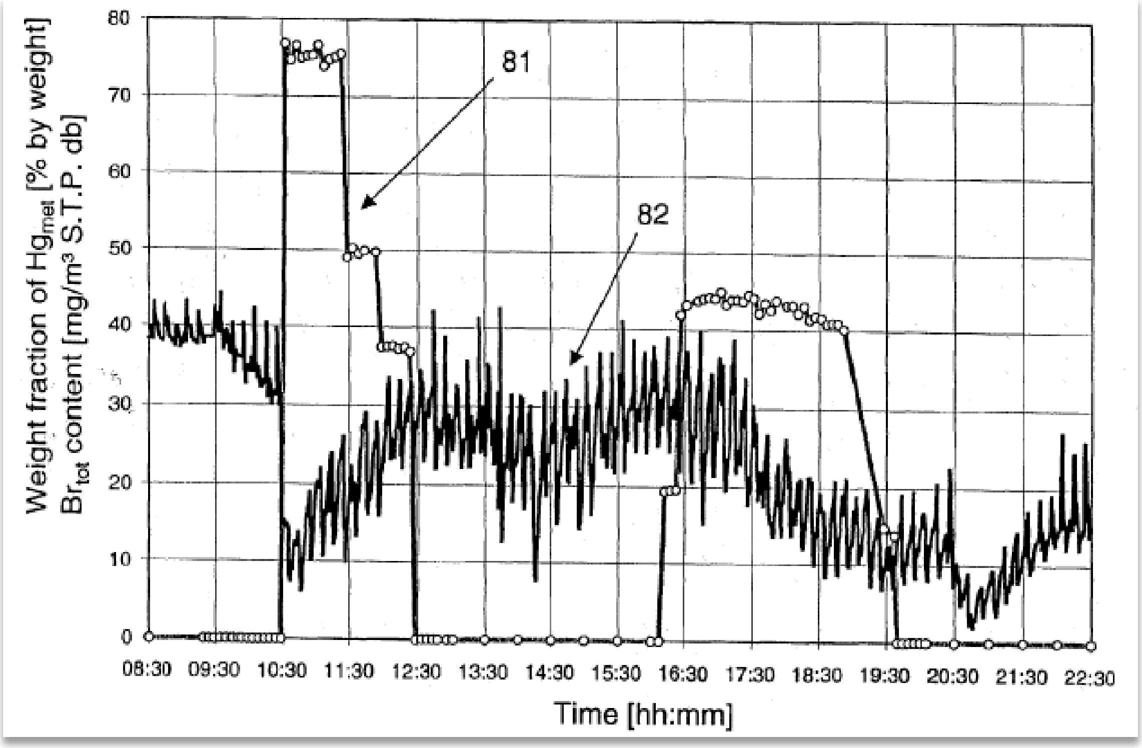
[617] EX1009 (Mass-EPA) at 5.

desired levels proposed by regulatory authorities in order to avoid paying regulatory fines and other penalties that would incur upon rule implementation.

d. Claim 29: "The method of claim 25, wherein the mercury-containing gas comprises about 1 g to about 30 g of the element bromine per 100 g of the sorbent."

333. This claim element is disclosed by the combinations of Vosteen589 with Starns (Ground A1) and Vosteen589 with Mass-EPA (Ground A2).

334. Vosteen589 describes in connection with Figure 8 (copied below), that he sought "to demonstrate the effect of bromine on mercury removal in a coal-fired power station of Bayer AG in Uerdingen."[618]



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[618] EX1005 (Vosteen589) ¶[0046], Fig. 8.

In curve 82 above, Vosteen589 plots the ratio of elemental mercury (Hg_{met}) to the total mercury (Hg_{tot}, which is elemental + oxidized) as a function of time.[619] In Figure 8, Vosteen589 also plots "the total bromine content (Br_{tot}) in the boiler flue gas in mg/m^3 S.T.P. db (curve 81) as a function of time."[620] The units of mg/m^3 S.T.P. db refer to milligrams of the element bromine (Br) per cubic meter of mercury-containing flue gas, on a dry basis at standard temperature (25 ºC) and standard pressure (1 atm). Vosteen589 explains the amount of bromine added:

> [A]t 10:30, then the addition of bromine to the combustion chamber was also started (as aqueous NaBr solution). …. Curve 81 in FIG. 8 depicts the increase in Br content in the boiler flue gas induced by adding aqueous NaBr solution. At 10:30 the bromine content in the flue gas upstream of the ESP was initially increased by at least 75 mg/M^3 S.T.P. db and decreased again stepwise. At 16:10, there was a renewed increase in bromine content by approximately 43 mg/M^3 S.T.P. db.[621]

Thus, Vosteen589 discloses two values for the concentration of bromine in the flue gas: 43 and 75 mg/M^3 S.T.P. db. Vosteen589 also discloses "the flue gas volume flow rate" of $110x10^3$ m^3 S.T.P. db/hr.[622]

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[619] EX1005 (Vosteen589) ¶[0031].

[620] EX1005 (Vosteen589) ¶[0031].

[621] EX1005 (Vosteen589) ¶[0048].

[622] EX1005 (Vosteen589) ¶[0048].

335. Vosteen589 also describes that activated carbon is used in his system,[623] but does not expressly state the injection rate of activated carbon into the system downstream of the combustion chamber. A person of ordinary skill in the art would have known to use, or at least start with as a first approximation, widely accepted values for injection rates of activated carbon. As described above,[624] it was routine in the industry to use injection rates of activated carbon of around 10 pounds/MMacf (million actual cubic feet of flue gas) to capture mercury.

336. This injection rate is further confirmed in Ground A1, as this is the value that Starns uses to obtain maximum mercury removal:

> Effective mercury removal between 40 – 50% was obtained at 1 lb/MMacf.
>
> Effective mercury removal between 50 – 60% was obtained at 3 lb/MMacf.
>
> Effective mercury removal between 60 – 70% was obtained at 10 lb/MMacf.[625]

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[623] EX1005 (Vosteen589) ¶[0019].

[624] *See* Technology Background and State of the Art, § IX.C.5.

[625] EX1008 (Starns) at 20.

337. This injection rate is also confirmed in Ground A2, as Mass-EPA also discloses sorbent injection rates at 10 lbs/MMacf.[626]

338. Regarding Ground A1 and Ground A2, based on the data presented by Vosteen589 of 43 mg bromine per m^3 of flue gas S.T.P. db[627], and a standard and well-known injection rate of activated carbon of around 10 pounds/MMacf (as described in each of Starns and in Mass-EPA), a person of ordinary skill in the art would have used, or at least tried using, a mercury-containing gas that comprises about 20 grams of the element bromine per 100 grams of sorbent, which is within the claimed range of 1-30 grams bromine per 100 grams sorbent. I explain my calculations below.

339. In order to determine a ratio of bromine concentration in the flue gas to activated carbon in the flue gas, the concentrations must have the same units—such as grams per actual cubic feet (ACF) or pounds per million actual cubic feet (MACF). Vosteen589 provides the gas-phase concentration of bromine in units of mg/m^3 Standard Temperature and Pressure (STP) dry basis (db). Activated-carbon injection concentrations were typically provided in pounds (lbs.) per million actual

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[626] EX1009 (Mass-EPA) at 73 (Brayton Point testing); p. 12 (Chart 2, showing Gaston, Brayton Point, and Pleasant Prairie).

[627] EX1005 (Vosteen589) ¶[0048].

cubic feet (MACF) of flue gas, as in Starns. Converting between the two would have been a routine calculation at a power plant to a POSITA and would have involved such basic concepts as the ideal gas law (to convert concentrations between temperatures and pressures), which would have been taught in first semester undergraduate chemistry to a person of skill in the art.[628] Such unit conversion would have also involved basic engineering knowledge of a power-plant operation, such as a typical flue gas temperature, pressure, and moisture content. Each of these would have been well-known to a person of skill in the art.

340. A person of skill in the art would have known that a typical flue gas has approximately 10% water content by volume. As such, volume on an actual basis equals (volume on a dry basis) / 0.9. A person of ordinary skill in the art would have understood that ten percent is a nominal value for moisture in flue gas because moisture levels diminish for coals of progressively higher rank. It was known, for example, that lignite and subbituminous coals can produce flue gas with 15 % moisture or greater, and anthracites can produce as little as 5 % moisture or less.[629]

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[628] *See* Technology Background and State of the Art ("Common Units of Measurement"), §IX.A.9.

[629] EX1027 (B&W: Steam) at 8-5 to 8-6.

For example, estimates for a low volatile bituminous coal gave 8.1 % moisture in flue gas.[630]

341. Regarding the second conversion, a person of skill in the art would have understood from the ideal gas law (PV = nRT) that the density of a gas is proportional to pressure and inversely proportional to temperature. A person of skill in the art would have learned from undergraduate chemistry that standard temperature and pressure (STP) refers to 25 ºC (298 K) and 1 atm, respectively, and would have known that a typical flue gas temperature where sorbent would be injected is 150 ºC (413 K) and also 1 atm of pressure. In fact, Starns (Ground A1) discloses a temperature of 290 ºF, which is 143 ºC (416 K).[631] Mass-EPA (Ground A2) also discloses "flue gas temperatures range from 284 to 320ºF (140 to 160°C)."[632] A person of ordinary skill in the art would have understood that this temperature is a typical value for sorbent injection downstream of an air preheater and upstream of an ESP or fabric filter. A POSITA would have known that air preheaters typically do not operate with outlet gas temperatures below the acid dew

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[630] EX1005 (Vosteen589) ¶[0008] ("bituminous coal-fired or lignite-fired power stations").

[631] EX1008 (Starns) at 10.

[632] EX1009 (Mass-EPA) at 26.

points of sulfuric acid, which are given as 120 – 150°C.[633] Thus, a temperature of 416 Kelvin (142ºC) is used for the calculations, as this temperature is disclosed by Starns and within the range disclosed by Mass-EPA. Last, a person of ordinary skill in the art would have found in readily available tables of unit conversions that 1 m^3 = 35.3 ft^3.

342. Accordingly, 43 mg / m^3 S.T.P. db (as disclosed by Vosteen589, and which equals 0.043 g / m^3 S.T.P. db) and at a temperature of 416 K (the temperature of flue gas where the activated carbon is injected, as in Starns and Mass-EPA) converts to the following in terms of grams bromine / million actual cubic feet.

$$\frac{0.043\ gBr}{1\ m^3_{STP.DB}} \times \left(\frac{0.9m^3_{STP.DB}}{1.0m^3_{STP}}\right) \times \left(\frac{298K\ std}{416K\ act}\right) \times \left(\frac{1m^3}{35.3ft^3}\right) \times \left(\frac{10^6 ACF}{1\ MACF}\right) = 785.3\,\frac{g\ Br\ element}{MACF\ flue\ gas}$$

343. A person of ordinary skill in the art would have also been readily able to convert pounds activated carbon to grams activated carbon (and vice versa) through the well-known unit conversion that there are 453.592 grams per pound. Accordingly, at a typical activated-carbon injection rate of 10 pounds per MACF, as in Starns and in Mass-EPA, the injection rate of activated carbon would equal:

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[633] EX1027 (B&W: Steam) at 19-11.

$$10\,\frac{pounds\ PAC}{MACF} \times \frac{453.592\ grams}{pound} = 4{,}536\,\frac{grams\ PAC}{MACF}$$

Dividing the two rates—the bromine concentration of Vosteen589 (43 mg / m^3 S.T.P. db) with the activated carbon concentration of Starns and Mass-EPA (10 lb/MMacf)—provides a mercury-containing gas that comprises about 17.3 grams of the element bromine per 100 grams of activated-carbon sorbent, which is within the range of 1 gram to 30 grams. And even if one were to use the highest sorbent injection rate tested in Chart 2 of Mass-EPA, which is 30 lb/MMacf,[634] the ratio would still be 5.8, which is within the claimed range. And if one were to use the higher bromine concentration disclosed in Vosteen589 (75 mg/M^3 S.T.P. db)[635] with 10 lbs/MMacf sorbent, that would still provide a mercury-containing gas that comprises about 29.6 grams of the element bromine per 100 grams of activated-carbon sorbent, which is within the range of 1 gram to 30 grams.

344. It would have been obvious to try other ratios, such as by increasing the halogen concentration (while reducing the activated carbon injection), or decreasing the halogen concentration (while increasing the active carbon injection) as part of routine process optimization to achieve the desired mercury removal. Claim 29 is

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[634] EX1009 (Mass-EPA) at 12.

[635] EX1005 (Vosteen589) ¶[0048].

merely an attempt to claim a broad workable range for combining a conventional halogen (bromine) being used in a conventional way with a conventional sorbent (to oxidize mercury and promote activated carbon). Nothing in the ’114 Patent specification attributes significance to the claimed range, or establishes that the claimed range “achieves unexpected results.” The range presents nothing more than optimization of “result-effective” variables that would have been obvious to a POSITA.

e. Claim 30: “The method of claim 25, wherein the mercury/sorbent composition comprises the element bromine, the sorbent material, and mercury.”

345. This claim element is disclosed by the combination of Vosteen589 with Starns (Ground A1) and Vosteen589 with Mass-EPA (Ground A2).

346. As described above, the system in Vosteen589 works “based on the <u>adsorption of</u> ionic mercury compounds.”[636] The halogen-containing species are used to oxidize mercury from its metallic (Hg) into its ionic form (such as $HgBr_2$),[637] because “the ionic mercury … is readily <u>adsorbable to</u> a range of adsorbents.”[638]

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[636] EX1005 (Vosteen589) ¶¶[0017]-[0019].

[637] EX1005 (Vosteen589) ¶[0019].

[638] EX1005 (Vosteen589) ¶[0007].

Vosteen589 also refers to this as the “mercury sorption stage.”[639] In order to be adsorbed onto the activated-carbon sorbent, the mercury must contact the sorbent. Vosteen589 explains that the mercury forms a mercury/sorbent composition that comprises mercury, bromine, and activated carbon. Vosteen589 states regarding the dry emission control system, “Mercury bromide $HgBr_2$ <u>adsorbs more strongly to dry sorbents</u> than mercury chloride $HgCl_2$.”[640] Also, the title of Vosteen589 is “Process for Removing Mercury from Flue Gases,” and the way mercury gets removed from a flue gas, in a dry-sorbent system, is by forming a composition with the sorbent (activated carbon) that is then removed.

347. This claim limitation is also confirmed by Starns (Ground A1): through “the injection of sorbents such as powdered activated carbon (PAC) into the flue gas upstream of the particle control equipment,” the “gas-phase mercury in the flue gas <u>contacts the sorbent</u> and attaches to its surface.”[641]

348. This claim limitation is further confirmed by Mass-EPA (Ground A2): “Gaseous mercury adsorbs onto injected carbon, and the particulate matter is then

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[639] EX1005 (Vosteen589) ¶[0019].

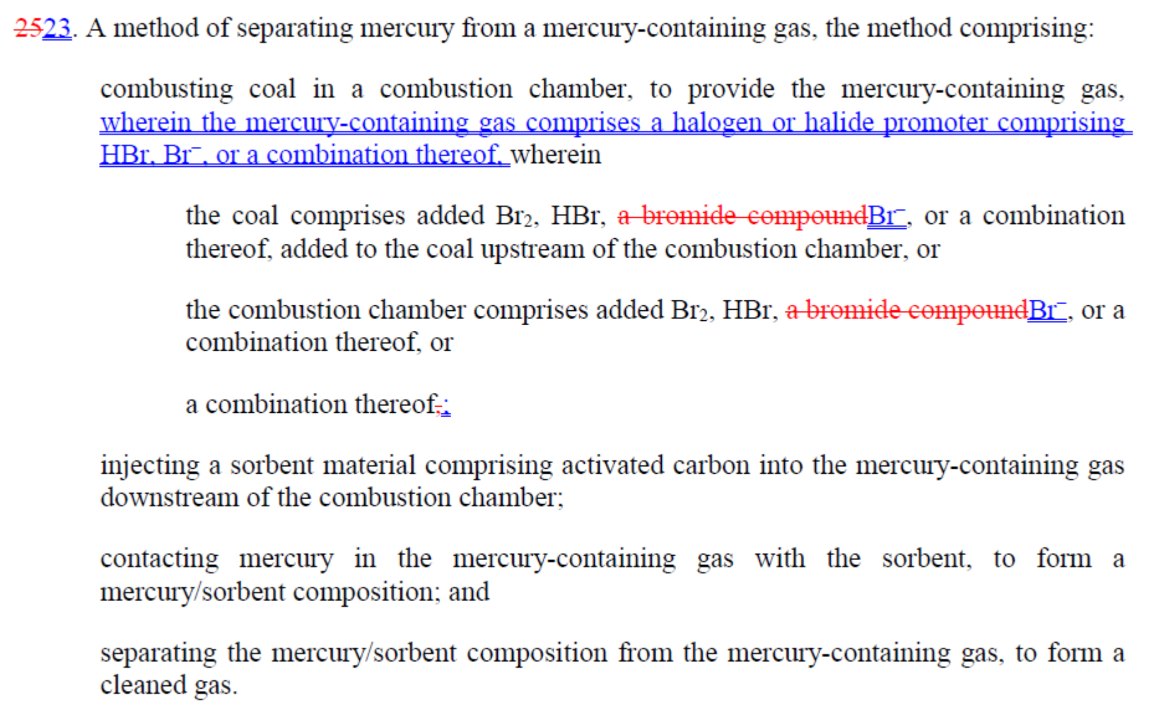
[640] EX1005 (Vosteen589) ¶[0019].

[641] EX1008 (Starns) at 2 (Introduction).

removed in the PM control device."[642] "Both elemental and oxidized mercury adsorb onto porous solids such as fly ash, powdered activated carbons (PAC),"[643] though oxidized mercury (i.e., through halogenation in Vosteen589) adsorbs better: "Hg^{2+} is believed to be more readily captured by adsorption than Hg^0."[644]

3. Independent Claim 23

349. As shown in the redline below, claim 23 is nearly identical to claim 25, with minor changes.



~~25~~23. A method of separating mercury from a mercury-containing gas, the method comprising:

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

the coal comprises added Br_2, HBr, ~~a bromide compound~~Br^-, 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~~Br^-, or a combination thereof, or

a combination thereof~~,~~;

injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber;

contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition; and

separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas.

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[642] EX1009 (Mass-EPA) at 13.

[643] EX1009 (Mass-EPA) at 20.

[644] EX1009 (Mass-EPA) at 24.

Accordingly, my analysis provided for claim 25 applies to claim 23.

a. Claim 23: Preamble—"A method of separating mercury from a mercury-containing gas, the method comprising:"

350. The language of the preamble of claim 23 is identical to the preamble of claim 25. Accordingly, the explanation I provide above for the preamble of claim 25 applies equally to the preamble of claim 23.

b. Claim 23: Element 23(a)—"combusting coal in a combustion chamber, to provide the mercury-containing gas, wherein"

351. The language of Claim Element 23(a) is identical to the language of Claim Element 25(a). Accordingly, the explanation I provide above for Claim Element 25(a) applies equally to Claim Element 23(a).

c. Claim 23: Element 23(b)—"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 coal upstream of the combustion chamber, or the combustion chamber comprises added Br_2, HBr, Br^-, or a combination thereof, or a combination thereof;"

352. The language of Claim Element 23(b) is similar to the language of Claim Element 25(b), and I refer to my discussion of that claim element. Claim 23(b) has the following changes, as compared to claim 25(b):

> 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^{--}~~, 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, Br^{--}~~, a bromide compound,~~ or a combination thereof,
>
> or a combination thereof;

353. Claim Element 23(b) is disclosed by Vosteen589 in Ground A1 and Ground A2. The claim recites examples of chemicals that qualify as halogen or halide promoters—"a halogen or halide promoter comprising HBr, Br^-, or a combination thereof"—and Vosteen589 discloses these express examples. As described above for Claim Element 25(b), Vosteen589 discloses adding to the combustion chamber and/or coal aqueous hydrogen bromide (HBr), bromide compounds in solid or aqueous form (e.g., sodium bromide, NaBr), molecular bromine (Br_2), and mixtures thereof. Vosteen589 also discloses adding a bromide ion (Br^-) to the coal and to the combustion chamber in the form of aqueous solutions of hydrogen bromide and sodium bromide, each of which dissociates in water to form bromide ions (Br^-).[645] At least a portion of the Br added to the coal and/or combustion chamber would have vaporized in the combustion chamber and reacted to form vapor-phase HBr in the combustion chamber. When bromine-containing

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[645] EX1005 (Vosteen589) ¶¶[0006], [0009], [0013], [0014].

species (e.g., HBr) and carbon come into contact with each other, the bromine acts as a promoter.[646]

354. At the temperatures of the combustion chamber and flue gas, at least the molecular bromine (Br_2) and hydrogen bromide (HBr) are each vaporized and thus present in the gas-phase in mercury-containing flue gas. The boiling point of Br_2 is only 58.8ºC (it is a fuming liquid at room temperature), and the boiling point of hydrogen bromide is -66.38ºC (i.e., it is a gas at room temperature).[647] For example, the flue gas in Starns (Ground A1) is typically at a temperature of 290ºF, which is 143ºC.[648] The flue gas in Mass-EPA (Ground A2) ranges from 284 to 320ºF (140-160ºC) after the air heater or 350-450ºC before the air heater.[649] These temperatures are well-above the limit at which the mercury-containing gas would be in the gas phase, and the halogen promoters (such as HBr and Br_2) would likewise be vaporized.

355. For example, Vosteen589 describes applying aqueous hydrogen bromide (HBr) to the coal and into the combustion chamber, and at combustion

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[646] *See* Technology Background and State of the Art, §IX.C.3, §IX.G.2.

[647] EX1036 (CRC Press: March 2005) at 4-53 and 4-65.

[648] EX1008 (Starns) at 10.

[649] EX1009 (Mass-EPA) at 26.

temperatures (much greater than the boiling point of water), the HBr evaporates into the gas phase, such that the mercury-containing gas also includes HBr. Vosteen589 further describes that the mercury-containing gas contains a halogen or halide promoter (e.g., bromine-containing species). For example, Figures 2, 5, 6, and 8 of Vosteen589 each display the concentration of bromine and mercury in the flue gas.[650] Vosteen589 confirms that bromine-containing species are present in the mercury-containing gas, stating "that the mass ratio of bromine to mercury in the flue gas is in the range from 10^2 to 10^4."[651]

356. In addition to adding the bromine-containing materials to the combustion chamber and/or coal, as discussed above, Vosteen589 discloses that the bromine-containing materials can also be added directly to the mercury-containing gas:

> In a further embodiment of the inventive process, it is also possible to feed the bromine compound, for example an aqueous solution of hydrogen bromide or sodium bromide, at a fine dispersion to the combustion air and/or if appropriate to a recirculated substream, in particular recirculated flue gas, recirculated ash and recirculated fly ash.[652]

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[650] EX1005 (Vosteen589) at [0025], [0028], [0031] (describing Figures 2, 5, 6, and 8).

[651] EX1005 (Vosteen589) at Claim 5.

[652] EX1005 (Vosteen589) ¶[0014].

A recycled flue gas stream is an example of a mercury-containing gas, as exemplified by Claim 1 and dependent Claim 3 of Vosteen589:

> 1. Process for <u>removing mercury from flue gases</u> of high-temperature plants, in particular from power stations and waste incineration plants, characterized in that bromine and/or a bromine compound and/or a mixture of various bromine compounds is fed to the if appropriate multistage furnace and/or to the flue gas in a plant section downstream of the furnace.
>
> 3. Process according to one of claims 1 to 2, characterized in that the bromine compound and/or the mixture of bromine compounds are liquid and/or solid high-bromine wastes.[653]

Thus, the "flue gases" contain mercury, and the bromine compounds are added to the "furnace <u>and/or</u> to the flue gas."

d. Claim 23: Element 23(c)—"injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber; contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition; and"

357. The language of Claim Element 23(c) is identical to the language of Claim Element 25(c). Accordingly, the explanation I provide above for Claim Element 25(c) applies equally to Claim Element 23(c).

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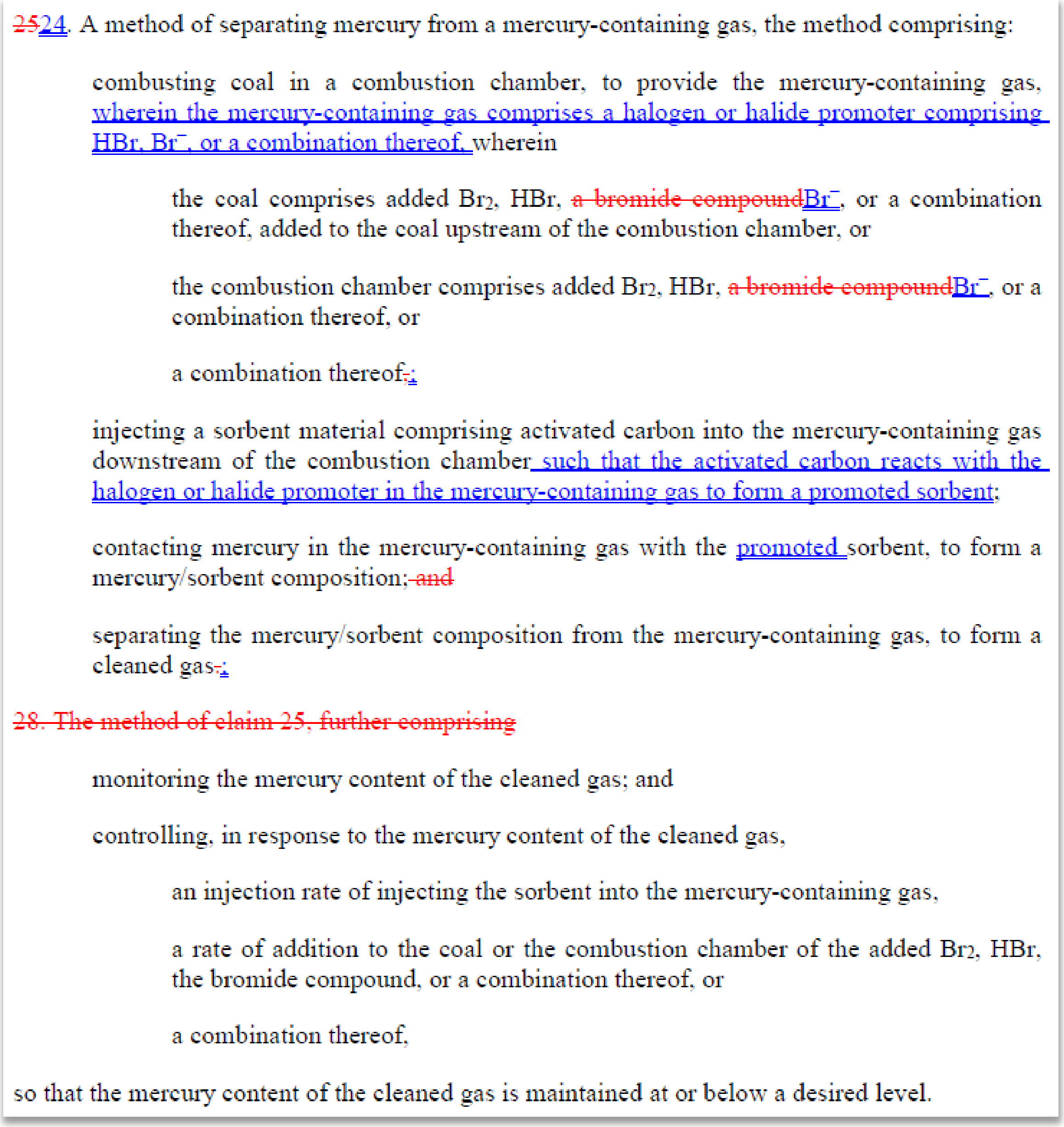
[653] EX1005 (Vosteen589) at Claims 1(emphasis added), 3.

e. Claim 23: Element 23(d)—"separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas."

358. The language of Claim Element 23(d) is identical to the language of Claim Element 25(d). Accordingly, the explanation I provide above for Claim Element 25(d) applies equally to Claim Element 23(d).

4. Independent Claim 24

359. As shown in the redlines below, claim 24 is nearly identical to claims 25 and 28, with minor changes.



~~25~~24. A method of separating mercury from a mercury-containing gas, the method comprising:

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

the coal comprises added Br_2, HBr, ~~a bromide compound~~Br^-, 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~~Br^-, or a combination thereof, or

a combination thereof~~,~~;

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;

contacting mercury in the mercury-containing gas with the promoted sorbent, to form a mercury/sorbent composition;~~ and~~

separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas~~.~~;

~~28. The method of claim 25, further comprising~~

monitoring the mercury content of the cleaned gas; and

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 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.

Claim 24 combines limitations of claim 23 ("wherein the mercury-containing gas comprises …) and claims 25 and 28. Accordingly, as discussed below, my analysis already provided for claims 23, 25, and 28 also applies to claim 24.

a. Claim 24: Preamble—"A method of separating mercury from a mercury-containing gas, the method comprising:"

360. The language of the preamble of claim 24 is identical to the preamble of claim 23 (which is identical to the preamble of claim 25). Accordingly, the explanation I provide above for the preambles of claims 25 and 23 applies equally to the preamble of claim 24.

b. Claim 24: Element 24(a)—"combusting coal in a combustion chamber, to provide the mercury-containing gas, wherein"

361. The language of Claim Element 24(a) is identical to the language of Claim Element 23(a) (which is identical to Claim Element 25(a)). Accordingly, the explanation I provide above for those claim elements applies equally to Claim Element 24(a).

c. Claim 24: Element 24(b)—"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 coal upstream of the combustion chamber, or the combustion chamber comprises added Br_2, HBr, Br^-, or a combination thereof, or a combination thereof;"

362. The language of Claim Element 24(b) is identical to the language of Claim Element 23(b). Accordingly, the explanation I provide above for Claim Element 23(b) applies equally to Claim Element 24(b).

d. Claim 24: Element 24(c)—"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; contacting mercury in the mercury-containing gas with the promoted sorbent, to form a mercury/sorbent composition;"

363. The language of Claim Element 24(c) is similar to the language of Claim Element 23(c) (which is identical to the language of Claim Element 25(c)), and I refer to my discussion of those claim elements. Claim element 24(c) has the following changes:

> 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;
>
> contacting mercury in the mercury-containing gas with the promoted sorbent, to form a mercury/sorbent composition; ~~and~~

The limitations added to claim 24(c) are disclosed because a mercury/sorbent/bromine composition is formed. As described above with respect to claim 30, Vosteen589 describes (for Ground A1 and Ground A2) that a mercury/sorbent/bromine composition is formed (which thus includes a mercury/sorbent composition), in that the "mercury bromide ($HgBr_2$) adsorbs" to the activated carbon.[654] For example, it was well known that halides improved mercury capture both by: oxidizing elemental mercury (Hg^0) to the more easily removed Hg^{2+} form, and also by enhancing the reactivity of activated carbon to mercury. A POSITA would have also known that on account of the enhanced reactivity of activated carbon to mercury, the sorbent/halogen composition would have been considered a "promoted" sorbent. A POSITA would have also understood that the sorbent and halogen would have reacted to form at least a quantity of promoted sorbent upon contact.[655]

364. Specifically, by 2003, it was well-known to a POSITA that halides "improve[d] Hg capture both by conversion of the Hg^0 to the more easily removed Hg^{2+} forms and by enhancing the reactivity of Hg^0 with activated carbons."[656] As described in my Technology Background section,[657] this was done with two mechanisms: by oxidizing the mercury (thus rendering it more susceptible to removal), and also by increasing the capacity of activated carbon to bind with the mercury. Thus, the halogen or halide promoter is reacting with both the activated

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[654] EX1005 (Vosteen589) ¶[0019].

[655] See Technology Background and State of the Art, §IX.C.3, § IX.G.2.

[656] EX1062 (Crocker) at 2-3.

[657] See Technology Background and State of the Art, §IX.C.32.

carbon and with the mercury. "Both elemental and oxidized mercury adsorb onto porous solids such as fly ash, powdered activated carbons (PAC),"[658] though oxidized mercury (i.e., through halogenation in Vosteen589) adsorbs better: "Hg^{2+} is believed to be more readily captured by adsorption than Hg^0."[659] A POSITA would have known that the introduction of halogens helped remove mercury by increasing the ability of the activated carbon to bind with the mercury. Further, through enhanced reactivity between mercury and activated carbon because of the halogens (bromine), a POSITA would have known that the sorbent/halogen complex would have been referred to as a "promoted" sorbent.

e. Claim 24: Element 24(d)—"separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas;"

365. The language of Claim Element 24(d) is identical to the language of Claim Element 23(d) (which is identical to the language of Claim Element 25(d)). Accordingly, the explanation I provide above for those claim elements applies equally to Claim Element 24(d).

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[658] EX1009 (Mass-EPA) at 20.

[659] EX1009 (Mass-EPA) at 24.

f. Claim 24: Element 24(e)—"monitoring the mercury content of the cleaned gas; and"

366. The language of Claim Element 24(e) is identical to the language of Claim Element 28(a). Accordingly, the explanation I provide above for Claim Element 28(a) applies equally to this claim element.

g. Claim 24: Element 24(f)(1)—"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 bromide compound, or a combination thereof, or a combination thereof,"

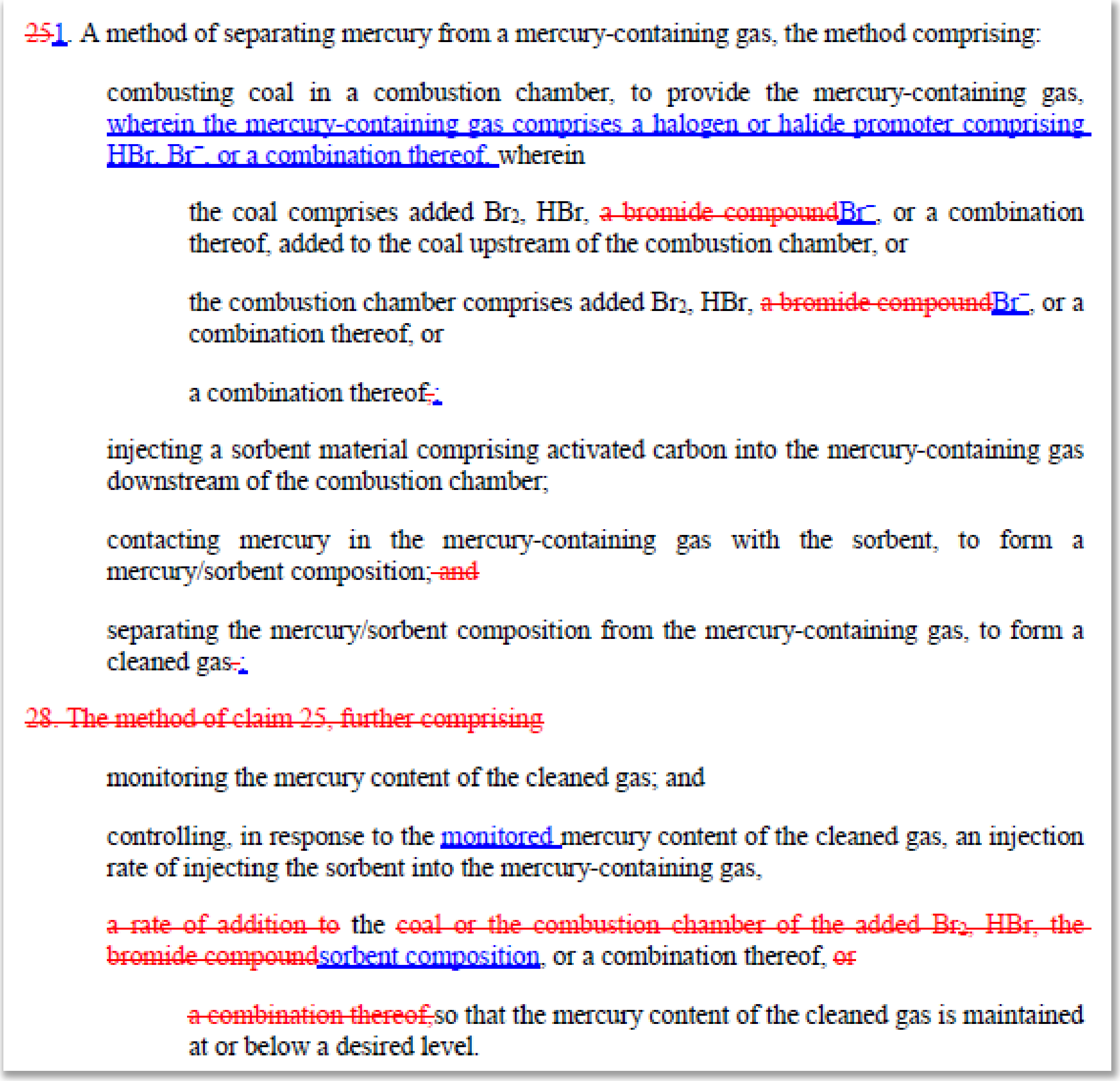
367. The language of Claim Element 24(f)(1) is identical to the language of Claim Element 28(a). Accordingly, the explanation I provide above for Claim Element 28(a) applies equally to this claim element.

h. Claim 24: Element 24(f)(2)—"so that the mercury content of the cleaned gas is maintained at or below a desired level."

368. The language of Claim Element 24(f)(2) is identical to the language of Claim Element 28(b). Accordingly, the explanation I provide above for Claim Element 28(b) applies equally to this claim element.

5. <u>Independent Claim 1</u>

369. As shown in the redlines below, claim 1 is nearly identical to claims 23 and 25/28, with minor changes.



~~25~~1. A method of separating mercury from a mercury-containing gas, the method comprising:

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

the coal comprises added Br_2, HBr, ~~a bromide compound~~Br^-, 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~~Br^-, or a combination thereof, or

a combination thereof~~,~~;

injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber;

contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition;~~ and~~

separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas~~.~~;

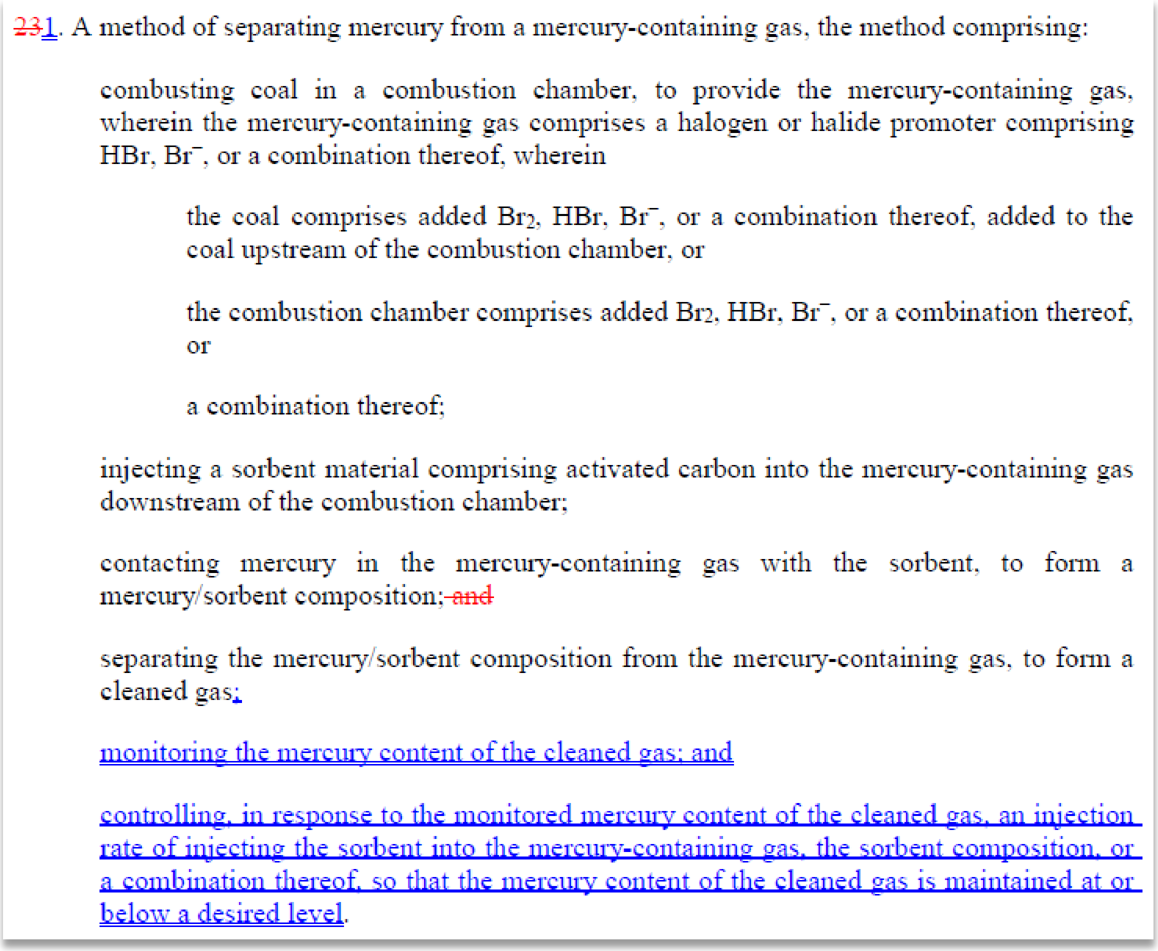
~~28. The method of claim 25, further comprising~~

monitoring the mercury content of the cleaned gas; and

controlling, in response to the monitored 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 bromide compound~~sorbent composition, 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.



~~23~~1. A method of separating mercury from a mercury-containing gas, the method comprising:

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

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;

injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber;

contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition; ~~and~~

separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas;

monitoring the mercury content of the cleaned gas; and

controlling, in response to the monitored mercury content of the cleaned gas, an 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.

Accordingly, my analysis provided for claims 23, 24, 25, and 28 also applies to claim 1.

a. Claim 1: Preamble—"A method of separating mercury from a mercury-containing gas, the method comprising:"

370. The language of the preamble of claim 1 is identical to the preamble of claim 25 (which is identical to the preamble of claims 23 and 24). Accordingly, the explanation I provide above for the preambles of claims 23-25 applies equally to the preamble of claim 1.

b. Claim 1: Element (1)(a)—"combusting coal in a combustion chamber, to provide the mercury-containing gas, wherein"

371. The language of claim element 1(a) is identical to the language of Claim Element 25(a) (which is identical to Claim Elements 23(a) and 24(a)). Accordingly, the explanation I provide above for those claim elements applies equally to claim element 1(a).

c. Claim 1: Element (1)(b)—"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 coal upstream of the combustion chamber, or the combustion chamber comprises added Br_2, HBr, Br^-, or a combination thereof, or a combination thereof;"

372. The language of claim element 1(b) is identical to the language of Claim Element 23(b) (which is identical to Claim Element 24(b) and similar to Claim Element 25(b)). Accordingly, the explanation I provide above for those claim elements applies equally to claim element 1(b).

d. Claim 1: Element (1)(c)—"injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber; contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition;"

373. The language of claim element 1(c) is identical to the language of Claim Element 25(c) (which is identical to Claim Element 23(c) and similar to Claim

Element 24(c)). Accordingly, the explanation I provide above for those claim elements applies equally to claim element 1(c).

e. Claim 1: Element (1)(d)—"separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas;"

374. The language of claim element 1(d) is identical to the language of Claim Element 23(d) (which is identical to the language of Claim Elements 24(d) and 25(d)). Accordingly, the explanation I provide above for those claim elements applies equally to claim element 1(d).

f. Claim 1: Element (1)(e)—"monitoring the mercury content of the cleaned gas; and"

375. The language of claim element 1(e) is identical to the language of claim 28(a) (which is identical to the language of Claim Element 24(e)). Accordingly, the explanation I provide above for those claim elements applies equally to claim element 1(e).

g. Claim 1: Element (1)(f)(1)—"controlling, in response to the monitored mercury content of the cleaned gas, an injection rate of injecting the sorbent into the mercury-containing gas, the sorbent composition, or a combination thereof."

376. As discussed above for Claim Element 28, this limitation is disclosed by the combination of Vosteen589 and Starns (Ground A1) and Vosteen589 and Mass-EPA (Ground A2). As discussed above for Claim Element 28(a) and Ground

A1, Starns discloses continuously monitoring the mercury content of the cleaned gas and controlling an injection rate of injecting the sorbent into the mercury-containing gas. And as also discussed above for Claim 28(a) and Ground A2, Mass-EPA discloses continuously monitoring the mercury content of the cleaned gas and controlling an injection rate of injecting the sorbent into the mercury-containing gas.

h. Claim 1: Element (1)(f)(2)—"so that the mercury content of the cleaned gas is maintained at or below a desired level."

377. The language of claim element 1(f)(2) is identical to the language of Claim Element 28(b). Accordingly, the explanation I provide above for Claim Element 28(b) applies equally to claim element 1(f)(2).

6. Claims Depending from Claim 1

a. Claim 2: "The method of claim 1, comprising removing greater than 70 wt % of the mercury in the mercury-containing gas."

378. Claim 2 would have been obvious over the combination of Vosteen589 and Starns (Ground A1) and the combination of Vosteen589 and Mass-EPA (Ground A2). Each of the three references achieve greater than 70 wt% mercury removal, and the combinations would as well. For example, Vosteen589 describes "an object of the invention to provide a process for removing mercury, in particular for the substantially complete removal of mercury (Hg), from flue gases of high-

temperature processes."[660] In one example involving industrial wastewater incineration, which was known to have even more mercury than coal combustion, Vosteen589 was able to remove more than 99.9% of total mercury.[661] Shown in Figure 5, reproduced below, Vosteen589 discloses removing more than 98% of the mercury from the mercury-containing gas.[662]

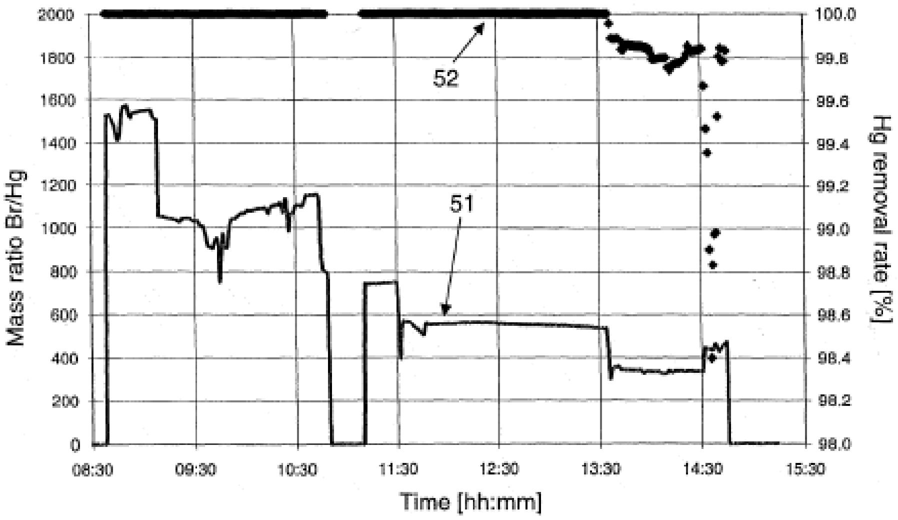


Fig. 5

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[660] EX1005 (Vosteen589) ¶[0005].

[661] EX1005 (Vosteen589) ¶[0037].

[662] EX1005 (Vosteen589) at Figure 5; *see also* ¶¶[0028], [0042].

The Y-axis on the right is labeled “Hg removal rate [%].”[663] Vosteen598 explains that using his processes, with injection of bromine, “the mercury content in the flue gas markedly decreases with addition of the bromine compound.”[664]

379. In the example of the coal power plant, Vosteen589 demonstrates that with the addition of the bromine, the fraction of elemental mercury Hg_{met} markedly decreases as compared to elemental oxidized mercury, including to less than 10%:

> Curve 81 in FIG. 8 depicts the increase in Br content in the boiler flue gas induced by adding aqueous NaBr solution. At 10:30 the bromine content in the flue gas upstream of the ESP was initially increased by at least 75 mg/M^3 S.T.P. db and decreased again stepwise. At 16:10, there was a renewed increase in bromine content by approximately 43 mg/M^3 S.T.P. db. . . . Furthermore, the curve 82 in FIG. 8 shows the initially abrupt decrease in proportion of metallic mercury species with addition of bromine (decrease from approximately 40% by weight to approximately 10% by weight at 10:30).[665]

Figure 8 of Vosteen589 is shown below:

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[663] EX1005 (Vosteen589) ¶[0042] (describing Figure 5).

[664] EX1005 (Vosteen589) ¶[0049].

[665] EX1005 (Vosteen589) ¶¶[0048]-[0049].

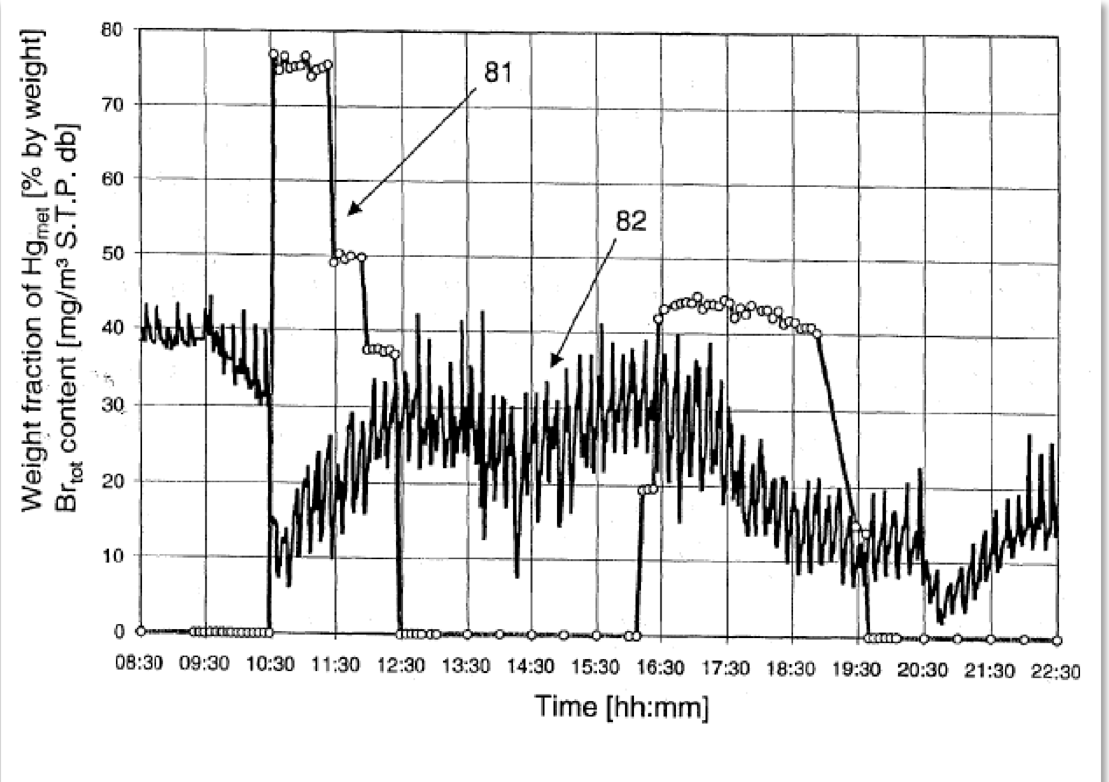

Fig. 8

A POSITA would have understood that with the conversion of elemental mercury to oxidized mercury approaching 90%, then nearly 90% of the total mercury content (oxidized + elemental) would be removed on the sorbent:

> As high a proportion as possible of ionic mercury is advantageous, since the ionic mercury is readily water soluble, that is to say it can be scrubbed out, and is readily adsorbable to a range of adsorbents.[666]

380. In addition to the disclosure of Vosteen589, and with respect to Ground A1, Starns also discloses removing 70% mercury when using 10 lb/MMacf of

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[666] EX1005 (Vosteen589) ¶[0007].

activated carbon.[667] When combined with the improved oxidation through the halogenation of Vosteen589, the removal would be even greater than the 70%.

381. In addition to the disclosure of Vosteen589, and with respect to Ground A2, Mass-EPA discloses removing greater than 70% mercury, such as at the Gaston and Brayton Point plants.[668] When combined with the improved oxidation through the halogenation of Vosteen589, the removal would be even greater than the 70%.

382. In addition to the mercury removal percentages disclosed by Vosteen589, Starns, and Mass-EPA, Claim 2 would have been obvious to a person of skill in the art in that Vosteen589 discloses removing sufficient mercury to comply with legal and regulatory requirements.[669] As described in the Technology Background and State of the Art regarding EPA Regulations and government-funded research,[670] a person of skill in the art would have known that by 2004, the EPA had already put the industry on notice of upcoming laws and regulations requiring 70% mercury removal, including EPA's Clean Air Mercury Rule (CAMR). Notice of these regulations exerted a strong outside impetus on the industry to evaluate control

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[667] EX1008 (Starns) at 20.

[668] EX1009 (Mass-EPA) at 11-12 (Chart 2 and accompanying discussion).

[669] EX1005 (Vosteen589) ¶¶[0002], [0015].

[670] Technology Background and State of the Art, §§ IX.D – IX.F.

schemes to comply with the regulations' eventual implementation. Through routine process optimization and routine experimentation, a person of ordinary skill in the art would have adjusted the bromine injection rate and/or activated carbon injection rate to meet and exceed (for purposes of safety margin) the EPA's proposed rules requiring a 70% removal of mercury.

b. Claim 3: "The method of claim 1, comprising removing greater than 70 wt % of the mercury in the mercury-containing gas on the sorbent."

383. Claim 3 would have been obvious over the combination of Vosteen589 in view of Starns (Ground A1) and Vosteen589 in view of Mass-EPA (Ground A2). For example, as described for Claim 2 above, Vosteen589 discloses removing more than 98% of the mercury from the mercury-containing gas. Vosteen589 discloses that his invention is particularly suited "for those high-temperature plants <u>which do not have a wet flue gas emission control system</u>, but solely have a dry emission control system having a mercury <u>sorption stage</u>."[671] Such plants with "solely" a dry emission control system, and without a scrubber, would be dependent on the activated carbon for mercury removal. Moreover, the Hg removals on sorbents alone would meet or exceed the 70% removal threshold under the configurations disclosed by Vosteen589 in view of the activated carbon injection of Starns (Ground A1) and

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[671] EX1005 (Vosteen589) ¶[0019].

the activated carbon injection of Mass-EPA (Ground A2). Specifically, Vosteen589 discloses that "lignite-fired power stations"[672] would benefit from his Hg control methods. A person of ordinary skill in the art would have understood that such plants typically have very low concentrations of inherent chlorine in their flue gas as well as very low LOI (loss on ignition) levels in their fly ash.[673] Under such circumstances, Hg capture on inherent unburned carbon is minimal. Consequently, a person of ordinary skill in the art would have understood that adding bromine to the furnace of a plant with "solely" a dry emission control system, and without a scrubber, while injecting a sorbent ahead of the particle collection device, as Vosteen589 teaches, ensures that virtually all the Hg captured in a particle collection device would be bound to the sorbent. Furthermore, Vosteen589 also teaches how to adjust the bromine addition level to achieve Hg removal up to essentially complete removal, including 70 % removal.

384. In addition, the activated carbon injection in Starns (Ground A1) takes place with solely a dry emissions system, and the activated carbon injection is

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[672] EX1005 (Vosteen589) ¶[0008].

[673] *See* Technology Background and State of the Art, §IX.B.1.

particularly suited as "mercury control technology for coal-fired utility plants that do not have scrubbers for SO_2 control."[674]

385. The activated carbon injection in Mass-EPA (Ground A2) also takes place at units that did not have scrubbers. At the time the Mass-EPA report was issued in December 2002, Massachusetts utilities operated four coal-fired power plants with a total of 10 combustion furnaces. All of these units operated with solely dry emissions systems in which particulates were collected on ESPs.[675] One of these plants, Brayton Point, was the site for field tests whose results, "indicate that the higher the concentration of sorbent injected, the more mercury removed. Removal values range from 0 – 50% at 3 lb/MMacf and 75 – 95% at the highest sorbent injection rate of 20 lb/MMacf."[676] The entire range of removals with the highest ACI concentration are greater than 70 %.

386. As described in the Technology Background and State of the Art,[677] a person of skill in the art would have known that by 2004, the EPA had already put the industry on notice of upcoming laws and regulations requiring 70% mercury

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[674] EX1008 (Starns) p. 2 (Abstract).

[675] EX1009 (Mass-EPA) at 70.

[676] EX1009 (Mass-EPA) at 74.

[677] *See* Technology Background and State of the Art, IX.D – IX.F.

removal, such as the EPA's Clean Air Mercury Rule (CAMR). Notice of these regulations exerted a strong outside impetus on the industry to adjust processes to comply with the regulations' eventual implementation. Through routine process optimization and routine experimentation, a person of ordinary skill in the art would have adjusted the bromine injection rate and/or activated carbon injection rate in a plant he described as preferred (one that relied solely on a dry emission control system having a mercury sorption stage) to meet and exceed (for purposes of safety margin) the EPA's proposed rules requiring a 70% removal of mercury.

c. Claim 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."

387. Claim 4 would have been obvious over the combination of Vosteen589 in view of Starns (Ground A1) and Vosteen589 in view of Mass-EPA (Ground A2). Claim 4 is merely an attempt to claim the optimum or workable range for a process of combining a particular conventional halogen (bromine) being used in a conventional way (halogens are inherent to coal, and both oxidize mercury and promote activated carbon) with a conventional sorbent (activated carbon). Nothing about the particular range of 1 g to about 30 g of the halide promoter per 100 g of the sorbent would have led to an unexpected result from what was already known to one of skill in the art.

388. As described in the State of the Art,[678] it was known that the saturation limit of activated carbon for bromine (i.e., how much bromine the activated carbon can actually adsorb at equilibrium), was up to 31 to 38 grams per 100 grams of activated carbon. Given the residence times in flue gas, and other inefficiencies, a person of ordinary skill in the art would have understood that the actual bromine loaded onto activated carbon would have been less than the saturation limit.

389. A person of ordinary skill in the art would have recognized that there would have been sufficient bromine in the flue gas, according to Vosteen589's processes and the sorbent injection concentration of Starns (Ground A1) and Mass-EPA (Ground A2) (each described above for Claims 28 and 29), to provide a ratio of between 1 g to 30 g of bromine per 100 g of activated carbon. A person of ordinary skill in the art operating a plant with solely a dry emission control system (i.e., without a wet scrubber), would have been motivated to seek to load the activated carbon up to nearly its saturation limit, because it was known in the art that halides "improve[d] Hg capture both by conversion of the Hg^0 to the more easily removed Hg^{2+} forms and by enhancing the reactivity of Hg^0 with activated

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[678] *See* Technology Background and State of the Art, § IX.C.3.

carbons."[679] Vosteen589 expressly discloses the former,[680] and the latter was well-known in the art. For example, Mass-EPA states: "Both elemental and oxidized mercury adsorb onto porous solids such as fly ash, powdered activated carbons (PAC),"[681] though oxidized mercury (i.e., through halogenation in Vosteen589) adsorbs better: "Hg^{2+} is believed to be more readily captured by adsorption than Hg^0."[682]

390. Through routine process optimization and routine experimentation, a person of ordinary skill in the art would have adjusted the rate of addition of bromine-containing species and/or activated carbon injection rate to achieve halide promoter on the activated-carbon sorbent from about 1 g to about 30 g.[683]

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[679] EX1062 (Crocker) at 2-3.

[680] EX1005 (Vosteen589) ¶¶[0007], [0016].

[681] EX1009 (Mass-EPA) at 20.

[682] EX1009 (Mass-EPA) at 24.

[683] Patent Owner's expert, Mr. O'Keefe, agrees. EX1092 (O'Keefe Report) at 153 (concluding with regard to claim 4 that "power plants employing bromine additives and activated carbon would necessarily produce a sorbent that is 1 g to 30 g bromine per 100 g of activated carbon).

d. Claim 5: "The method of claim 1, wherein the combustion chamber comprises the halogen or halide promoter."

391. Vosteen589 discloses this limitation in Ground A1 and Ground A2 for the reasons discussed above for Claim Element 25(b) and Claim 27. As described above for Claim Element 25(b), Vosteen589 discloses adding to the combustion chamber and/or coal aqueous hydrogen bromide, bromide compounds in solid or aqueous form (e.g., sodium bromide), molecular bromine (Br_2), and mixtures thereof. Vosteen589 also discloses adding a bromide ion (Br^-) to the coal and to the combustion chamber in the form of aqueous solutions of hydrogen bromide and sodium bromide, each of which dissociates in water to form bromide ions (Br^-).[684] When bromine-containing species (e.g., HBr) and carbon come into contact with each other, the bromine acts as a promoter.[685] HBr is expressly disclosed by claims 1 and 23 as examples of "a halogen or halide promoter."

e. Claim 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."

392. The language of claim 6 is similar to the language of Claim Element 25(b) and claim 26, and I refer to my discussion of Claim Element 25(b) and claim

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[684] EX1005 (Vosteen589) ¶¶[0006], [0009], [0013], [0014].

[685] *See* Technology Background and State of the Art, Sections IX.C.3, IX.G.2.

26 for Ground A1 and Ground A2. Claim 6 has the following changes, as compared to claim 26:

> wherein the coal comprises ~~the~~ added Br_2, HBr, Br-, ~~the bromide compound~~ or a combination thereof, added to the coal upstream of the combustion chamber

Claim 6 is disclosed, as discussed for claim 26. As I explain for claim 26, Vosteen589 describes that bromine-containing ingredients are added to the coal.

> The bromine compound, for example, sodium bromide, can be added in solid form, for example as salt, or liquid form, for example as aqueous solution, to the waste mixture, coal or the like to be burnt, upstream of the furnace. [686]

Vosteen589 includes "bromine and/or a bromine compound and/or a mixture of various bromine compounds."[687] The "bromine" refers to molecular bromine, Br_2. Vosteen589 also discloses that "sodium bromide, can be added in solid form, for example as salt, or liquid form, for example as aqueous solution, to the waste mixture, coal or the like to be burnt, upstream of the furnace. [688] Aqueous hydrogen bromide HBr (aq) can also be added to the coal.[689] Hydrogen bromide and sodium bromide each dissociate in water to form bromide ions (Br^-).

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[686] EX1005 (Vosteen589) ¶[0013].

[687] EX1005 (Vosteen589) ¶[0006].

[688] EX1005 (Vosteen589) ¶[0013].

[689] EX1005 (Vosteen589) ¶¶[0009], [0014], [0044], claim 2.

f. Claim 7: "The method of claim 1, wherein the promoter is contacted with the sorbent in vapor form, gaseous form, liquid form, or in an organic solvent."

393. Claim 7 would have been obvious over the combination of Vosteen589 in view of Starns (Ground A1) and Vosteen589 in view of Mass-EPA (Ground A2). As described for the independent claims, the combination of Vosteen589 in view of Starns (Ground A1) and the combination of Vosteen589 in view of Mass-EPA (Ground A2) each injects activated carbon into the mercury-containing flue gas. The boiling point of Br_2 is only 58.8ºC (it is a fuming liquid at room temperature), and the boiling point of hydrogen bromide is -66.38 ºC (i.e., it is a gas at room temperature).[690] Each of these is well below the temperature of the mercury-containing flue gas. As described for Claim 23, for the other species that Vosteen589 adds to the coal and/or combustion chamber, at least a portion of the Br would have vaporized in the combustion chamber and reacted to form vapor-phase HBr. When bromine-containing species (e.g., HBr) and carbon come into contact with each other, the bromine acts as a promoter.[691]

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[690] EX1036 (CRC Press: March 2005) at 4-53 and 4-65.

[691] *See* Technology Background and State of the Art, Sections IX.C.3, IX.G.2.

394. Regarding Ground A1, Starns discloses typical flue gas temperatures of 290 ºF, which is 143 ºC.[692] Regarding Ground A2, the flue gas in Mass-EPA ranges from 284 to 320ºF (140-160ºC) after the air heater or 350-450ºC before the air heater.[693] In each of these configurations, the temperatures are well-above the limit at which the mercury-containing gas would be in the gas phase, and the halogen promoters (such as HBr and Br_2) would likewise be vaporized.

395. Regarding Ground A1 and Ground A2, the boiling point of water is around 100 ºC, so a POSITA would have understood, or at the very least found it obvious, that the mercury-containing flue gas (which also contains promoter) would be at a temperature well above the boiling point of water and remain in the gas phase. In each combination, the promoter would have remained in the gaseous form as it is transported with the flue gas and eventually contacted the activated-carbon sorbent.

g. Claim 8: "The method of claim 1, further comprising injecting a secondary material into the mercury-containing gas downstream of the combustion chamber."

396. This limitation is disclosed by Vosteen589 in Ground A1 and Ground A2. Vosteen589 discloses multiple examples of secondary materials added to the mercury-containing flue gas downstream of the combustion chamber, including a

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[692] EX1008 (Starns) at 10.

[693] EX1009 (Mass-EPA) at 26.

sulfur compound, additional bromine-containing compounds, and other halogens. Each of these are in addition to the halogens being applied to the coal and combustion chamber.

397. As for the sulfur compound, Vosteen589 explains:

> The addition of a bromine compound and if appropriate <u>a sulphur compound is</u> made according to the invention to the furnace and/or <u>to the flue gas in a plant section downstream of the furnace</u> . . . .[694]

398. In addition to adding the bromine-containing species to the combustion chamber and/or coal, as discussed above, Vosteen589 discloses that the bromine materials are provided at a second point in the process, including being injected directly into the mercury-containing gas:

> In a further embodiment of the inventive process, it is also possible to feed the bromine compound, for example an aqueous solution of hydrogen bromide or sodium bromide, at a fine dispersion to the combustion air and/or if appropriate to a <u>recirculated substream, in particular recirculated flue gas</u>, recirculated ash and recirculated fly ash.[695]

This is a second point of addition of the bromine-containing species, because as Vosteen589 states, the "bromine and/or a bromine compound and/or a mixture of various bromine compounds <u>is fed to the if appropriate multistage furnace and/or to</u>

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[694] EX1005 (Vosteen589) ¶[0013].

[695] EX1005 (Vosteen589) ¶[0014].

the flue gas in a plant section downstream of the furnace."[696] As described above for Claim 25(c), it would have been obvious to use "injection" as the method to introduce materials into a flue-gas.

399. Other secondary materials in Ground A1 and Ground A2 include additional halogens, such as a "chlorine and/or iodine and/or a chlorine compound and/or an iodine compound and/or a mixture of such compounds" that can be fed "as a supplement to, or partial replacement of, the added bromine compound."[697]

400. With respect to Ground A1, Starns discloses activated-carbon that is co-injected with "SO_3 flue gas conditioning."[698] A POSITA would recognize SO_3 as an exemplary secondary material recited in claim 8 because its impact on Hg removals is being characterized in Starns's test series. Starns's matrix of test conditions in Table 5 contains two tests without SO_3 injection (nos. 1 and 7) and 14 tests with SO_3 injection.

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[696] EX1005 (Vosteen589) at Claim 1; *see also* EX1005 (Vosteen589) ¶[0006].

[697] EX1005 (Vosteen589) ¶[0016].

[698] EX1008 (Starns) at 10.

401. With respect to Ground A2, Mass-EPA also discloses SO_3 injection into the mercury-containing flue gas.[699] Mass-EPA further discloses co-injection of not only activated carbon sorbents, but also sodium carbonate and lime:

> In one study (Ref. 28), activated carbon was co-injected with either sodium carbonate or lime for SO_2 control. With either of these sorbents, an improvement in the adsorption of gaseous Hg by the activated carbon was reported.[700]
>
> Increased removal of mercury from gas has been demonstrated by co-injection of activated carbon and calcium-based sorbents in spray dryer adsorber systems in full-scale coal-fired power plants. [701]
>
> In addition to using sorbents with higher mercury adsorption capacity and/or lower costs (such as composite PAC-lime sorbents or impregnated activated carbons)… could improve the cost-effectiveness of PAC injection-based technologies.[702]

A person of ordinary skill in the art would recognize that alkaline sorbents, among many other options, are secondary materials that can be injected into flue gas to enhance the performance of ACI in removing Hg.

402. In addition, and with respect to Ground A2, Mass-EPA discloses injecting "[m]odified activated carbons (i.e., doped with sulfur, iron, chlorine, and

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[699] EX1009 (Mass-EPA) at 39-40.

[700] EX1009 (Mass-EPA) at 37.

[701] EX1009 (Mass-EPA) at 32.

[702] EX1009 (Mass-EPA) at 52.

iodine."[703] The modified activated carbon with chlorine and iodine is a compound derived from a halogen.

h. Claim 9: "The method of claim 8, wherein the secondary material comprises a halogen, a compound derived from a halogen, a hydrohalide, a compound comprising a Group V or Group VI element and a molecular halogen, or a combination thereof."

403. This claim is disclosed by Vosteen589 in Ground A1 and Ground A2. As described for claim 8, Vosteen589 discloses bromine compounds, chlorine compounds, and/or iodine compounds fed to the mercury-containing flue gas, which are in addition to the bromine fed to the coal and/or combustion chamber. Each of these examples comprises a halogen or compound derived from a halogen, such that claim 9 is also disclosed.

404. In addition, and with respect to Ground A2, Mass-EPA discloses injecting "[m]odified activated carbons (i.e., doped with sulfur, iron, chlorine, and iodine."[704] The modified activated carbon with chlorine and iodine is a compound derived from a halogen.

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[703] EX1009 (Mass-EPA) at 33.

[704] EX1009 (Mass-EPA) at 33.

i. Claim 10: "The method of claim 1, wherein the sorbent material injected into the mercury-containing gas further comprises a non-carbon sorbent material."

405. Claim 10 would have been obvious over the combination of Vosteen589 in view of Starns (Ground A1) and Vosteen589 and Mass-EPA (Ground A2).

406. Regarding Ground A1 and Ground A2, Vosteen589 repeatedly discloses adding "lime" or "slaked lime" to the mercury-containing flue gas, including by mixing the lime with activated-carbon sorbent.[705] Lime contains calcium oxide (CaO), and slaked lime contains calcium hydroxide ($Ca(OH)_2$). As I describe above regarding Technology Background and State of the Art,[706] a POSITA would have known that lime and slaked lime are sorbents in that they adsorb other flue-gas constituents (such as SO_3), which would otherwise compete with mercury for binding sites on the activated-carbon sorbent.

407. With respect to Ground A1, Starns refers to "injection of sorbents such as powdered activated carbon (PAC) into the flue gas."[707] When the activated-carbon sorbent is mixed with lime or slaked lime (as in Vosteen589), that lime or

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[705] EX1005 (Vosteen589) ¶[0019].

[706] Technology Background and State of the Art, §IX.A.4, §IX.B.5.b, §IX.G.1.

[707] EX1008 (Starns) at 2.

slaked lime would also be injected into the mercury-containing flue gas along with the PAC (as in Starns). With respect to Ground A2, Mass-EPA discloses co-injection of not only activated carbon sorbents, but also calcium-based sorbents and other non-carbon sorbents:

> In one study (Ref. 28), activated carbon was co-injected with either sodium carbonate or lime for SO_2 control. With either of these sorbents, an improvement in the adsorption of gaseous Hg by the activated carbon was reported.[708]
>
> Increased removal of mercury from gas has been demonstrated by co-injection of activated carbon and calcium-based sorbents in spray dryer adsorber systems in full-scale coal-fired power plants. [709]
>
> Various types of sorbents have been under investigation. These include various types of activated carbon, calcium-based and sodium-based (trona) sorbents, various clays and zeolites, alkaline-earth sulfides, as well as lime and lime-silica multi-pollutant sorbents. Activated Carbon and calcium-based sorbents have been the most actively researched and tested sorbents. [710]

The "calcium-based sorbents" are examples of non-carbon sorbent material. Calcium-based sorbents and other alkaline materials adsorb other constituents from the flue gas (e.g., SO_3), which would otherwise compete with mercury for the active binding sites on activated-carbon sorbent.

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[708] EX1009 (Mass-EPA) at 37.

[709] EX1009 (Mass-EPA) at 32.

[710] EX1009 (Mass-EPA) at 32.

j. Claim 11: "The method of claim 10, wherein the non-carbon sorbent material comprises at least one of a porous felsic material, a vesicular felsic material, a porous basaltic material, a vesicular basaltic material, a clay-based compound, an alkaline compound, a calcium hydroxide compound, a sodium acetate compound, and a bicarbonate compound."

408. Claim 11 would have been obvious over the combination of Vosteen589 in view of Starns (Ground A1) and Vosteen589 in view of Mass-EPA (Ground A2).

409. Regarding Ground A1 and Ground A2, as discussed for Claim 10, Vosteen589 discloses co-injecting lime and slaked lime (an alkaline and calcium hydroxide compound).

410. Regarding Ground A2, and as discussed for Claim 10, Mass-EPA also discloses co-injecting lime (alkaline compound, alkaline-earth sulfides (an alkaline compound), and various clays and zeolites (clay-based compound).

k. Claim 12: "The method of claim 1, wherein the activated carbon comprises powdered activated carbon, granular activated carbon, or a combination thereof."

411. Claim 12 would have been obvious over the combination of Vosteen589 in view of Starns (Ground A1) and the combination of Vosteen589 and Mass-EPA (Ground A2). Vosteen589 further specifies "granulated activated

carbon" as the sorbent.[711] A person of skill in the art would have recognized that "granular" activated carbon and "granulated" activated carbon are two words for the same material.

412. For Ground A1, the activated carbon injected by Starns is "powdered activated carbon," which is also abbreviated as "PAC": "The most mature, retrofit technology available today is the injection of sorbents such as powdered activated carbon (PAC) into the flue gas upstream of the particle control equipment."[712]

413. For Ground A2, Mass-EPA discussed powdered activated carbon (abbreviated as "PAC") throughout the reference, including how "one mercury-specific control technology (powdered activated carbon injection) has the potential for commercialization in the near future."[713]

l. Claim 13: "The method of claim 1, wherein the sorbent material injected into the mercury-containing gas is substantially free of halogen and halide promotion."

414. Claim 13 would have been obvious over the combination of Vosteen589 in view of Starns (Ground A1) and Vosteen589 in view of Mass-EPA (Ground A2). As discussed above for Claim Element 1(c), each of these

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[711] EX1005 (Vosteen589) ¶[0019].

[712] EX1008 (Starns) at 2.

[713] EX1009 (Mass-EPA) at 22; *see also* p. 32 ("Powdered Activated Carbon … has been the most extensively studied sorbent for mercury adsorption.").

combinations includes injecting an activated carbon into the mercury-containing flue gas. Vosteen589 does not characterize the sorbent as having been pre-brominated or otherwise impregnated with a halogen promoter prior to injection, and a person of ordinary skill in the art would have understood the disclosure of Vosteen589 to refer to sorbent material that is substantially free of halogen and halide promotion. A POSITA would have selected halogen-free sorbent due to its lower cost (compared to pre-brominated PAC), particularly for applications (e.g., types of coal) that do not require the enhanced removal properties of PAC.[714]

415. In addition, for Ground A1, Starns discloses Norit "Darco FGD":

> At each site, at least two sorbents are evaluated during the parametric tests. A standard powdered activated carbon (FGD), which is a lignite-derived sorbent supplied by Norit Americas Inc., is tested in all cases as the benchmark sorbent.[715]

For Ground A2, the same activated carbon was used: "Norit FGD," specifically "Norit America's 'Darco FGD.'"[716] A POSITA would have recognized that the Norit Darco FGD is substantially free of halogen and halide promotion. Articles

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[714] See Technology Background and State of the Art, §IX.B.1**Error! Reference source not found.**.

[715] EX1008 (Starns) at 3.

[716] EX1009 (Mass-EPA) at 73, 74.

dating back to at least 1998 confirm that the chemical composition of "Norit Darco FGD" does not have halogens.[717]

m. Claim 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."

416. Claim 14 would have been obvious over the combination of Vosteen589 in view of Starns (Ground A1). A person of ordinary skill in the art would have been motivated, and would have had a reasonable expectation of success, to try pre-halogenating the activated carbon prior to injecting it into the mercury-containing flue gas. For example, it was well-known in the art since the 1930s to remove mercury vapors by injecting pre-halogenated sorbents into a mercury-containing flue gas.[718]

417. Claim 14 would have also been obvious over the combination of Vosteen589 in view of Mass-EPA (Ground A2). Mass-EPA discloses two alternatives for the powdered activated carbon: "activated carbon (or the impregnated activated carbon)."[719] Mass-EPA explains that exemplary forms of the

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[717] EX1048 (Carey) at 1169 (Table 1, discussing chemical analysis of Norit FGD).

[718] *See* Technology Background and State of the Art, §IX.C, §IX.G (including EX1029 (Stock)).

[719] EX1009 (Mass-EPA) at 32.

impregnated activated carbon are "chlorine-impregnated activated carbon."[720] Mass-EPA also discloses "[m]odified activated carbons (i.e., doped with … chlorine and iodine") as an alternative that "can provide higher mercury adsorption capacity, but often have higher production costs."[721] Chlorine and iodine are each types of halogens, and the activated carbon reacts with these halogens and is promoted.[722]

418. For Ground A1 and Ground A2, a person of ordinary skill in the art would have been motivated to at least try such a pre-halogenated sorbent in conjunction with the processes of Vosteen589 and Starns in order to further enhance mercury removal, particularly for coals with higher native mercury content (or lower native halogen content and/or lower unburned carbon in fly ash) where a greater percentage of elemental mercury makes removal more troublesome, or for systems that did not employ a scrubber. Indeed, Vosteen589 describes plants that "do not have a wet flue gas emission control system, but solely have a dry emission control system having a mercury sorption stage."[723]

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[720] EX1009 (Mass-EPA) at 34 & n.44.

[721] EX1009 (Mass-EPA) at 33.

[722] See Technology Background and State of the Art, §IX.C.32.

[723] EX1005 (Vosteen589) ¶[0019].

n. Claim 15: "The method of claim 1, wherein the combustion chamber comprises a boiler."

419. This claim is disclosed by Vosteen589 (Ground A1 and Ground A2). As discussed for claim element 1(b) and 25(b), Vosteen589 discloses adding the bromine-containing species to a combustion chamber of "a <u>coal-fired power station of B</u>ayer AG in Uerdingen, which essentially consists of a slag-tap fired <u>boiler</u> …."[724] Vosteen589 later refers to the "coal-fired power station of Bayer AG in Uerdingen (see FIG. 9)" with "two parallel slag-tap fired <u>boilers</u> 91, 91' having temperatures in the combustion chamber."[725]

o. Claim 16: "The method of claim 1, wherein the mercury-containing gas is a flue gas."

420. This claim is disclosed by Vosteen589 (Ground A1 and Ground A2). For example, the title of Vosteen589 is "Process for Removing Mercury from Flue Gases," and the Abstract refers to "removing mercury from flue gases of high-temperature plants, in particular power stations."[726] This element is also disclosed

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[724] EX1005 (Vosteen589) ¶[0034].

[725] EX1005 (Vosteen589) ¶¶[0046]-[0047], Fig. 9; *see also* EX1005 (Vosteen589) ¶[0005] ("coal-fired power stations"),

[726] EX1005 (Vosteen589) at Title, Abstract.

by the claims of Vosteen589, such as claim 1 ("Process for removing mercury from flue gases … power stations").[727]

p. Claims 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."

421. This claim would have been obvious over the combination of Vosteen589 and Starns (Ground A1) and Vosteen589 and Mass-EPA (Ground A2).

422. Vosteen589 discloses an embodiment, which makes use of an electrostatic precipitator (ESP),[728] which is a type of particulate separator. Vosteen589 explains that "mercury adsorption intensifies on the fly ash of ESPs."[729] Vosteen589 also explains that "[m]ercury bromide $HgBr_2$ adsorbs more strongly to dry sorbents than mercury chloride $HgCl_2$."[730] The dry sorbents disclosed by Vosteen589 include "granulated activated carbon" and "pulverulent slaked lime/activated carbon."[731] A person of ordinary skill in the art would have understood that, as taught by Vosteen589, adsorption of $HgBr_2$ by activated carbon

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[727] EX1005 (Vosteen589) at claim 1.

[728] EX1005 (Vosteen589) ¶¶[0019], [0034], [0047], Fig. 9 (item 96), claim 8.

[729] EX1005 (Vosteen589) ¶[0019].

[730] EX1005 (Vosteen589) ¶[0019].

[731] EX1005 (Vosteen589) ¶[0019].

occurs with direct contact between $HgBr_2$ and the activated carbon particles in the flue gas. A POSITA would have known that, once entrained in flue gas, the activated carbon would have been transported downstream to a particle collection device (PCD), such as a fabric filter or ESP.[732]

423. Though the specific figures in Vosteen589 disclose a cold-side ESP, a POSITA would have known that there are a finite number of options (really, just two) categories of ESPs: hot-side ESP and cold-side ESP. A cold-side ESP is located downstream from the air-preheater, whereas a hot-side ESP is located upstream of the air-preheater. In a hot-side ESP, the sorbent would be injected upstream of the ESP, i.e., so that it can be removed, as per Claim 25(d). Because the hot-side ESP is located upstream of the air preheater, then any activated-carbon sorbent injected upstream of the ESP would have also been injected upstream of the air preheater.

i. Ground A1 (Vosteen589 and Starns)

424. This claim would have further been obvious over Vosteen589 in view of Starns. Starns discloses that at one of the sites (Gaston), a “hotside electrostatic precipitator” was used.[733] Thus, it would have been at least obvious to try a hot-side ESP when combining Vosteen589 and Starns, and with such a configuration, the

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[732] *See* Technology Background and State of the Art, § IX.B.5.a.

[733] EX1008 (Starns) at 3.

activated carbon would have been injected upstream of the air preheater. Starns recommends "using activated carbon injection upstream of an ESP."[734] A POSITA would have been motivated, as Starns suggests, to use activated carbon injection between the combustion chamber (furnace) and a hot-side ESP (electrostatic precipitator) in Vosteen589.[735]

ii. Ground A2 (Vosteen589 and Mass-EPA)

425. This claim would have been further obvious over Vosteen589 in view of Mass-EPA. The Massachusetts EPA tabulated an assortment of approaches "demonstrated or under investigation to control mercury" in Table 1.[736] The Mass-EPA recognized that devices already present for controlling other pollutants (such as SOx or NOx) can also be useful to provide some mercury capture, including "Electro Static Precipitator (ESP), cold side and hotside."[737]

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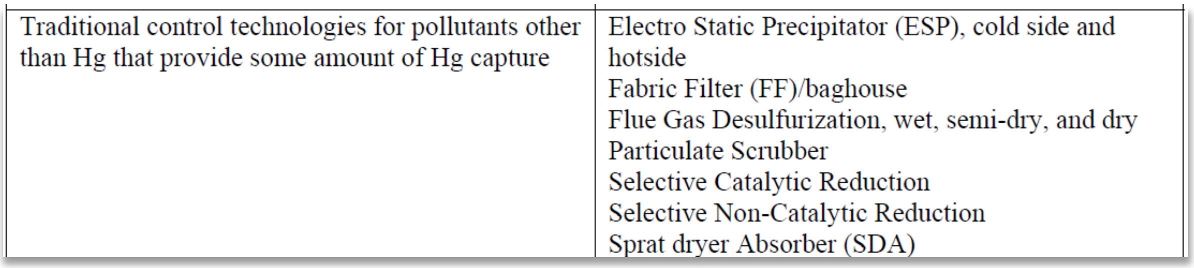
[734] EX1008 (Starns) at 20.

[735] EX1005 (Vosteen589) ¶¶[0019], [0033], [0037], [0039], [0042], [0047]-[0049], claim 8 (discussing use of an ESP).

[736] EX1009 (Mass-EPA) at 7.

[737] EX1009 (Mass-EPA) at 7.



Traditional control technologies for pollutants other than Hg that provide some amount of Hg capture	Electro Static Precipitator (ESP), cold side and hotside Fabric Filter (FF)/baghouse Flue Gas Desulfurization, wet, semi-dry, and dry Particulate Scrubber Selective Catalytic Reduction Selective Non-Catalytic Reduction Sprat dryer Absorber (SDA)

426. A POSITA would readily have known that, as disclosed in Mass-EPA, a hot-side ESP is located upstream of an air preheater.

> ESPs and FFs fall into two classifications, coldside (CS) or hotside (HS), depending on whether they are installed after an air heater, where flue gas temperatures range from 284 to 320ºF (140 to 160°C), or before an air heater, where flue gas temperatures range from 662 to 842ºF (350 to 450°C). Currently available data indicate that mercury capture in HS-ESPs is very low.

In the above quote, the "air heater" is another term for the air pre-heater. Mass-EPA suggests adding activated carbon injection, "incorporate retrofit PAC injection-based technologies on various existing coal-fired utility boiler plant pollution control systems," to improve the efficiency of mercury removal up to 60-90%, depending on the injection rate.[738] Mass-EPA teaches injecting activated carbon "upstream" of the ESP,[739] which means the activated carbon can also be injected upstream of the air preheater.

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[738] EX1009 (Mass-EPA) at 50.

[739] EX1009 (Mass-EPA) at 53, 54.

q. Claim 18: "The method of claim 1, wherein the injection of the sorbent material into the mercury-containing gas occurs upstream of a particulate separator or a scrubber."

427. These claims would have been obvious over the combination of Vosteen589 and Starns (Ground A1) and Vosteen589 and Mass-EPA (Ground A2). As described above for Claim 17, each of the three references discloses an electrostatic precipitator (ESP), and Starns (Ground A1) and Mass-EPA (Ground A2) each specify that the activated carbon sorbent is injected upstream of the ESP. An ESP is an example of a particulate separator.

428. With respect to Ground A1, Starns states that the activated-carbon sorbent is carried "from the feeders to distribution manifolds located on the <u>ESP inlet</u> duct, feeding the injection probes"[740] further demonstrating that the injection of sorbent into the mercury-containing gas occurs upstream of a particulate separator.

429. With respect to Ground A2, Mass-EPA refers to the "injection of a sorbent into the exhaust system and <u>subsequent</u> collection of the particulates in a PM [particulate matter] control device."[741] This again demonstrates that the sorbent injection into the mercury-containing gas occurs upstream of a particulate separator.

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[740] EX1008 (Starns) at 7.

[741] EX1009 (Mass-EPA) at 32.

r. Claim 19: "The method of claim 1, wherein the coal comprises added halide sorbent enhancement additive."

430. Vosteen589 discloses this limitation in Ground A1 and Ground A2. As I explain regarding Claim Element 25(b) and Claim 26, Vosteen589 describes that bromine-containing ingredients are added to the coal, including molecular bromine (Br_2), aqueous sodium bromide (NaBr), and hydrogen bromide (HBr). Each of these are express examples of a sorbent enhancement additive, as evidenced by Claim 21 ("sorbent enhancement additive that comprises Br^-") and Claim 22 ("sorbent enhancement additive comprises a bromide compound"). NaBr and HBr, when in aqueous form, dissolve to form Br^- ions. Vosteen589 also discloses adding a sulfur compound to the coal,[742] additional bromine-containing species,[743] and other (supplemental) halogens,[744] each of which can be considered a sorbent enhancement additive.

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[742] EX1005 (Vosteen589) ¶¶[0013], [0014], [0022], claim 1, claim 10.

[743] EX1005 (Vosteen589) at claim 1.

[744] EX1005 (Vosteen589) ¶[0016]; *see also* EX1005 (Vosteen589) at Claim 6 (chlorine, iodine, and related compounds).

s. Claim 20: "The method of claim 1, wherein the combustion chamber comprises added Br_2, HBr, Br^-, or a combination thereof."

431. Vosteen589 discloses this claim in Ground A1 and Ground A2. The language of claim 20 is similar to the language of claim 27, and I refer to my discussion of that claim. Claim 20 has the following changes, as compared to claim 27:

> wherein the combustion chamber comprises ~~the~~ added Br_2, HBr, Br-, ~~the bromide compound~~, or a combination thereof."

As discussed regarding claim 27, claim 20 is disclosed because exemplary bromine-containing ingredients added to the combustion chamber include molecular bromine (Br_2) and hydrogen bromide (HBr). These ingredients are added to "into one or both combustion chambers."[745]

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[745] EX1005 (Vosteen589) ¶[0013]; see ¶[0007] ("addition of bromine or bromine compounds to the furnace"); ¶[0010] ("addition of a bromine compound to the furnace"); ¶[0011] ("sodium bromide is added to the furnace"); claim 1 ("bromine … is fed to the if appropriate multistage furnace").

t. Claims 21-22

> **Claim 21: "The method of claim 1, wherein the coal comprises added sorbent enhancement additive that comprises Br^-."**

> **Claim 22: "The method of claim 21, wherein the sorbent enhancement additive comprises a bromide compound."**

432. Vosteen589 discloses claims 21 and 22 in Ground A1 and Ground A2. As I explain regarding Claim Element 25(b) and claim 26, Vosteen589 describes that bromine-containing ingredients are added to the coal, including molecular bromine (Br_2), aqueous sodium bromide (NaBr), and hydrogen bromide (HBr). A person of skill in the art would have recognized that when dissolved in water (i.e., in the aqueous form Vosteen589 discloses), hydrogen bromide and sodium bromide dissociate to form bromide ions (Br^-).[746]

XIV. GROUND A3: ANTICIPATION BY DOWNS-BOILER

433. It is my opinion that Downs-Boiler anticipates each of claims 23, 25-27, and 30 of the '114 Patent. I start my analysis below with claim 25 because it has the fewest limitations. I then discuss claims dependent from claim 25 and follow with claim 23 which repeats many of the limitations of claim 25. In the subsections below, I rely on the disclosure of Downs-Boiler. The material I rely on was also

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[746] EX1005 (Vosteen589) ¶¶[0006], [0009], [0013], [0014].

disclosed and supported by Downs-Boiler-Provisional, so parallel citations to Downs-Boiler-Provisional are also included.

A. INDEPENDENT CLAIM 25

1. Claim 25: Preamble—"A method of separating mercury from a mercury-containing gas, the method comprising:"

434. Downs-Boiler discloses the preamble. The title of Downs-Boiler is "Bromine Addition for the Improved Removal of Mercury from Flue Gas.[747] Flue gas is an example of a mercury-containing gas, and "removal of mercury" refers to separating the mercury from a mercury-containing gas in order to reduce mercury emissions. Downs-Boiler repeatedly characterizes the disclosed process as for removing (i.e., separating) mercury from flue gas (i.e., a mercury-containing gas):

> [T]he use of bromine-containing compounds, added to the coal, or to the boiler combustion furnace, are significantly more effective than chlorine-containing compounds in enhancing the oxidation of mercury, thereby enhancing the overall removal of mercury in downstream pollution control devices.[748]

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[747] EX1006 (Downs-Boiler) at Title; EX1007 (Downs-Boiler-Provisional) at Title.

[748] EX1006 (Downs-Boiler) ¶[0007]; EX1007 (Downs-Boiler-Provisional) ¶[0013].

Claim 1 of Downs-Boiler also recites a similar preamble: "1. A method of removing a portion of the elemental mercury in a flue gas"[749] The removal of mercury from the flue gas as described by Downs-Boiler is by separating the mercury along with a sorbent:[750]

> The sorbent, and its burden of adsorbed mercury, are subsequently removed from the flue gases in a downstream particulate collector. Adsorption is a technique that has often been successfully applied for the <u>separation and removal</u> of trace quantities of undesirable components.

Downs-Boiler characterizes its disclosed "invention" as "a cost-effective method of removing elemental mercury from coal combustion flue gases."[751]

2. <u>Claim 25: Element 25(a)—"combusting coal in a combustion chamber, to provide the mercury-containing gas, wherein"</u>

435. Downs-Boiler discloses this claim element. The primary application taught by Downs-Boiler is with "[c]oal-fired utility boilers [that] are a known major source of anthropogenic mercury emissions in the United States."[752] Downs-Boiler

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[749] EX1006 (Downs-Boiler) at Claim 1; see also EX1007 (Downs-Boiler-Provisional) at Claim 1 ("1. A method of reducing the mercury concentration of a flue gas comprising.").

[750] EX1006 (Downs-Boiler) ¶[0004]; EX1007 (Downs-Boiler-Provisional) ¶[005].

[751] EX1006 (Downs-Boiler) ¶[0018]; EX1007 (Downs-Boiler-Provisional) ¶[021].

[752] EX1006 (Downs-Boiler) ¶[0001]; see also EX1007 (Downs-Boiler-Provisional) ¶[002].

illustrates a conventional coal-fired utility boiler (labeled "boiler" below) used for the purpose of combusting coal, as represented by the arrow into combustion chamber 14. This is shown in Figures 2 and 4-6 of Downs-Boiler:[753]

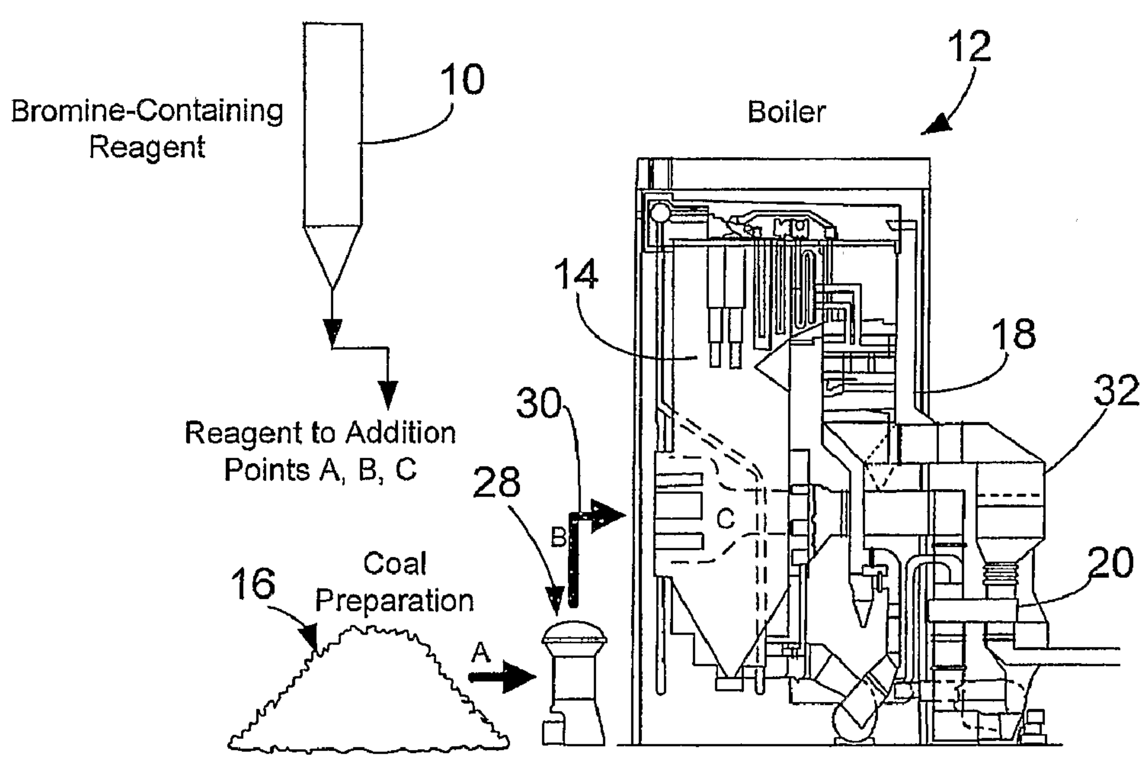

FIG. 2

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[753] EX1006 (Downs-Boiler) ¶[0010]-[0014], Figures 2, 4-6; see also EX1007 (Downs-Boiler-Provisional) ¶¶[0012]-[0016], Figures 2, 4-6.

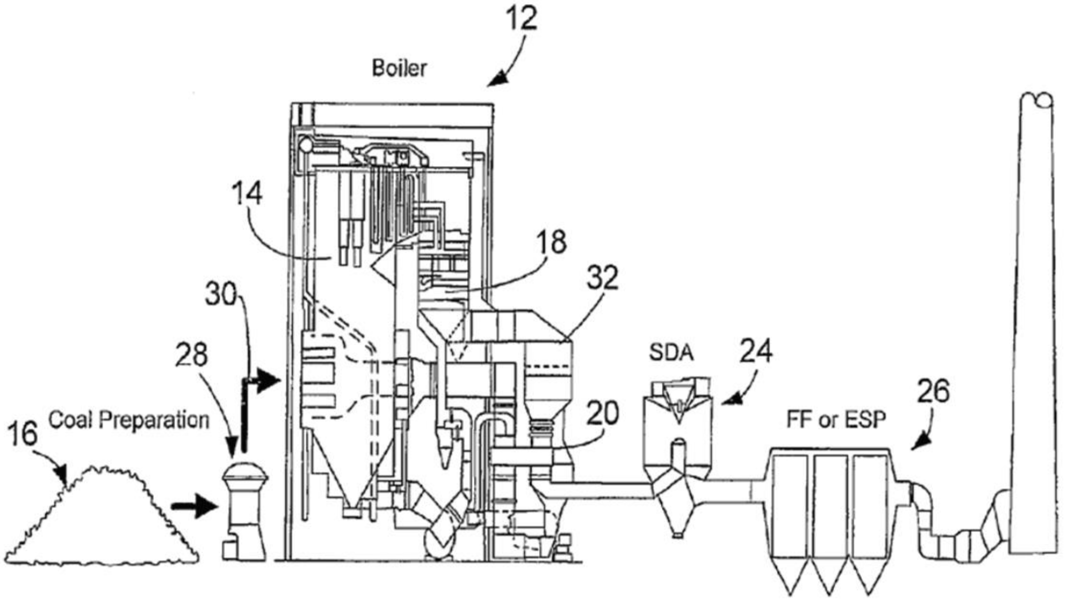
12
Boiler
14
18
32
30
28
SDA
24
Coal Preparation
20
26
16
FF or ESP

FIG. 4

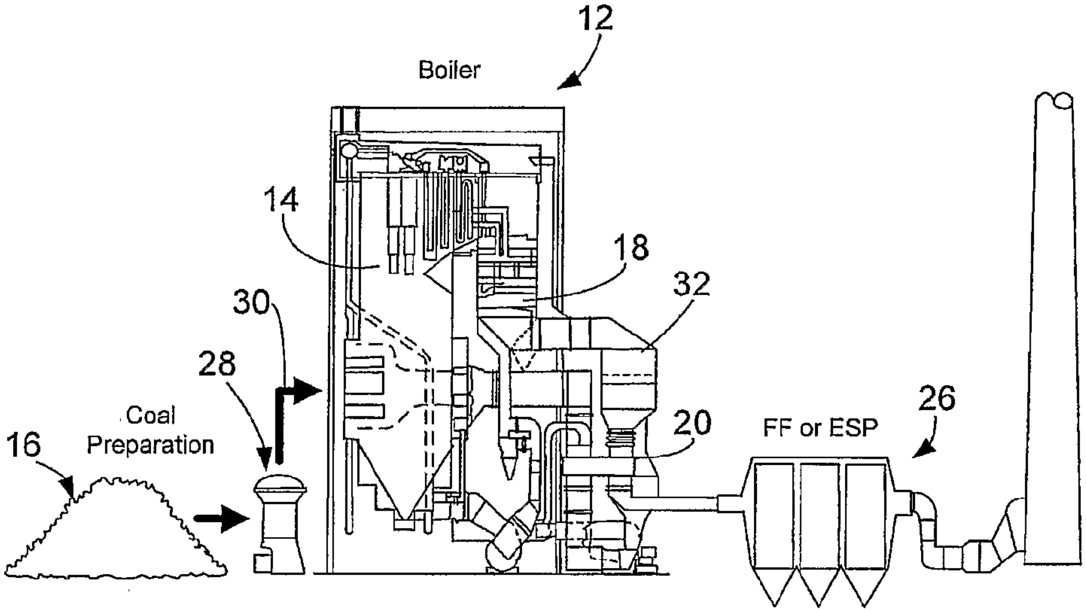
12
Boiler
14
18
32
30
28
Coal Preparation
20
26
16
FF or ESP

FIG. 5

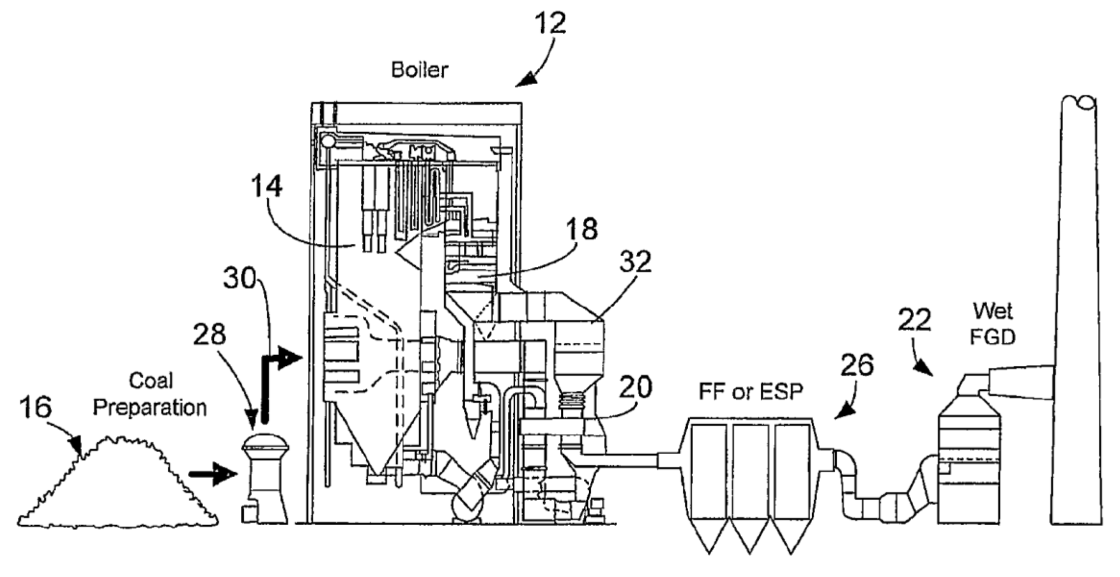

FIG. 6

436. Downs-Boiler goes on to describe such a combustion of coal together with an added bromine-containing reagent, as illustrated in Figures 2 and 4-6:[754]

> A bromine containing reagent 10 is added to the boiler 12 combustion furnace 14, either directly or by premixing with the incoming coal 16. Bromine species released during the combustion process enhance the oxidation of mercury as the combustion gases pass through the furnace 14 and, in particular, through the cooler sections of the boiler convection pass 18 and combustion air preheater 20.

Downs-Boiler describes combusting common ranks of coal used by the electric utility industry and, specifically, that "the coal-fired boiler fuel 16 may include

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[754] EX1006 (Downs-Boiler) ¶[0015]; see also EX1007 (Downs-Boiler-Provisional) ¶[0018].

bituminous, subbituminous, and lignite coals and blends, thereof."[755] Finally, Downs-Boiler states that "[m]ercury appears in coal combustion flue gases in both solid and gas phases."[756] This flue gas referred to by Downs-Boiler is an example of a mercury-containing gas, and it was generated from the combustion of coal.

3. Claim 25: Element 25(b)—"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 combination thereof,"

437. Downs-Boiler discloses this claim element. Although the claim only requires one to be shown, Downs-Boiler discloses both: 1) adding Br_2, HBr, and/or a bromide compound to the coal upstream of the combustion chamber, and 2) adding Br_2, HBr, and/or a bromide compound to the combustion chamber.

438. First, Downs-Boiler discloses Br_2, HBr, a bromide compound, or a combination thereof, added to the coal upstream of the combustion chamber. Downs-Boiler explains that the bromine-containing reagent may comprise, "but is not limited to, alkali metal and alkaline earth metal bromides, hydrogen bromide

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[755] EX1006 (Downs-Boiler) ¶[0020]; see also EX1007 (Downs-Boiler-Provisional) ¶[0023].

[756] EX1006 (Downs-Boiler) ¶[0002]; see also EX1007 (Downs-Boiler-Provisional) ¶[003].

(HBr) or bromine (Br_2).”[757] Downs-Boiler also specifically discloses calcium bromide ($CaBr_2$) as another suitable bromide compound for use as the bromine-containing reagent.[758]

439. This bromine-containing reagent is applied to the coal upstream of the combustion chamber. Downs-Boiler teaches that a “bromine containing reagent 10 is added to the boiler 12 combustion furnace 14, either directly or by premixing with the incoming coal 16.”[759] According to the preferred embodiment of Downs-Boiler, “an aqueous solution of calcium bromide is sprayed onto the crushed coal 16 before the coal 16 is pulverized for combustion. The aqueous solution is easily handled and metered onto the coal 16 [such that the] coal pulverizers 28 intimately mix the bromide reagent 10 with the coal 16, and the pulverized coal conveying system 30 to the several coal burners (not shown) ensures an even distribution of the reagent 10 across the boiler furnace 14.”[760] Thus, upstream of the combustion chamber, such

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[757] EX1006 (Downs-Boiler) ¶[0021]; see also EX1007 (Downs-Boiler-Provisional) ¶[0024].

[758] EX1006 (Downs-Boiler) ¶[0018]-[0019]; see also EX1007 (Downs-Boiler-Provisional) ¶[0021-22].

[759] EX1006 (Downs-Boiler) ¶[0015]; see also EX1006 (Downs-Boiler) ¶[0007]; EX1007 (Downs-Boiler-Provisional) ¶¶[009], [0018].

[760] EX1006 (Downs-Boiler) ¶[0019], Figure 2; see also EX1007 (Downs-Boiler-Provisional) ¶[0022], Figure 2.

as in the coal pulverizers and the pulverized coal conveying system, at least one or a combination of Br_2, HBr, and a bromide compound (e.g., calcium bromide ($CaBr_2$)) has been added on the coal.

440. Second, Downs-Boiler discloses "the combustion chamber comprises added Br_2, HBr, a bromide compound, or a combination thereof." As described above—where the bromine-containing reagent is disclosed as added to the coal and/or the coal conveying system—this further discloses that the combustion chamber comprises added bromine-containing reagent (e.g., Br_2, HBr, a bromide compound, or a combination thereof). As explained by Downs-Boiler, as a result of adding the bromine-containing reagent to the coal and/or the coal conveying system, the "<u>[b]romine species released during the combustion process enhance the oxidation of mercury as the combustion gases pass through the furnace 14</u>."[761] That the bromine-containing reagent is "sprayed on the crushed coal 16 before the coal is pulverized <u>for combustion</u>" additionally "ensures even distribution of the [bromine-containing] reagent 10 <u>across the boiler furnace</u>" (i.e., in the combustion chamber).[762]

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[761] EX1006 (Downs-Boiler) ¶[0015]; see also EX1007 (Downs-Boiler-Provisional) ¶[0018].

[762] EX1006 (Downs-Boiler) ¶[0019]; see also EX1007 (Downs-Boiler-Provisional) ¶[0022].

441. Downs-Boiler also discloses introduction of Br_2, HBr, and/or a bromide compound (i.e., the bromine-containing reagent) directly into the combustion chamber. Downs-Boiler teaches that a "<u>bromine containing reagent 10 is added to the boiler 12 combustion furnace 14, either directly</u> or by premixing with the incoming coal 16."[763] Downs-Boiler describes that the inventors successfully tested direct introduction of the bromine-containing reagent—specifically, a bromide compound of calcium bromide ($CaBr_2$)—"injected into the combustion chamber 14 through a coal burner."[764] Downs-Boiler further recognizes that "the bromine-containing reagent 10 may be fed to the boiler combustion zone 14 in gaseous, liquid, or solid form."[765] Thus, the combustion chamber comprises at least one or a combination of Br_2, HBr, and a bromide compound (e.g., calcium bromide ($CaBr_2$)).

442. Third, Downs-Boiler discloses adding a bromine-containing reagent to both the coal and the combustion chamber. As described above, Downs-Boiler describes applying the bromine-containing reagent to the coal upstream of the

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[763] EX1006 (Downs-Boiler) ¶[0015]; see also EX1007 (Downs-Boiler-Provisional) ¶[0018].

[764] EX1006 (Downs-Boiler) ¶[0019]; see also EX1007 (Downs-Boiler-Provisional) ¶[0021].

[765] EX1006 (Downs-Boiler) ¶[0022]; see also EX1007 (Downs-Boiler-Provisional) ¶[0025].

combustion chamber in such a way that added Br_2, HBr, and/or a bromide compound (e.g., calcium bromide ($CaBr_2$)) is both on the coal <u>and in</u> the combustion chamber.

443. Furthermore, as illustrated in Figure 2, reproduced below as annotated, Downs-Boiler illustrates that the bromine-containing reagent may be introduced "to addition points A, B, C" including "coal preparation" (point A), "the pulverized coal conveying system 30" (point B) and "the boiler furnace 14" (point C).[766]

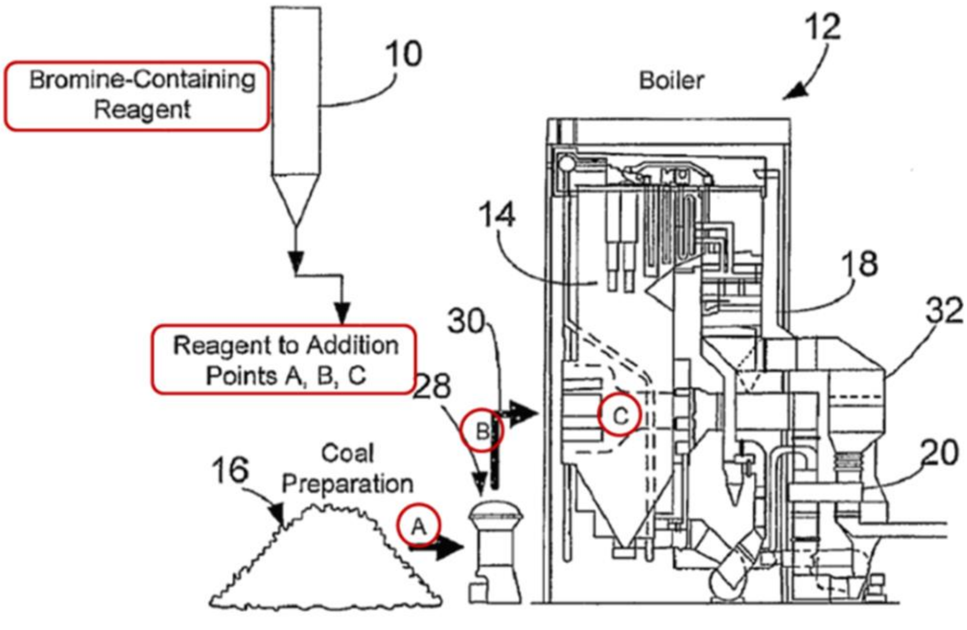

FIG. 2

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[766] EX1006 (Downs-Boiler) ¶[0019], Figure 2 (annotated); see also EX1007 (Downs-Boiler-Provisional) ¶[0022], Figure 2.

Downs-Boiler in no way restricts simultaneous introduction to each of points A, B, and C. Rather, as described above, Downs-Boiler invites, if not encourages, simultaneous introduction to each of points A, B, and C or some combination of A/B and C to "intimately mix the bromide reagent 10 with the coal" so as to achieve a more "even distribution of the reagent 10 across the boiler furnace 14."[767] Accordingly, Downs-Boiler discloses each and every limitation of Claim Element 25(b).

4. **Claim 25: Element 25(c)—"injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber; contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition; and"**

444. Downs-Boiler discloses this claim element. Downs-Boiler discloses injecting activated carbon into a mercury-containing flue gas downstream of the combustion chamber and contacting mercury with the sorbent to form a mercury/sorbent composition.

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[767] EX1006 (Downs-Boiler) ¶[0019]; see also EX1007 (Downs-Boiler-Provisional) ¶[0022].

a. "injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber"

445. Downs-Boiler discloses injecting a sorbent material comprising activated carbon, referring to the example of "powdered activated carbon (PAC)."[768] Downs-Boiler explains that the use of a conventional PAC injection process is improved by the addition of bromine, in that the bromine-containing reagent "enhances the removal of mercury across a <u>PAC injection</u> process."[769] Downs-Boiler repeats in other places that the bromine-containing reagent saves costs by making more efficient use of the activated-carbon sorbent material that is "inject[ed]."[770] As explained by Downs-Boiler, the disclosed injected activated-carbon sorbent materials (e.g., sorbent injection systems using PAC) are part of "<u>downstream</u> pollution control systems such as . . . <u>PAC injection</u> systems."[771] Here, "downstream" is relative to the location of the combustion chamber (also referred to

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[768] EX1006 (Downs-Boiler) ¶[0025]; see also EX1007 (Downs-Boiler-Provisional) ¶[0028].

[769] EX1006 (Downs-Boiler) ¶[0016]; see also EX1007 (Downs-Boiler-Provisional) ¶[0019].

[770] EX1006 (Downs-Boiler) ¶¶[0004], [0015], [0016], and [0025]; see also EX1007 (Downs-Boiler-Provisional) ¶¶[005], [0018], [0019], and [0028].

[771] EX1006 (Downs-Boiler) ¶[0015]; see also EX1007 (Downs-Boiler-Provisional) ¶[0018].

as the "boiler"), and thus after generation of the mercury-containing gas.[772] A POSITA would also have understood that the sorbent would be injected downstream (and not upstream) of the furnace, or else it would be burned just like coal, and thus not available to adsorb any mercury. Rather, the activated-carbon sorbent material is injected into a mercury-containing gas: "injection of a carbonaceous sorbent (e.g., powdered activated carbon, or PAC) into the flue gas upstream of the dust collector to adsorb vapor-phase mercury."[773]

b. "contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition"

446. In the context of conventional mercury removal by PAC injection, Downs-Boiler explains that adsorption (i.e., contact) of the mercury by the sorbent occurring in the mercury-containing (flue) gas system (i.e., downstream of the combustion chamber) has been successfully shown to form a mercury/sorbent composition:[774]

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[772] EX1006 (Downs-Boiler) ¶¶[0012]-[0014] (discussing "downstream" with respect to the "boiler"); see also EX1007 (Downs-Boiler-Provisional) ¶¶[0014]-[0016].

[773] EX1006 (Downs-Boiler) ¶[0004]; see also EX1007 (Downs-Boiler-Provisional) ¶[005].

[774] EX1006 (Downs-Boiler) ¶[0004]; see also EX1007 (Downs-Boiler-Provisional) ¶[005].

> injection of a carbonaceous sorbent (e.g., powdered activated carbon, or PAC) into the flue gas upstream of the dust collector to adsorb vapor-phase mercury. The sorbent, and its burden of adsorbed mercury, are subsequently removed from the flue gases in a downstream particulate collector. Adsorption is a technique that has often been successfully applied for the separation and removal of trace quantities of undesirable components.

The "sorbent, and its burden of adsorbed mercury" discloses a mercury/sorbent composition, because the "adsorbed mercury" is adsorbed onto sorbent. For this process, described by Downs-Boiler as taking place as part of a dry emission-control system that further includes an electrostatic precipitator or fabric filter, the "adsorption" of mercury refers to a process by which atoms, ions, or molecules in a fluid (typically a gas) are bound to the surface of a sorbent, and thus by definition the sorbent is "contacting mercury in the mercury-containing gas," as per Claim Element 25(c).

447. Downs-Boiler recognizes that, when contacted with a sorbent, mercury in the mercury-containing gas forms a mercury/sorbent composition through the sorbent "bond[ing] with adsorbed mercury species" and that the strength of this bond is improved by halogens.[775] In particular, Downs-Boiler explains that adding bromine in conjunction with activated carbon "results in an increased fraction of particulate-bound mercury," which includes an increase in the formation of sorbent-

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[775] EX1006 (Downs-Boiler) ¶[0004]; EX1007 (Downs-Boiler-Provisional) ¶[005].

bound mercury.[776] This increase in the fraction of particulate-bound mercury is explained as leading to a mercury/sorbent composition due to the increased "reactivity of oxidized mercury with PAC."[777]

448. In addition, a person of skill in the art would have understood that the scope of a "mercury/sorbent composition" is broad enough to encompass a "mercury/sorbent/bromine" composition, because, for example, independent claim 25 of the '114 Patent recites a "mercury/sorbent composition" and its dependent claim 30 recites that "the mercury/sorbent composition comprises the element bromine, the sorbent material, and mercury."[778] A POSITA would have also understood that the sorbent and halogen would have reacted to form at least a quantity of a mercury/sorbent composition upon contact.[779]

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[776] EX1006 (Downs-Boiler) ¶[0015]; EX1007 (Downs-Boiler-Provisional) ¶[0018].

[777] EX1006 (Downs-Boiler) ¶[0016]; EX1007 (Downs-Boiler-Provisional) ¶[0019].

[778] EX1001 ('114 Patent) at Claims 25, 30.

[779] See Technology Background and State of the Art, §IX.C.3, § IX.G.2.

5. Claim 25: Element 25(d)—"separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas."

449. Downs-Boiler discloses this claim element. Downs-Boiler explains that the desired removal of mercury from the flue gas is by a separation of the particulate-bound mercury. Separation of the particulate-bound mercury (mercury/sorbent composition), which includes the oxidized mercury adsorbed onto the PAC as discussed above regarding Claim Element 25(c)(2), is removed from the mercury-containing gas by a particulate collector as a way to clean the flue gas:[780]

> The sorbent, and its burden of adsorbed mercury, are subsequently removed from the flue gases in a downstream particulate collector. Adsorption is a technique that has often been successfully applied for the separation and removal of trace quantities of undesirable components.

The "sorbent, and its burden of adsorbed mercury" refers to a mercury/sorbent composition, and it is "removed" by separating the mercury/sorbent composition from the mercury-containing gas to form a cleaned gas. Downs-Boiler illustrates a number of example particulate collection devices that may be used to separate the mercury-sorbent composition to produce a cleaned gas, each of which were well known to a POSITA. These particulate collectors include "electrostatic precipitators

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[780] EX1006 (Downs-Boiler) ¶[0004]; see also EX1007 (Downs-Boiler-Provisional) ¶[005].

(ESP) or fabric filters (FF), sometimes called baghouses" that "provide high-efficiency removal of particulate-bound mercury."[781]

B. CLAIMS DEPENDING FROM CLAIM 25 (CLAIMS 26, 27, 30)

1. Claim 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."

450. Downs-Boiler discloses this claim. As I explain regarding Claim Element 25(b), Downs-Boiler describes that the bromine-containing reagent is added to the coal upstream of the combustion chamber. Exemplary bromine-containing reagents added to the coal "comprise, but [are] not limited to, alkali metal and alkaline earth metal bromides, hydrogen bromide (HBr) or bromine (Br_2)"[782] including "calcium bromide"[783] ($CaBr_2$).

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[781] EX1006 (Downs-Boiler) ¶¶[0003], [0023], Figures 4-6; see also EX1007 (Downs-Boiler-Provisional) ¶¶ [004] [0026], Figures 4-6.

[782] EX1006 (Downs-Boiler) ¶[0021]; see also EX1007 (Downs-Boiler-Provisional) ¶[0024].

[783] EX1006 (Downs-Boiler) ¶[0019]; see also EX1007 (Downs-Boiler-Provisional) ¶[0022].

2. Claim 27: "The method of claim 25, wherein the combustion chamber comprises the added Br_2, HBr, the bromide compound, or a combination thereof."

451. Downs-Boiler discloses this claim. As I explain regarding Claim Element 25(b), Downs-Boiler describes that the bromine-containing reagent is added to the combustion chamber (occasionally referred to as a "boiler combustion furnace" by Downs-Boiler). Exemplary bromine-containing reagents added to the combustion chamber "comprise, but [are] not limited to, alkali metal and alkaline earth metal bromides, hydrogen bromide (HBr) or bromine (Br_2)"[784] and "calcium bromide."[785]

3. Claim 30: "The method of claim 25, wherein the mercury/sorbent composition comprises the element bromine, the sorbent material, and mercury."

452. Downs-Boiler discloses this claim. As described above for Claim Element 25(c), Downs-Boiler discloses that mercury in the flue gas is oxidized by the bromine-containing species and adsorbed onto activated carbon. Downs-Boiler describes that the use of the bromine-containing halogen in the presence of mercury results in an "increased fraction of mercury appearing in the oxidized form"—the

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[784] EX1006 (Downs-Boiler) ¶[0021]; see also EX1007 (Downs-Boiler-Provisional) ¶[0024].

[785] EX1006 (Downs-Boiler) ¶[0019]; see also EX1007 (Downs-Boiler-Provisional) ¶[0022].

oxidized form being that of mercuric bromide ($HgBr_2$).[786] The reaction that Downs-Boiler discloses as "due to the higher reactivity of oxidized mercury with PAC" occurs within the presence of each of the element bromine, the sorbent material, and mercury.[787] A POSITA would have understood that the reaction between the oxidized mercury appearing as mercuric bromide ($HgBr_2$) with the sorbent results in the formation of a composition with each of the constituent elements: bromine, the sorbent material, and mercury. Downs-Boiler confirms that "PAC injection removes both oxidized and elemental mercury species, although removal efficiencies are higher for the oxidized form."[788] Because the reaction taking place between the oxidized mercuric bromide ($HgBr_2$) is explained by Downs-Boiler as adsorption by the sorbent, a POSITA would therefore have understood that each of the three constituents of the reaction are present in the resultant mercury/sorbent composition which comprises the element bromine, the sorbent material, and mercury.

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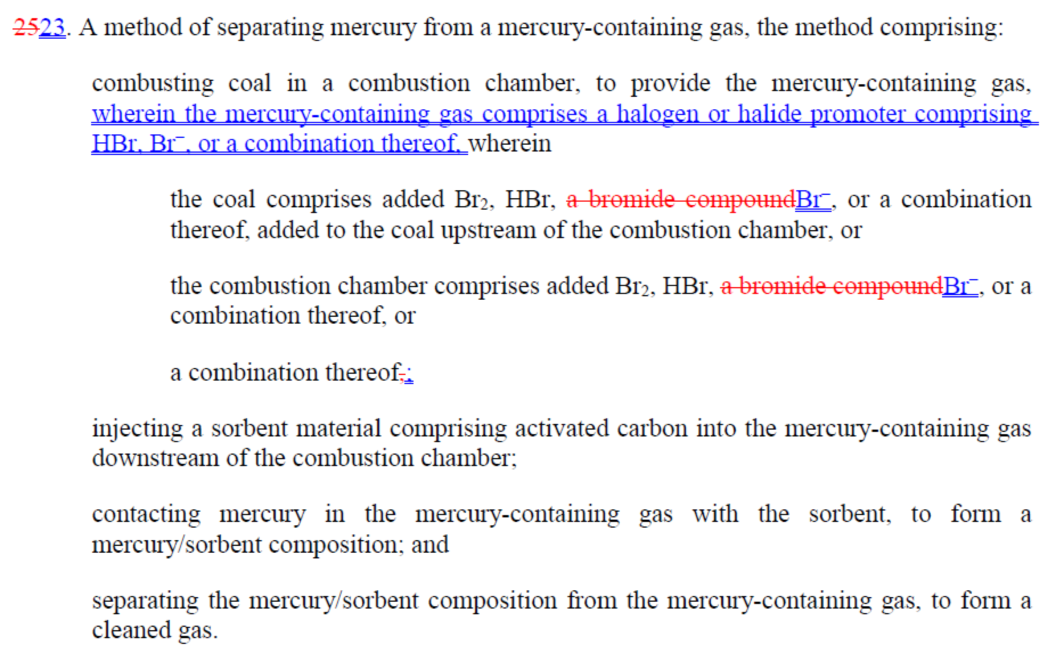
[786] EX1006 (Downs-Boiler) ¶[0015]; see also EX1007 (Downs-Boiler-Provisional) ¶[0018].

[787] EX1006 (Downs-Boiler) ¶[0016]; EX1007 (Downs-Boiler-Provisional) ¶[0019].

[788] EX1006 (Downs-Boiler) ¶[0004]; EX1007 (Downs-Boiler-Provisional) ¶[005].

C. INDEPENDENT CLAIM 23

453. As shown in the redline below, claim 23 is nearly identical to claim 25, with minor changes.



~~25~~23. A method of separating mercury from a mercury-containing gas, the method comprising:

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

the coal comprises added Br_2, HBr, ~~a bromide compound~~Br^-, 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~~Br^-, or a combination thereof, or

a combination thereof~~,~~;

injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber;

contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition; and

separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas.

Accordingly, my analysis provided for claim 25 applies to claim 23.

1. Claim 23: Preamble—"A method of separating mercury from a mercury-containing gas, the method comprising:"

454. The language of the preamble of claim 23 is identical to the preamble of claim 25. Accordingly, the explanation I provide above for the preamble of claim 25 applies equally to the preamble of claim 23.

2. Claim 23: Element 23(a)—"combusting coal in a combustion chamber, to provide the mercury-containing gas, wherein"

455. The language of Claim Element 23(a) is identical to the language of Claim Element 25(a). Accordingly, the explanation I provide above for Claim Element 25(a) applies equally to Claim Element 23(a).

3. Claim 23: Element 23(b)—"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 coal upstream of the combustion chamber, or the combustion chamber comprises added Br_2, HBr, Br^-, or a combination thereof, or a combination thereof;"

456. The language of Claim Element 23(b) is similar to the language of Claim Element 25(b), and I refer to my discussion of that claim element. Claim 23(b) has the following changes, as compared to claim 25(b):

> 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^{--}~~, 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, Br^{--}~~, a bromide compound,~~ or a combination thereof,
>
> or a combination thereof;

457. Claim element 23(b) is disclosed by Downs-Boiler. As explained with respect claim to element 25(b), Downs-Boiler discloses that the combustion chamber

and/or the coal upstream of the combustion chamber has added bromine-containing reagent. As further explained with respect to Claim Element 25(b) above, Downs-Boiler discloses that the bromine-containing reagent may comprise Br_2 and HBr. Additionally, Downs-Boiler discloses that the bromine-containing reagent may be an "aqueous solution of calcium bromide ($CaBr_2$)," in which $CaBr_2$ dissociates in solution to form bromide ions.[789] Downs-Boiler describes applying this "aqueous solution of calcium bromide" ($CaBr_2$) to the coal,[790] as well as directly into the combustion chamber.[791] In these aqueous solutions (solutions of water) with calcium bromide ($CaBr_2$), $CaBr_2$ dissociates to form bromide ions (Br^-). The Br- ions may be stabilized by the coal surfaces or by moisture on the coal surfaces. Downs-Boiler therefore discloses wherein the coal comprises added Br_2, HBr, and/or Br^-.

458. Claim element 23(b) recites express examples of chemicals that qualify as halogen or halide promoters—"a halogen or halide promoter comprising HBr, Br-, or a combination thereof"—and Downs-Boiler discloses these express examples.

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[789] EX1006 (Downs-Boiler) ¶¶[0018]-[0019]; see also EX1007 (Downs-Boiler-Provisional) ¶¶[0021]-[0022].

[790] EX1006 (Downs-Boiler) ¶[0019]; see also EX1007 (Downs-Boiler-Provisional) ¶[0022].

[791] EX1006 (Downs-Boiler) ¶[0018]; see also EX1007 (Downs-Boiler-Provisional) ¶[0021].

As described above for Claim Element 25(b), Downs-Boiler discloses adding "alkali metal and alkaline earth metal bromides, hydrogen bromide (HBr) or bromine (Br_2)" to the coal upstream of the combustion chamber and/or to the combustion chamber itself.[792] And, as described in the preceding paragraph, Downs-Boiler also discloses adding bromide ions (Br^-) onto the coal in the form of an "aqueous solution of calcium bromide ($CaBr_2$)," in which $CaBr_2$ dissociates in solution to form the bromide ions.[793] Downs-Boiler explains that these bromine-containing species pass through the combustion chamber[794] and, as a result, these halogen or halide promoters "enhance[] the removal of mercury across a PAC injection process."[795] At the temperatures of the combustion chamber and flue gas, at least the molecular bromine (Br_2) and hydrogen bromide (HBr) are each vaporized and thus present in the gas-phase in mercury-containing flue gas. The boiling point of Br_2 is only 58.8ºC

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[792] EX1006 (Downs-Boiler) ¶[0021]; see also EX1007 (Downs-Boiler-Provisional) ¶[0024].

[793] EX1006 (Downs-Boiler) ¶[0018]; see also EX1007 (Downs-Boiler-Provisional) ¶[0021].

[794] EX1006 (Downs-Boiler) ¶[0015]; see also EX1007 (Downs-Boiler-Provisional) ¶[0018].

[795] EX1006 (Downs-Boiler) ¶¶[0015]-[0016]; see also EX1007 (Downs-Boiler-Provisional) ¶¶[0018]-[0019].

(it is a fuming liquid at room temperature), and the boiling point of hydrogen bromide is -66.38 ºC (i.e., it is a gas at room temperature).[796]

4. Claim 23: Element 23(c)—"injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber; contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition; and"

459. The language of Claim Element 23(c) is identical to the language of Claim Element 25(c). Accordingly, the explanation I provide above for Claim Element 25(c) applies equally to Claim Element 23(c).

5. Claim 23: Element 23(d)—"separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas."

460. The language of Claim Element 23(d) is identical to the language of Claim Element 25(d). Accordingly, the explanation I provide above for Claim Element 25(d) applies equally to Claim Element 23(d).

XV. GROUND A4 AND GROUND A5: OBVIOUSNESS OVER DOWNS-BOILER IN VIEW OF STARNS [GROUND A4] AND DOWNS-BOILER IN VIEW OF MASS-EPA [GROUND A5]

461. It is my opinion that claims 1-8 and 12-30 would have been obvious over the combination of Downs-Boiler and Starns (Ground A4). Claims 1-30 would have been obvious over the combination of Downs-Boiler and Mass-EPA (Ground

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[796] EX1036 (CRC Press: March 2005) at 4-53 and 4-65.

A5). Ground A4 and Ground A5 largely rely on the common disclosure of Downs-Boiler, with certain limitations disclosed by Starns (Ground A4) and by Mass-EPA (Ground A5) (in some cases, in addition to disclosure of those limitations already present in Downs-Boiler).

A. REASONS TO COMBINE

462. A person of ordinary skill in the art would have been motivated to combine Downs-Boiler with Starns (Ground A4) and Downs-Boiler with Mass-EPA (Ground A5), and with reasonable expectation of success, because all three references are directed towards the same goal (removing mercury from coal-combustion flue gas) and are interoperable with one another.

463. As described above in Ground A3 and more fully below, Downs-Boiler describes processes for improving the removal of mercury released from the combustion of coals. Downs-Boiler discloses that the "mercury removal" may be performed with "a sorbent injection system" using "carbonaceous sorbents [that] include, but are not limited to, powdered activated carbon (PAC)."[797] Downs-Boiler seeks to enhance the effectiveness of mercury removal, including through PAC, by using a bromine-containing promoter added either to the coal or to a combustion

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[797] EX1006 (Downs-Boiler) ¶[0025].

furnace.[798] Downs-Boiler also discloses that the mercury-sorbent composition would be removed by an electrostatic precipitator (ESP) or fabric filter.[799]

464. Downs-Boiler however does not fully disclose all the details about how to implement the PAC injection system, such as injection rates or the type of activated-carbon to use. Such details were well-known to a person of skill in the art by the priority date of the Challenged Patent, as described in the Technology Background and State of the Art,[800] and Starns and Mass-EPA each supplies those details. In particular, as explained above regarding Technology Background and State of the Art, a POSITA would have readily understood how to add the activated-carbon sorbent to the system, namely by injection into the mercury-containing flue gas between the combustion chamber and the PCD (such as the ESP or fabric filter). Starns and Mass-EPA each provides these details, and a POSITA would have been motivated to combine Downs-Boiler with Starns (Ground A4) and Downs-Boiler with Mass-EPA (Ground A5).

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[798] EX1006 (Downs-Boiler) at Abstract.

[799] EX1006 (Downs-Boiler) Figure 6; see also EX1006 (Downs-Boiler) Figures 4-5; EX1007 (Downs-Boiler-Provisional) Figures 4-6.

[800] Technology Background and State of the Art ("Sorbents/Activated Carbon"), §IX.C.

1. Ground A4 (Combination of Downs-Boiler with Starns)

465. Like Downs-Boiler, Starns also pertains to systems for removing mercury from the flue gas of coal-combustion plants. The title of Starns is, "Full-Scale Test of Mercury Control with Sorbent Injection and an ESP at Wisconsin Electric's Pleasant Prairie Power Plant."[801] Like Downs-Boiler, Starns touts a dry emission system using sorbent, particularly activated carbon injection (ACI), to remove the mercury. Starns touts this as "mature" and readily available technology:

> The most mature, retrofit technology available today is the injection of sorbents such as powdered activated carbon (PAC) into the flue gas upstream of the particle control equipment. The gas-phase mercury in the flue gas contacts the sorbent and attaches to its surface.[802]

466. Starns provides details as to how to supply activated carbon to the system and processes of Downs-Boiler:

- **Injection of the activated carbon:** "injection equipment" that includes a "bulk-storage silo and twin blower/feeder trains ...."[803] The injection equipment at a full-scale coal-fired power plant is shown below, in Figure 2 of Starns:

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[801] EX1008 (Starns) at 1.

[802] EX1008 (Starns) at 2.

[803] EX1008 (Starns) at 7; *see also* EX1008 (Starns) at Fig. 2.

- **Control of activated carbon injection (ACI):** "A PLC [programmable logic controller] is used to control system operation and adjust injection rates."[804] One of the "[p]rimary variables" to control how much mercury is removed is "injection concentration" of the sorbent.[805]

- **Type of activated carbon:** Starns describes that powdered activated carbon (PAC) should be used: "Four sorbents were selected for full-scale evaluation in the parametric test series. All four sorbents were PACs …."[806]

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[804] EX1008 (Starns) at 7; *see also* EX1008 (Starns) at Fig. 2.

[805] EX1008 (Starns) at 10; *see also* EX1008 (Starns) at 13-16, Figs. 4, 5 (achieving up to 70% mercury removal by increasing the sorbent concentration).

[806] EX1008 (Starns) at 9.

467. Starns provides the details of ACI—what Starns describes as the "most mature retrofit technology available today"[807]—to purify the mercury-containing flue gas, including how the sorbent concentration affects the mercury-removal rate. A POSITA would have been motivated, with a reasonable expectation of success, to use the activated carbon injection (ACI) system and control scheme of Starns with the halogenation and coal-combustion system of Downs-Boiler.

468. As discussed above, Downs-Boiler discloses that, in its system that injects calcium bromide to improve the removal of mercury in a particulate collector such as a fabric filter or an ESP, "mercury removal may be further enhanced by utilizing a sorbent injection system."[808] Downs-Boiler also discloses that this injected sorbent is powdered activated carbon.[809] However, Downs-Boiler does not fully disclose certain details regarding the specifics of how such an activated carbon sorbent might be injected in the Downs-Boiler system. Starns does disclose such details for an ACI system. As ACI was already a "mature" technology by the time of Starns, the combination of Downs-Boiler and Starns represents no more than

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[807] EX1008 (Starns) at 2.

[808] EX1006 (Downs-Boiler) ¶[0025]

[809] EX1006 (Downs-Boiler) ¶[0025]

combining prior art elements according to known methods to yield predictable results of removing mercury. Moreover, the activated carbon injection of Starns was a "known technique" and introducing the halogens (as described in Downs-Boiler) would yield the predictable results in the form of improved mercury removal.

469. A POSITA would have a reasonable expectation of success in combining Downs-Boiler with Starns because, as Starns explains, "The most mature, retrofit technology available today is the injection of sorbents such as powdered activated carbon (PAC) into the flue gas upstream of the particle control equipment."[810] The particle control equipment in Starns is an electrostatic precipitator (ESP), and Starns recommends "using activated carbon injection upstream of an ESP."[811] A POSITA would have been motivated, as Starns suggests, to use activated carbon injection between the combustion chamber (furnace) and the ESP or fabric filter in Downs-Boiler.[812] The mercury-sorbent composition is eventually removed by standard and well-known particulate control devices, such as the electrostatic precipitators (ESPs) in Downs-Boiler and in Starns.

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[810] EX1008 (Starns) at 2.

[811] EX1008 (Starns) at 20. Starns also discloses that a fabric filter can be used. EX1008 (Starns) at 19 (Fig. 8).

[812] EX1006 (Downs-Boiler) Figure 6 (annotated; see also EX1006 (Downs-Boiler) Figures 4-5; EX1007 (Downs-Boiler-Provisional) Figures 4-6.

2. Ground A5 (Combination of Downs-Boiler with Mass-EPA)

470. Like Downs-Boiler, Mass-EPA also pertains to systems for removing mercury from the flue gas of coal-combustion plants. The title of Mass-EPA is, "Evaluation of the Technological and Economic Feasibility of Controlling and Eliminating Mercury Emissions from the Combustion of Solid Fossil Fuel."[813] And like Downs-Boiler, Mass-EPA discusses the use of sorbents with dry emission particulate management (PM) control systems, such as ESPs:

> A number of technologies have been under development specifically to address mercury control and are in various stages of research, development, and testing. They include use of sorbents (processes that use injection and fixed-bed configurations), mercury oxidation materials, and mercury oxidation catalysts. A number of these technologies can be used in plants equipped with a PM control device (ESP and/or FF).[814]
>
> Mercury can be captured and removed from gas by injection of a sorbent into the exhaust system and subsequent collection of the particulates in a PM control device. Availability of low-cost and efficient sorbents and effective particulate collection are key in implementation of this type of mercury control.[815]

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[813] EX1008 (Starns) at 1.

[814] EX1009 (Mass-EPA) at 31 (section entitled, "Mercury-Specific Control Technologies").

[815] EX1009 (Mass-EPA) at 32 (subsection entitled, "Sorbent Injection").

471. In particular, Mass-EPA touts a dry emission system using sorbent, particularly activated carbon injection (ACI) alone or by co-injection of activated carbon with lime:

> In the near term, activated carbon seems the most likely technology to be commercialized for mercury control because there have been full-scale tests of this technology that have generated promising results.[816]
>
> Increased removal of mercury from gas has been demonstrated by co-injection of activated carbon and calcium-based sorbents in spray dryer adsorber systems in full-scale coal-fired power plants.[817]

Mass-EPA discloses "activated carbon <u>injection</u>" in numerous other places.[818]

472. Mass-EPA concludes that the "estimated costs for <u>powdered activated carbon injection</u>-based technology, which most likely will reach commercialization for mercury control before other technologies, is within the current control costs for NOx."[819] Thus, a POSITA would have been motivated, with a reasonable expectation of success, to use the activated carbon injection (ACI) system and control scheme of Mass-EPA with the halogenation and ACI of Downs-Boiler.

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[816] EX1009 (Mass-EPA) at 32.

[817] EX1009 (Mass-EPA) at 32.

[818] EX1009 (Mass-EPA) at 31, 35, 36, 49, 52, 56.

[819] EX1009 (Mass-EPA) at 58.

473. A POSITA would have looked to Mass-EPA for practical applications of the discovery disclosed in Downs-Boiler relating to the use of halogen species added to the coal or to the combustor to improve the uptake of mercury on activated carbon sorbents. A POSITA would have used “injection” (as described by Mass-EPA) as the method for introducing activated-carbon sorbent (as described by both Downs-Boiler and Mass-EPA) into the mercury-containing flue gas of Downs-Boiler. As ACI was already “the most likely technology to be commercialized for mercury control”[820] by the time the Massachusetts EPA released its report in December 2002, the combination of Downs-Boiler and Mass-EPA represents no more than combining prior art elements according to known methods to yield predictable results of removing mercury. Moreover, the activated carbon injection of Mass-EPA was a “known technique” and introducing the halogens (as described in Downs-Boiler) would yield the predictable results in the form of improved mercury removal.

474. A POSITA would have a reasonable expectation of success in combining Downs-Boiler with Mass-EPA because as Mass-EPA described, activated carbon injection was the “most extensively studied sorbent for mercury adsorption” and the “most likely candidate to reach commercialization for mercury

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[820] EX1009 (Mass-EPA) at 32.

removal in the near future."[821] The technology was mature, because "[e]xtensive tests have been performed at the bench, laboratory, pilot, and full scale for application of AC in the coal-fired utility boiler gas."[822] Mass-EPA concludes that the "estimated costs for <u>powdered activated carbon injection</u>-based technology, which most likely will reach commercialization for mercury control before other technologies, is within the current control costs for NOx."[823]

475. Mass-EPA further emphasizes that "research in understanding and improving mercury adsorption efficiency of activated carbons has been ongoing with the goal of improving carbon to mercury injection rates and reducing control costs."[824] Introducing the halogens (as described in Downs-Boiler), along with the activated carbons, would yield the predictable results in the form of improved mercury adsorption efficiency of activated carbons. This would allow lower amounts of activated carbon to be used for mercury removal and thus lower costs.

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[821] EX1009 (Mass-EPA) at 32.

[822] EX1009 (Mass-EPA) at 33.

[823] EX1009 (Mass-EPA) at 56.

[824] EX1009 (Mass-EPA) at 39.

B. DISCLOSURE AND TEACHINGS OF THE COMBINATIONS

476. It is my opinion that the combination of Downs-Boiler in view of Starns (Ground A4) and the combination of Downs-Boiler in view of Mass-EPA (Ground A5) each renders obvious the claims below of the Challenged Patent. I start with analyzing claim 25, because it has the fewest limitations. I then discuss claims depending from claim 25, and follow that with the remaining claims, which repeat many of the limitations of claim 25.

1. Independent Claim 23 and Independent Claim 25

477. As I discuss above in Ground A3, each of claims 23 and 25 is anticipated by Downs-Boiler. I understand that anticipation is the epitome of obviousness, and that therefore these claims would have also been obvious over Downs-Boiler.

a. Claim Element 23(b)—"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 coal upstream of the combustion chamber, or the combustion chamber comprises added Br_2, HBr, Br^-, or a combination thereof, or a combination thereof;"

478. In addition to the reasons stated in Ground A3, Claim Element 23(b) would be obvious over Downs-Boiler in view of Starns (Ground A4) and Mass-EPA (Ground A5) regarding "the mercury-containing gas comprises a halogen or halide promoter comprising HBr, Br_2, or a combination thereof." At the temperatures of

the combustion chamber, the calcium bromide vaporizes and reacts to form vapor-phase HBr in the combustion chamber. Further, at least the molecular bromine (Br_2) and hydrogen bromide (HBr) are each vaporized and thus present in the gas-phase in mercury-containing flue gas. The boiling point of Br_2 is only 58.8ºC (it is a fuming liquid at room temperature), and the boiling point of hydrogen bromide is -66.38 ºC (i.e., it is a gas at room temperature).[825] For example, the flue gas in Starns (Ground A4) is typically at a temperature of 290ºF, which is 143ºC.[826] The flue gas in Mass-EPA (Ground A5) ranges from 284 to 320ºF (140-160ºC) after the air heater or 350-450ºC before the air heater.[827] These temperatures are well-above the limit at which the mercury-containing gas would be in the gas phase, and the halogen promoters (such as HBr and Br_2) would likewise be vaporized and contact the sorbent in the mercury-containing gas.

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[825] EX1036 (CRC Press: March 2005) at 4-53 and 4-65.

[826] EX1008 (Starns) at 10.

[827] EX1009 (Mass-EPA) at 26.

b. Element 23(c) and Element 25(c)—"injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber; contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition; and"

479. In addition to the reasons stated in Ground A3, Claim Element 23(c) and Claim Element 25(c) would have been obvious over Downs-Boiler. Each of these limitations recites, "contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition."

480. As described above for Ground A3, Downs-Boiler discloses that the mercury in the flue gas is adsorbed onto the sorbent, and it is thus contacted with the sorbent to form a mercury/sorbent composition. Downs-Boiler discloses that "PAC injection removes both oxidized and elemental mercury species."[828] Downs-Boiler further discloses that the injected sorbent adsorbs vapor-phase mercury and that "the sorbent, and its burden of <u>adsorbed</u> mercury" are separated from the flue gas.[829] A POSITA would have understood that the "burden" of adsorbed mercury referred to by Downs-Boiler is the loading of mercury on the activated-carbon sorbent. Downs-Boiler additionally provides for the formation of a mercury/sorbent composition,

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[828] EX1006 (Downs-Boiler) ¶[0004]; EX1007 (Downs-Boiler-Provisional) ¶[005].

[829] EX1006 (Downs-Boiler) ¶[0004]; EX1007 (Downs-Boiler-Provisional) ¶[005].

referring to "the higher reactivity of oxidized mercury with PAC."[830] A POSITA would have understood that a chemical reaction is a form of contact and that the reaction between the oxidized mercury appearing as mercuric bromide ($HgBr_2$) with the sorbent results in the formation of a mercury/sorbent composition that also includes Br. A POSITA would have further understood that "adsorbed" refers to the results of a process by which mercury atoms or ions in a fluid (e.g., a mercury-containing gas) adhere to the surface of a sorbent (e.g., activated carbon), and thus by definition the sorbent is "contacting mercury in a mercury-containing gas."

481. In addition, a person of skill in the art would have understood that the scope of a "mercury/sorbent composition" is broad enough to encompass a "mercury/sorbent/bromine" composition, because, for example, independent claim 25 of the '114 Patent recites a "mercury/sorbent composition" and its dependent claim 30 recites that "the mercury/sorbent composition comprises the element bromine, the sorbent material, and mercury."[831] A POSITA would have also understood that the sorbent and halogen would have reacted to form at least a quantity of a mercury/sorbent composition upon contact. [832]

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[830] EX1006 (Downs-Boiler) ¶[0016]; EX1007 (Downs-Boiler-Provisional) ¶[0019].

[831] EX1001 ('114 Patent) at Claims 25, 30.

[832] See Technology Background and State of the Art, §IX.C.3, § IX.G.2.

482. Regarding Ground A4, Starns further verifies through the "injection of sorbents such as powdered activated carbon (PAC) into the flue gas upstream of the particle control equipment," the "gas-phase mercury in the flue gas <u>contacts the sorbent</u> and attaches to its surface."[833]

483. Regarding Ground A5, Mass-EPA further verifies that through activated-carbon injection, the "sorbent particles … contact the Hg in the flue gas."[834]

2. Claims Depending from Claim 25 (Claims 26-30)

484. As I discuss above in Ground A3, each of claims 26, 27, and 30 is anticipated by Downs-Boiler. I understand that anticipation is the epitome of obviousness, and that therefore these claims would have also been obvious over Downs-Boiler for the reasons stated in Ground A3. Additional claims are discussed below.

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[833] EX1008 (Starns) at 2.

[834] EX1009 (Mass-EPA) at 21 n.25. Page 33 also refers to "time available for the mercury to contact the AC [activated carbon] particle").

a. Claim 28: "The method of claim 25, further comprising monitoring the mercury content of the cleaned gas; and 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 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."

485. This claim would have been obvious over Downs-Boiler alone (Ground A3) and also over the combination of Downs-Boiler with Starns (Ground A4) and the combination of Downs-Boiler with Mass-EPA (Ground A5). All three references disclose the continuous monitoring of mercury concentration. Downs-Boiler achieves desired mercury removal by controlling the halogen injection rate, and Starns and Mass-EPA each achieves desired mercury removal by controlling the sorbent injection rate. Both control schemes meet the limitations of Claim 28.

i. Claim 28: Element 28(a)—"monitoring the mercury content of the cleaned gas; and 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 bromide compound, or a combination thereof, or a combination thereof"

486. This claim limitation would have been obvious over Downs-Boiler. The mercury content is monitored, as depicted by the Y-axis of Figure 3 (i.e., the

"Hg concentration" in µg/dscm).[835] The units "µg/dscm" refer to micrograms of mercury per standard cubic meter of flue gas on a dry basis. Figure 3 of Downs-Boiler, reproduced below as annotated, illustrates measuring mercury content of the cleaned gas (Y-Axis) and controls the injection rate of the bromide compound ($CaBr_2$) of up to 1000 ppm:[836]

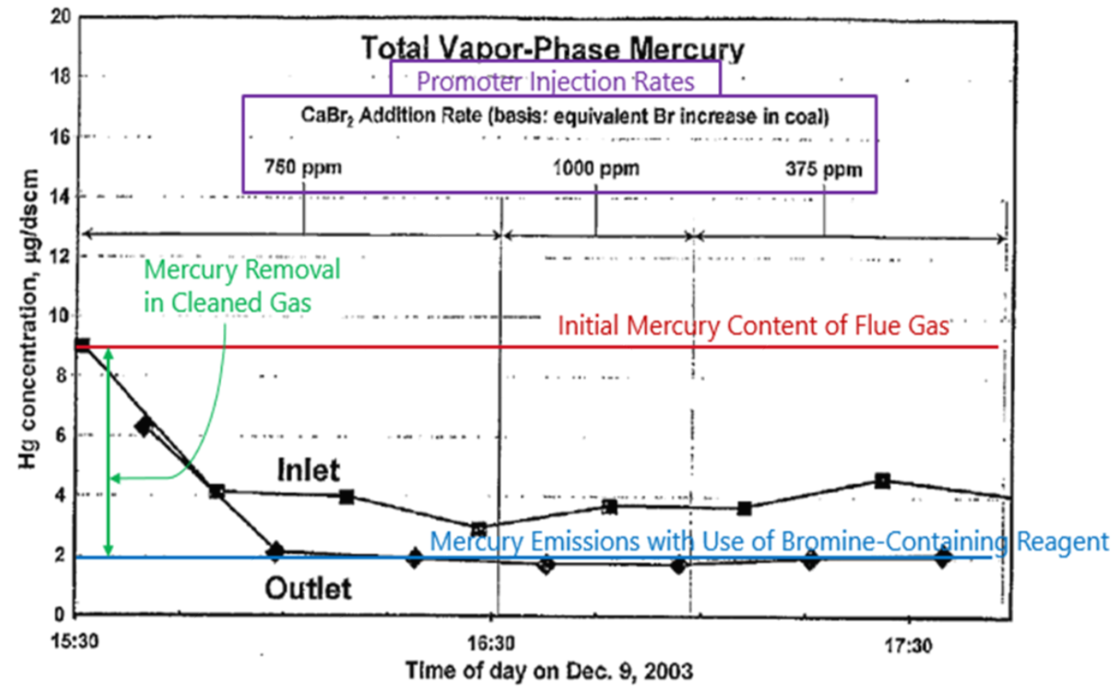

FIG. 3

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[835] EX1006 (Downs-Boiler) Figure 3 (annotated); see also EX1007 (Downs-Boiler-Provisional) Figure 3.

[836] EX1006 (Downs-Boiler) Figure 3 (annotated); see also EX1007 (Downs-Boiler-Provisional) Figure 3.

In particular, Figure 3 shows that the mercury content of the cleaned gas (the data set provided by diamond symbols for the outlet of the particulate collector) is monitored for a period of over two hours.[837] The associated description of Figure 3 of Downs-Boiler discloses controlling the rate of addition to the coal or the combustion chamber of the added Br_2, HBr, and/or the bromide compound (e.g., "aqueous solution of calcium bromide ($CaBr_2$) [] injected into the combustion chamber") (purple) was between 375 to 1000 parts per million of a bromine-containing reagent ($CaBr_2$).[838]

487. Downs-Boiler draws a direct correlation between the injection rate of the bromide compound and the measured mercury:

> FIG.3 is a graph of test data illustrating the effect of the addition of a particular halogen, calcium bromide, $CaBr_2$ on the total vapor-phase mercury produced during the combustion of coal, according to the present invention.
>
> It can be seen that upon injection of the calcium bromide, the vapor-phase mercury exiting the system dropped.[839]

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[837] EX1006 (Downs-Boiler) Figure 3; see also EX1007 (Downs-Boiler-Provisional) Figure 3.

[838] EX1006 (Downs-Boiler) ¶[0018], Figure 3 (annotated); see also EX1007 (Downs-Boiler-Provisional) ¶[0021], Figure 3.

[839] EX1006 (Downs-Boiler) ¶¶[0011], [0018]; see also EX1007 (Downs-Boiler-Provisional) ¶¶[0013], [0021].

A POSITA reviewing the monitored data as presented by Figure 3 of Downs-Boiler would have understood that the monitored mercury content at the outlet of the particulate collector could be used to control the addition rate of the bromine-containing reagent. It is further obvious over Downs-Boiler that the bromide addition rate is <u>in response to the mercury content of</u> the cleaned gas. A POSITA reviewing the monitored data of the tests, as presented by Figure 3 of Downs-Boiler, would have understood that the monitored mercury content is the information that would be used to adjust a rate of addition of the bromine-containing reagent (e.g., one of the four rates provided: 0, 375, 750, and 1000 ppm) by selecting a given rate or by interpolating an intermediate value in response to the monitored mercury content of the cleaned gas. A POSITA would have done so to ensure they were adding the right amount of bromine to achieve target limits.

(1) Ground A4 (Combination of Downs-Boiler with Starns)

488. In addition to this element being disclosed by Downs-Boiler alone, this element is also disclosed by the combination of Downs-Boiler with Starns (Ground A4). It would have been obvious to implement the control scheme of Starns with Downs-Boiler, to give Downs-Boiler the flexibility of adjusting another input (e.g., sorbent injection rate) based on the measured output (mercury content). Starns discloses a control scheme interoperable with that of Downs-Boiler, which is

controlling the sorbent concentration in the flue gas based on mercury measurements. A POSITA would have used such a control scheme either in place of the control scheme of Downs-Boiler, or in addition to that control scheme (e.g., control both sorbent injection rate and halogen addition rate in response to mercury measurements).

489. Starns discloses measuring "vapor phase mercury concentrations" in the flue gas using a "Semi-Continuous Emissions Monitor (S-CEM)," which was "operate[d] continuously."[840] The S-CEM was used to adjust sorbent concentration (activated carbon injection) and determine its effects on mercury removal:

> Mercury removal was monitored as a function of the sorbent injection concentration. In addition, the impact of sorbent injection on the performance of the ESP was monitored. An example of the data from the S-CEMs during the first week of parametric testing is presented in Figure 3…. Reduction and recovery of outlet mercury concentration can be seen to correlate with periods of sorbent injection.[841]

Starns plots the percentage of mercury removal against the concentration of activated carbon injected into the flue gas (in units of pounds activated carbon per million actual cubic feet of flue gas), both for the parametric testing and the long-

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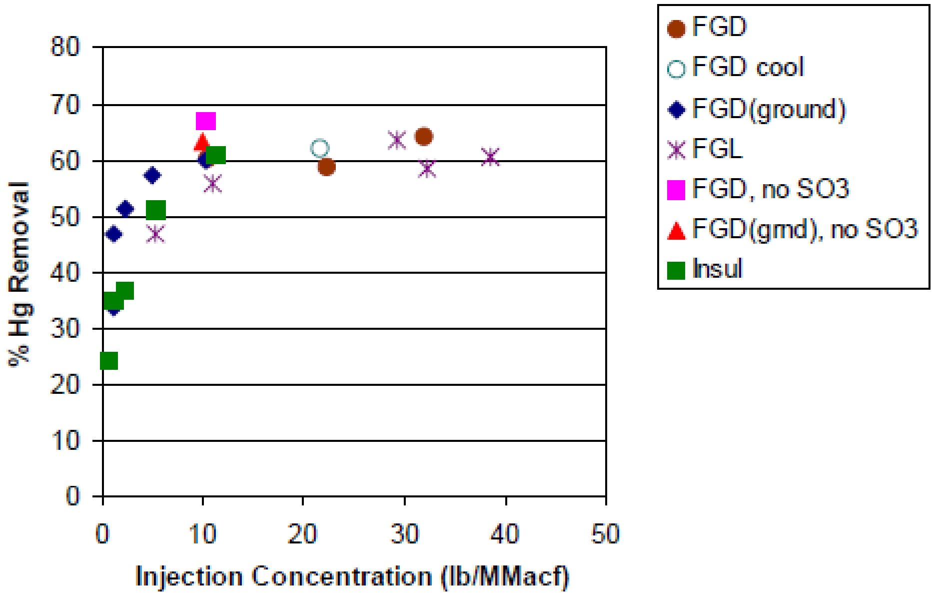
[840] EX1008 (Starns) at 8.

[841] EX1008 (Starns) at 11.

term testing in Figures 3-6.[842] Exemplary Figure 4 is shown below, which shows the direct connection between mercury emissions and sorbent concentration:[843]

Figure 4. Mercury Removal Trends Across ESP as a Function of PAC Injection Concentrations. Measurements Made During Parametric Tests, Sept-Oct 2001.



Thus, Starns discloses continuously monitoring the mercury content of the gas in response to the sorbent concentration. Controlling of the rate of addition of the sorbent <u>in response to the mercury content of</u> the cleaned gas is also obvious over Starns. A POSITA reviewing the monitored data of the tests, as presented by Figures 3-6 of Starns, would have understood that the monitored mercury content (dependent variable in the graphs) is the information that would be used to adjust a rate of

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[842] EX1008 (Starns) at Figs. 3-6.

[843] EX1008 (Starns) at 13.

addition of the sorbent (the independent variable in the graphs) by either selecting a given rate or by interpolating an intermediate value in response to the monitored mercury content of the cleaned gas. Adding more sorbent than required to remove the necessary amount of mercury would be wasteful, and adding less sorbent would not achieve target limits. A person of skill in the art would have been motivated to continuously adjust an injection concentration of the sorbent into the mercury-containing gas, in response to the monitoring of the mercury content of that gas, to provide the necessary amount of sorbent needed to remove a targeted amount of mercury. This control scheme is all the more obvious in view of the hardware disclosed by Starns: "A PLC [programmable logic controller] is used to control system operation and adjust injection rates."[844]

490. As described above, Downs-Boiler discloses that the injection of sorbents was effective for the removal of mercury but as the rate of injecting the sorbent into the mercury-containing gas increases, the "economics of high injection rates can be prohibitive" due to the costs of the consumable sorbent material.[845] The normal desire of a POSITA to improve on a given process would have been to adjust

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[844] EX1008 (Starns) at 7.

[845] EX1006 (Downs-Boiler) ¶[0004]; see also EX1007 (Downs-Boiler-Provisional) ¶[005].

the result-effective variable of the injection rate of the sorbent so as not to wastefully inject excessive sorbent once sufficient mercury removal was demonstrated, in order to minimize costs associated with operating the sorbent injection system. Furthermore, due to the variability of the composition of coal as a fuel source (including for example, native mercury and halogen content), as described in the State of the Art,[846] it would have been obvious that some amount of adjustment to the rate of injection of the sorbent into the flue gas would be performed as part of routine process control and optimization to account for variances in the coal.

(2) Ground A5 (Combination of Downs-Boiler with Mass-EPA)

491. In addition to this element being disclosed by Downs-Boiler alone, this element is also disclosed by the combination of Downs-Boiler with Mass-EPA (Ground A5). It would have been obvious to implement the control scheme of Mass-EPA with Downs-Boiler, to give Downs-Boiler the benefit of adjusting the input (e.g., sorbent injection rate) based on the measured output (mercury content). Mass-EPA discloses a control scheme interoperable to that of Downs-Boiler, controlling the sorbent concentration in the flue gas based on mercury measurements. A POSITA would have used such a control scheme either in place of the control scheme of Downs-Boiler, or in addition to that control scheme (e.g., control both

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[846] See Technology Background and State of the Art, IX.B.1.

sorbent injection rate and halogen addition rate in response to mercury measurements).

492. Mass-EPA discloses using a "continuous emissions monitoring systems (CEMS) to monitor stack-level Hg emissions, averaging the data over a time period to be specified in the standard."[847] Mass-EPA recognized that a reason to monitor mercury was to understand the sorbent injection rate to use:

> [A] fraction of a pound increase in carbon injection rate increase[es] mercury removal from the gas by [as] much as 30%.[848]
>
> With respect to both the removal trend and the sorbent costs, preliminary results for Brayton Point indicate that the higher the amount of sorbent injected, the more mercury removed, with the highest removal values during long term tests ranging from 90-93% at the highest sorbent injection rate of 20 lb/MMacf. In contrast to the other two facilities for which data are available, Brayton Point does not exhibit a sorbent injection level at which further injection of sorbent provides no further mercury removal; instead, addition of more sorbent results in additional mercury reductions over the range of sorbent injection levels tested, with an approximately linear trend. [849]

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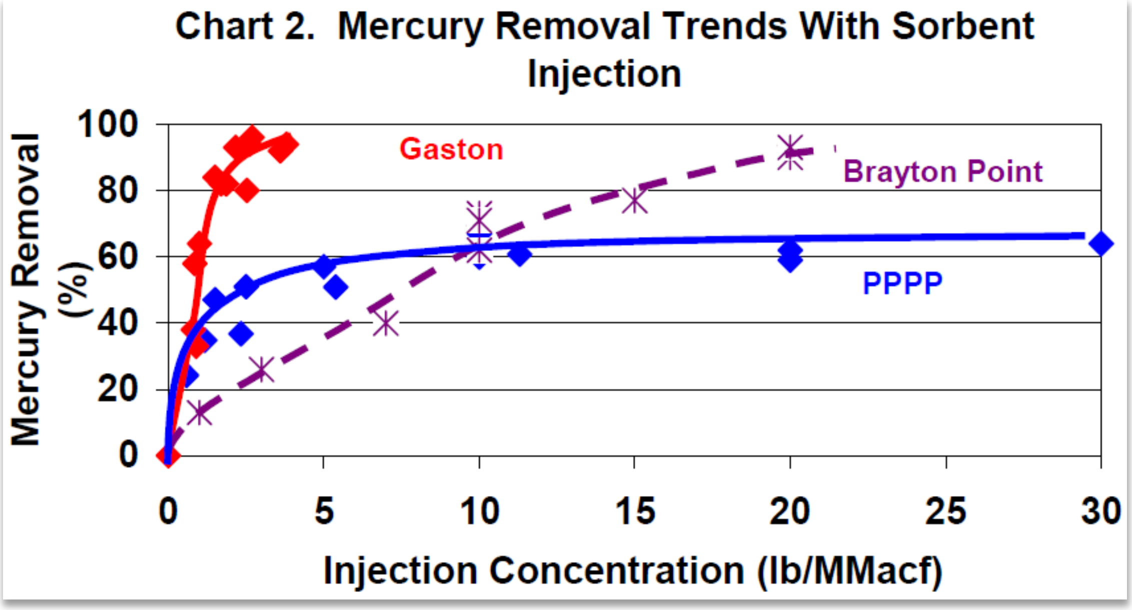
[847] EX1009 (Mass-EPA) at 60.

[848] EX1009 (Mass-EPA) at 33; *see also* p. 50 ("PAC injection rate requirements increase nonlinearly with increases in Hg removal efficiency."); p. 73 ("mercury removal as a function of [sorbent] injection rate").

[849] EX1009 (Mass-EPA) at 11.

The direct connection between mercury concentration and activated-carbon injection (ACI) rate is clearly seen in Chart 2, which shows mercury removals for various ACI rates measured at three coal-fired plants, in which the X-axis is the sorbent injection rate:[850]



Mass-EPA discusses the parametric testing as being "conducted at different sorbent, feed rate and operating conditions and were performed at full load. The areas of interest included mercury removal as a function of [sorbent] injection rate."[851]

493. At each plant, as shown in Chart 2, the mercury removal percentage increased (mercury concentration decreased) as the injection concentration

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[850] EX1009 (Mass-EPA) at 12

[851] EX1009 (Mass-EPA) at 73.

increased, until either they approached the upper limit of 100% removal or plateau at some lower removal. The Massachusetts EPA noted that this behavior closely resembled the performance of ACI in municipal waste combustors (MWCs), which ultimately became the basis for regulating MWC operators to reduce Hg emissions by implementing ACI: "The MWCs were required to optimize the level of carbon injection by selecting a carbon injection rate above which additional amounts of carbon injection would achieve limited additional mercury control."[852] In other words, monitor mercury content and, based on that measurement, control the rate of injecting the sorbent into the mercury-containing gas.

494. Accordingly, a person of skill in the art would have been motivated to continuously control an injection rate of the sorbent into the mercury-containing gas, in response to the monitoring of the mercury content of that gas, to provide the desired amount of sorbent needed to remove a targeted amount of mercury. A POSITA reviewing the monitored data of the tests, as presented by Chart 2 of Mass-EPA, would have understood that the monitored mercury content is the information that would be used to adjust a rate of addition of the sorbent by either selecting a given rate or by interpolating an intermediate value in response to the monitored mercury content of the cleaned gas. Adding more sorbent than required to remove

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[852] EX1009 (Mass-EPA) at 13.

the necessary amount of mercury would be wasteful, and adding less sorbent would not achieve target limits.

495. It would have also been obvious to control the sorbent injection rate. As described above, Downs-Boiler discloses that the injection of sorbents was effective for the removal of mercury but as the rate of injecting the sorbent into the mercury-containing gas increases, the "economics of high injection rates can be prohibitive" due to the costs of the consumable sorbent material.[853] The normal desire of a POSITA to improve on a given process would have been to adjust the result-effective variable of the injection rate of the sorbent so as not to wastefully inject excessive sorbent once sufficient mercury removal was demonstrated, in order to minimize costs associated with operating the sorbent injection system. Furthermore, due to the variability of the composition of coal as a fuel source (including for example, native mercury and halogen content), as described in the State of the Art,[854] it would have been obvious that some amount of adjustment to the rate of injection of the sorbent into the flue gas would be performed as part of routine process control and optimization to account for variances in the coal.

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[853] EX1006 (Downs-Boiler) ¶[0004]; see also EX1007 (Downs-Boiler-Provisional) ¶[005].

[854854] See Technology Background and State of the Art, §IX.B.1, §IX.C.5.

ii. Claim 28: Element 28(b)—"so that the mercury content of the cleaned gas is maintained at or below a desired level."

496. This claim element is disclosed by the combinations of Downs-Boiler with Starns (Ground A4) and Downs-Boiler with Mass-EPA (Ground A5). Downs-Boiler discloses maintaining mercury content of the cleaned gas below a desired level, as it discusses EPA standards regulating mercury emissions.[855] Such standards act as a "desired level," and a POSITA would have sought to maintain mercury below that level to avoid regulatory penalties.

(1) Ground A4 (Combination of Downs-Boiler with Starns)

497. This element is also disclosed by the combination of Downs-Boiler with Starns (Ground A4). Starns also discusses maintaining mercury content of the cleaned gas below a desired level based on activated carbon injection rate:

> Effective mercury removal between 40 – 50% was obtained at 1 lb/MMacf.
>
> Effective mercury removal between 50 – 60% was obtained at 3 lb/MMacf.
>
> Effective mercury removal between 60 – 70% was obtained at 10 lb/MMacf.[856]

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[855] EX1006 (Downs-Boiler) ¶[0001]; EX1007 (Downs-Boiler-Provisional) ¶[002].

[856] EX1008 (Starns) at 20.

The units above refer to pounds sorbent (activated carbon) per 1 million actual cubic feet of flue gas.

498. As I discuss in the State of the Art, the EPA and other regulatory bodies proposed rules that, upon implementation, would have required mercury emissions reductions by 70% (which was achieved by Starns and surpassed by Downs-Boiler).[857] In trying to ensure their plants were compliant upon eventual implementation and promulgation of the EPA rules, a person of skill in the art would have been motivated, and it would have been obvious, to keep mercury emissions below the desired levels proposed by regulatory authorities in order to avoid paying regulatory fines and other penalties that would incur upon rule implementation.

(2) Ground A5 (Combination of Downs-Boiler with Mass-EPA)

499. In addition to this element being disclosed by Downs-Boiler alone, this element is also disclosed by the combination of Downs-Boiler with Mass-EPA (Ground A5). The Massachusetts EPA surveyed several proposed rules at the federal level in various stages of development, but also concluded that, "In the face of these uncertain federal requirements,…the Department plans to propose emission standards for mercury within six months of completing this feasibility evaluation,

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[857] I discuss below for claims 2 and 3 how Downs-Boiler surpassed 70% mercury removal.

notwithstanding the federal MACT process."[858] The Conference of New England Governors and Eastern Canadian Premiers (NEG/ECP), which MA belongs to, adopted a Mercury Action Plan in 1998.[859] The goals of this Plan were explicit: "In 2001, after an evaluation of the interim goal, the NEG/ECP adopted another interim goal of an <u>overall reduction of 75% or greater</u> by 2010, with an evaluation in 2005 to allow for new information to be taken into account and to revise the target if necessary."[860] A person of ordinary skill in the art would have been motivated to target at least this "overall reduction of 75% or greater mercury removal, which is keeping the mercury content at or below a desired level. In trying to ensure their plants were compliant upon eventual implementation and promulgation of the EPA rules (including Mass-EPA rules), a person of skill in the art would have been motivated, and it would have been obvious, to keep mercury emissions below the desired levels proposed by regulatory authorities in order to avoid paying regulatory fines and other penalties that would incur upon rule implementation.

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[858] EX1009 (Mass-EPA) at 5.

[859] EX1009 (Mass-EPA) at 5.

[860] EX1009 (Mass-EPA) at 5.

b. Claim 29: "The method of claim 25, wherein the mercury-containing gas comprises about 1 g to about 30 g of the element bromine per 100 g of the sorbent."

500. This claim element is obvious over the combinations of Downs-Boiler with Starns (Ground A4) and Downs-Boiler with Mass-EPA (Ground A5). Downs-Boiler describes that bromine-containing reagent (e.g., HBr, Br_2, or aqueous solution of calcium bromide) was added to the coal to provide 375-1000 ppm equivalent Br increase in coal.[861] However, Downs-Boiler does not expressly state the gas-phase concentration of Br in the mercury-containing gas, and Downs-Boiler does not expressly state the injection rate of activated carbon into the system downstream of the combustion chamber. As described below, a POSITA would have been able to calculate and/or measure the gas-phase concentration of Br in the mercury-containing gas. Regarding the injection rate of activated carbon, as described above,[862] it was routine in the industry to use injection rates of activated carbon of around 10 pounds/MMacf (million actual cubic feet of flue gas) to capture mercury.

501. This injection rate is further confirmed in Ground A4, as this is the value that Starns uses to obtain maximum mercury removal:

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[861] EX1006 (Downs-Boiler) ¶[0018], Figure 3 (annotated); see also EX1007 (Downs-Boiler-Provisional) ¶[0021], Figure 3.

[862] *See* Technology Background and State of the Art, IX.C.5.

> Effective mercury removal between 40 – 50% was obtained at 1 lb/MMacf.
>
> Effective mercury removal between 50 – 60% was obtained at 3 lb/MMacf.
>
> Effective mercury removal between 60 – 70% was obtained at 10 lb/MMacf.[863]

502. This injection rate is also confirmed in Ground A5, as Mass-EPA also discloses sorbent injection rates at 10 lbs/MMacf.[864]

503. Regarding Ground A4 and Ground A5, based on the data presented by Downs-Boiler of 375 ppm Br added to coal, and a standard and well-known injection rate of activated carbon of around 10 pounds/MMacf (as described in each of Starns and in Mass-EPA), a person of ordinary skill in the art would have used, or at least tried using, a mercury-containing gas that comprises about 21 grams of the element bromine per 100 grams of sorbent, which is within the claimed range of 1-30 grams bromine per 100 grams sorbent. I explain my calculations below.

504. In order to determine a ratio of bromine concentration in the flue gas to activated carbon in the flue gas, the concentrations must have the same units—such as grams per actual cubic feet (ACF) or pounds per million actual cubic feet

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[863] EX1008 (Starns) at 20.

[864] EX1009 (Mass-EPA) at 73 (Brayton Point testing); p. 12 (Chart 2, showing Gaston, Brayton Point, and Pleasant Prairie).

(MACF). Downs-Boiler provides the concentration of bromine to coal, which can be converted to a concentration of bromine in the flue gas. Activated-carbon injection concentrations were typically provided in pounds (lbs.) per million actual cubic feet (MACF) of flue gas, as in Starns. Converting between the two would have been a routine calculation at a power plant to a POSITA and would have involved such basic concepts as the ideal gas law (to convert concentrations between temperatures and pressures), which was taught in first semester undergraduate chemistry to a person of skill in the art.[865] Such unit conversion would have also involved basic engineering knowledge of a power-plant operation, such as a typical flue gas temperature, pressure, and moisture content. Each of these would have been well-known to a person of skill in the art.

505. Downs-Boiler discloses usage of "western U.S. subbituminous coal," which is another name for Powder River Basin (PRB).[866] The concentration of Br in the mercury-containing gas is estimated for typical parameters for firing Powder River Basin (PRB) subbituminous coal in full-scale utility boilers beginning with

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[865] Technology Background and State of the Art ("Common Units of Measurement"), §IX.A.9.

[866] EX1006 (Downs-Boiler) ¶[0017]; see also EX1007 (Downs-Boiler-Provisional) ¶[0020].

the Br loading on coal. For a value of 375 ppm Br,[867] on coal from Downs-Boiler, the equivalent concentration of Br in flue gas can be calculated as follows:

$$\left(\frac{375\ g\ Br}{10^6\ g\ coal}\right) = 3.75x10^{-4}\,\frac{g\ \ Br}{g\ coal}$$

$$3.75x10^{-4}\,\frac{g\ Br}{g\ coal} \times \left(\frac{1\ g\ coal}{10\ g\ flue\ gas}\right) = 3.75x10^{-5}\,\frac{gBr}{gflue\ gas}$$

I note that the ratio of 10 grams flue gas per gram coal is a nominal value for subbituminous coals fired at 15 – 20 % excess air, and representative of the typical firing practices at coal-fired utility boilers. (In other words, combustion of 1 gram of subbituminous coal can be expected to provide approximately 10 grams flue gas). The molecular weight of flue gas is typically between 28-32 grams per mole (depending on the type of coal and amount of excess air), because flue gas is primarily: molecular nitrogen (molecular weight of 28, from excess air), carbon dioxide (molecular weight of 44), water (molecular weight of 18), and excess oxygen (molecular weight of 32). Accordingly, a typical value for the molecular weight of flue gas is 30 g/mol.

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[867] EX1006 (Downs-Boiler) ¶[0018], Figure 3 (annotated); see also EX1007 (Downs-Boiler-Provisional) ¶[0021], Figure 3.

Downs-Boiler discloses the units of “ppm.” A POSITA would have understood this to refer to ppm by weight, rather than on a molar basis, because the comparison is with respect to coal.

$$3.75x10^{-5}\,\frac{g\ Br}{g\ flue\ gas}\times\left(30\,\frac{g\ flue\ gas}{mol\ flue\ gas}\right)=1.12x10^{-3}\,\frac{g\ Br}{molf\ lue\ gas}$$

506. Regarding the second conversion, a person of ordinary skill in the art would have understood from the ideal gas law (PV = nRT) that the density of a gas is proportional to pressure and inversely proportional to temperature. A person of skill in the art would have learned from undergraduate chemistry that standard temperature and pressure (STP) refers to 25 ºC (298 K) and 1 atm, respectively, and would have known that a typical flue gas temperature where sorbent would be injected is 150 ºC (413 K) and also 1 atm of pressure. In fact, Starns discloses a temperature of 290 ºF, which is 143 ºC (416 K).[868] Mass-EPA also discloses "flue gas temperatures range from 284 to 320ºF (140 to 160°C)."[869] A person of ordinary skill in the art would have understood that this temperature is a typical value for sorbent injection downstream of an air preheater and upstream of an ESP or fabric filter. A POSITA would have known that air preheaters typically do not operate with outlet gas temperatures below the acid dew points of sulfuric acid, which are given as 120 – 150 °C.[870] This dewpoint range restricts the outlet temperatures to somewhat hotter values like 150 °C. Thus, a temperature of 416 Kelvin (143ºC) is

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[868] EX1008 (Starns) at 10.

[869] EX1009 (Mass-EPA) at 26.

[870] EX1027 (B&W: Steam) at 19-11.

used for the calculations, as this temperature is disclosed by Starns and within the range disclosed by Mass-EPA.

$$1.12x10^{-3}\frac{gBr}{mol\ flue\ gas}\times\left(\frac{1\ atm}{(416\ K)\left(0.082058\frac{L\ atm}{mol\ K}\right)\left(\frac{1\ acf}{28.3\ L}\right)}\right)\left(\frac{10^6\ acf}{Macf}\right)$$
$$=929\frac{g\ Br}{Macf\ flue\ gas}$$

507. A person of ordinary skill in the art would have also been readily able to convert pounds activated carbon to grams activated carbon (and vice versa) through the well-known unit conversion that there are 453.592 grams per pound. For an injection concentration of 10 lb PAC/Macf (as disclosed in Starns and in Mass-EPA), the concentration of PAC in the flue gas can be calculated in grams as:

$$10\frac{pounds\ PAC}{MACF}\times\frac{453.592\ grams}{pound}=4{,}536\frac{grams\ PAC}{MACF}$$

508. The estimated concentration of Br in flue gas is 929 g Br / Macf flue gas. For an injection concentration of 10 lb PAC/Macf, the concentration of PAC in the flue gas is 4,536 g PAC/Macf flue gas. Dividing the two rates—the bromine addition rate of Downs-Boiler with the activated carbon injection rate of Starns and Mass-EPA—provides a mercury-containing gas that comprises about 20.7 grams of the element bromine per 100 grams of activated-carbon sorbent, which is within the range of 1 gram to 30 grams. And even if one were to use the highest sorbent

injection rate tested in Chart 2 of Mass-EPA, which is 30 lb/MMacf,[871] the ratio would still be 6.9, which is within the claimed range.

509. It would have been obvious to try other ratios, such as by increasing the halogen concentration (while reducing the activated carbon injection), or decreasing the halogen concentration (while increasing the active carbon injection) as part of routine process optimization to achieve the desired mercury removal. Claim 29 is merely an attempt to claim a broad workable range for combining a conventional halogen (bromine) being used in a conventional way with a conventional sorbent (to oxidize mercury and promote activated carbon). Nothing in the '114 Patent specification attributes significance to the claimed range, or establishes that the claimed range "achieves unexpected results." The range presents nothing more than optimization of "result-effective" variables that would have been obvious to a POSITA.

c. Claim 30: "wherein the mercury/sorbent composition comprises the element bromine, the sorbent material, and mercury"

510. As described above for Ground A3, this claim is anticipated by Downs-Boiler. A mercury-sorbent composition is formed when mercury adsorbs onto activated-carbon sorbent, and when that sorbent is promoted with bromine (as in

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[871] EX1009 (Mass-EPA) at 12.

Downs-Boiler), the mercury/sorbent composition would also include the element bromine. Downs-Boiler confirms that this occurs because it refers to "sorbent … adsorb[s] vapor-phase mercury,"[872] so there is at least a mercury/sorbent composition. That composition also includes the element bromine, because as Downs-Boiler states, oxidized mercury is also adsorbed onto the carbon: "the higher reactivity of oxidized mercury with PAC."[873] A POSITA would have understood that a chemical reaction is a form of contact and that the reaction between the oxidized mercury appearing as mercuric bromide ($HgBr_2$) with the sorbent results in the formation of a mercury/sorbent composition that also includes Br.

511. This claim limitation is also confirmed by Starns (Ground A1): through "the injection of sorbents such as powdered activated carbon (PAC) into the flue gas upstream of the particle control equipment," the "gas-phase mercury in the flue gas <u>contacts the sorbent</u> and attaches to its surface."[874]

512. This claim limitation is further confirmed by Mass-EPA (Ground A5): "Gaseous mercury adsorbs onto injected carbon, and the particulate matter is then

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[872] EX1006 (Downs-Boiler) ¶[0004]; EX1007 (Downs-Boiler-Provisional) ¶[005].

[873] EX1006 (Downs-Boiler) ¶[0016]; EX1007 (Downs-Boiler-Provisional) ¶[0019].

[874] EX1008 (Starns) at 2 (Introduction).

removed in the PM control device."[875] "Both elemental and oxidized mercury adsorb onto porous solids such as fly ash, powdered activated carbons (PAC),"[876] though oxidized mercury (i.e., through halogenation in Downs-Boiler) adsorbs better: "Hg^{2+} is believed to be more readily captured by adsorption than Hg^0."[877]

3. Independent Claim 24

513. As shown in the redlines below, claim 24 is nearly identical to claims 25 and 28, with minor changes.

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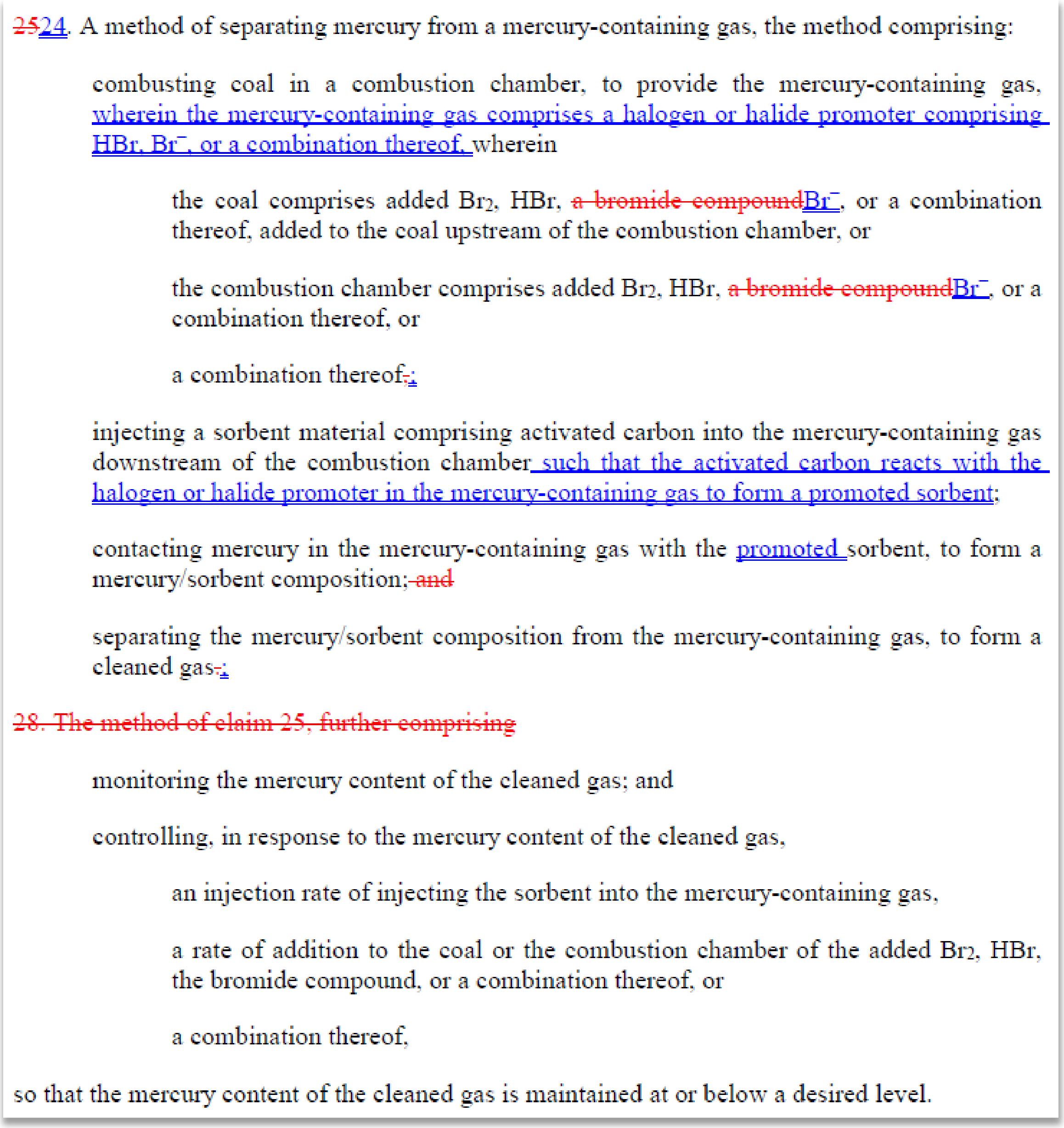
[875] EX1009 (Mass-EPA) at 13.

[876] EX1009 (Mass-EPA) at 20.

[877] EX1009 (Mass-EPA) at 24.



~~25~~24. A method of separating mercury from a mercury-containing gas, the method comprising:

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

the coal comprises added Br_2, HBr, ~~a bromide compound~~Br^-, 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~~Br^-, or a combination thereof, or

a combination thereof~~,~~;

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;

contacting mercury in the mercury-containing gas with the promoted sorbent, to form a mercury/sorbent composition;~~ and~~

separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas~~.~~;

~~28. The method of claim 25, further comprising~~

monitoring the mercury content of the cleaned gas; and

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 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.

Claim 24 combines limitations of claim 23 ("wherein the mercury-containing gas comprises …) and claims 25 and 28. Accordingly, as discussed below, my analysis already provided for claims 23, 25, and 28 also applies to claim 24.

a. Claim 24: Preamble—"A method of separating mercury from a mercury-containing gas, the method comprising:"

514. The language of the preamble of Claim 24 is identical to the preamble of claim 23 (which is identical to the preamble of claim 25). Accordingly, the explanation I provide above for the preambles of claims 25 and 23 applies equally to the preamble of claim 24.

b. Claim 24: Element 24(a)—"combusting coal in a combustion chamber, to provide the mercury-containing gas, wherein"

515. The language of Claim Element 24(a) is identical to the language of Claim Element 23(a) (which is identical to Claim Element 25(a)). Accordingly, the explanation I provide above for those claim elements applies equally to Claim Element 24(a).

c. Claim 24: Element 24(b)—"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 coal upstream of the combustion chamber, or the combustion chamber comprises added Br_2, HBr, Br^-, or a combination thereof, or a combination thereof;"

516. The language of Claim Element 24(b) is identical to the language of Claim Element 23(b). Accordingly, the explanation I provide above for Claim Element 23(b) applies equally to Claim Element 24(b).

d. Claim 24: Element 24(c)—"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; contacting mercury in the mercury-containing gas with the promoted sorbent, to form a mercury/sorbent composition;"

517. The language of Claim Element 24(c) is similar to the language of Claim Element 23(c) (which is identical to the language of Claim Element 25(c)), and I refer to my discussion of those claim elements. Claim element 24(c) has the following changes:

> 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;
>
> contacting mercury in the mercury-containing gas with the promoted sorbent, to form a mercury/sorbent composition; ~~and~~

The limitations added to claim 24(c) are disclosed because a mercury/sorbent/bromine composition is formed. As described above with respect to claim 30, Downs-Boiler describes (for Ground A4 and Ground A5) that a mercury/sorbent/bromine composition is formed (which thus includes a mercury/sorbent composition), in that the oxidized mercury ($HgBr_2$) is adsorbed onto the PAC sorbent.

518. In addition to contacting (adsorbing) one another, a POSITA would have understood that the activated-carbon sorbent and halogen (bromine) would have reacted to form at least a quantity of promoted sorbent. For example, it was well known that halides improved mercury capture both by: oxidizing elemental mercury (Hg^0) to the more easily removed Hg^{2+} form; and by enhancing the reactivity of Hg^0 with activated carbons. A POSITA would have also known that on account of the enhanced reactivity of activated carbon to mercury, the sorbent/halogen composition would have been considered a "promoted" sorbent. A POSITA would have also understood that the sorbent and halogen would have reacted to form at least a quantity of promoted sorbent upon contact.[878]

519. Specifically, by 2003, it was well-known that halides "improve[d] Hg capture both by conversion of the Hg^0 to the more easily removed Hg^{2+} forms and by enhancing the reactivity of Hg^0 with activated carbons."[879] As described in my Technology Background section,[880] this was done with two mechanisms: by oxidizing the mercury (thus rendering it more susceptible to removal), and also by increasing the capacity of activated carbon to bind with the mercury. Thus, the

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[878] See Technology Background and State of the Art, §IX.C.3, §IX.G.2.

[879] EX1062 (Crocker) at 2-3.

[880] See Technology Background and State of the Art, §IX.C.32.

halogen or halide promoter is reacting with both the activated carbon and with the mercury. A POSITA would have known that the introduction of halogens helped remove mercury by increasing the ability of the activated carbon to bind with the mercury. Thus, a POSITA would have known that the sorbent/halogen complex would have been referred to as a "promoted" sorbent. This is also confirmed by Downs-Boiler which admits that it was known in the art that halogens may be "incorporated into the carbonaceous sorbent" to "yield sorbents that more strongly bond with adsorbed mercury species" (i.e., forming a promoted sorbent).[881]

e. Claim 24: Element 24(d)—"separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas;"

520. The language of Claim Element 24(d) is identical to the language of Claim Element 23(d) (which is identical to the language of Claim Element 25(d)). Accordingly, the explanation I provide above for those claim elements applies equally to Claim Element 24(d).

f. Claim 24: Element 24(e)—"monitoring the mercury content of the cleaned gas; and"

521. The language of Claim Element 24(e) is identical to the language of Claim Element 28(a). Accordingly, the explanation I provide above for Claim Element 28(a) applies equally to Claim Element 24(e).

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[881] EX1006 (Downs-Boiler) ¶[0004]; EX1007 (Downs-Boiler-Provisional) ¶[005].

g. Claim 24: Element 24(f)(1)—“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 bromide compound, or a combination thereof, or a combination thereof,”

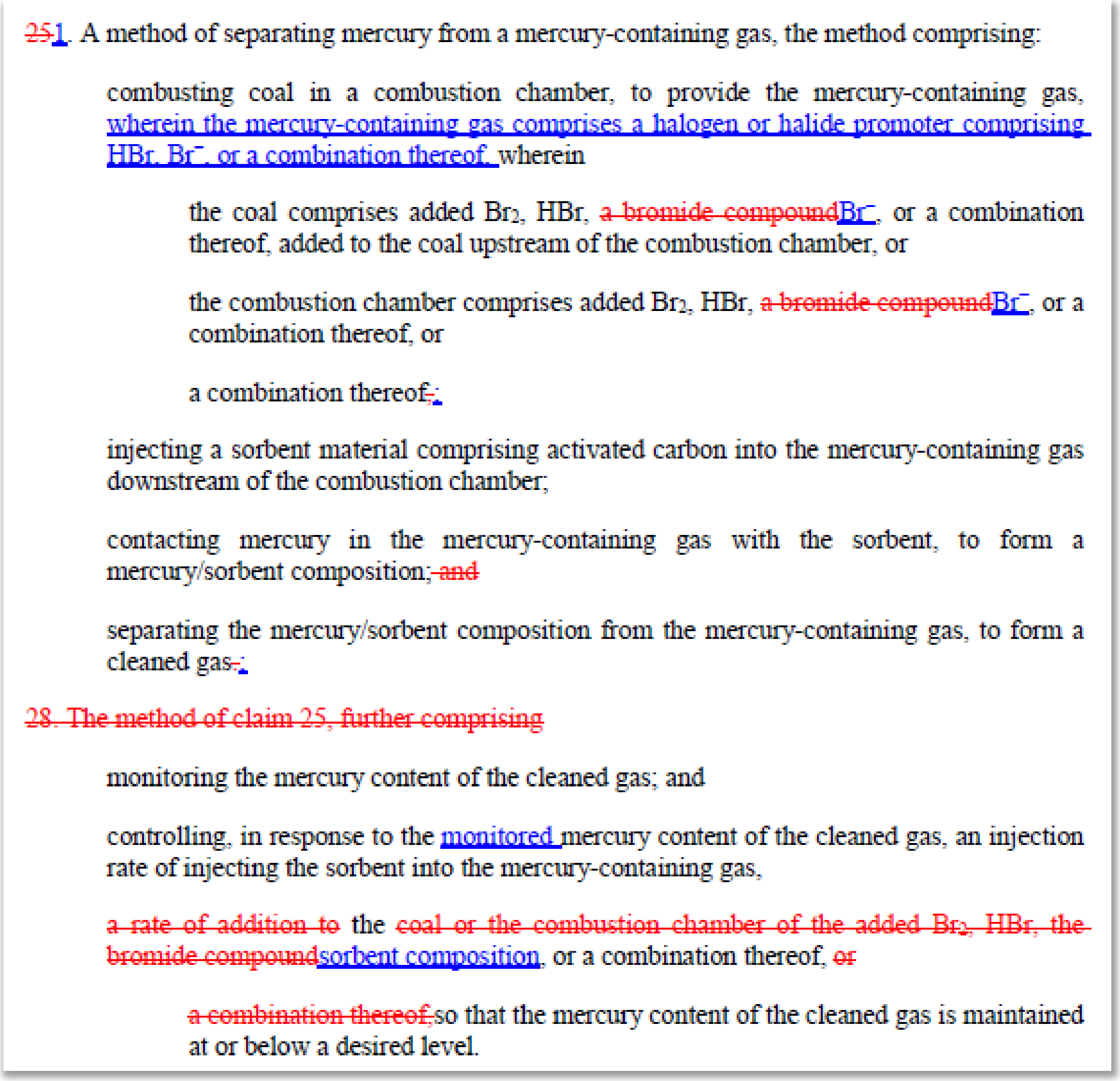
522. The language of Claim Element 24(f)(1) is identical to the language of Claim Element 28(a). Accordingly, the explanation I provide above for Claim Element 28(a) applies equally to this claim element.

h. Claim 24: Element 24(f)(2)—“so that the mercury content of the cleaned gas is maintained at or below a desired level.”

523. The language of Claim Element 24(f)(2) is identical to the language of Claim Element 28(b). Accordingly, the explanation I provide above for Claim Element 28(b) applies equally to this claim element.

4. <u>Independent Claim 1</u>

524. As shown in the redline below, claim 1 is nearly identical to claim 23 and 25/28, with additions shown below.



~~25~~1. A method of separating mercury from a mercury-containing gas, the method comprising:

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

the coal comprises added Br_2, HBr, ~~a bromide compound~~Br^-, 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~~Br^-, or a combination thereof, or

a combination thereof~~,~~;

injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber;

contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition;~~ and~~

separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas~~.~~;

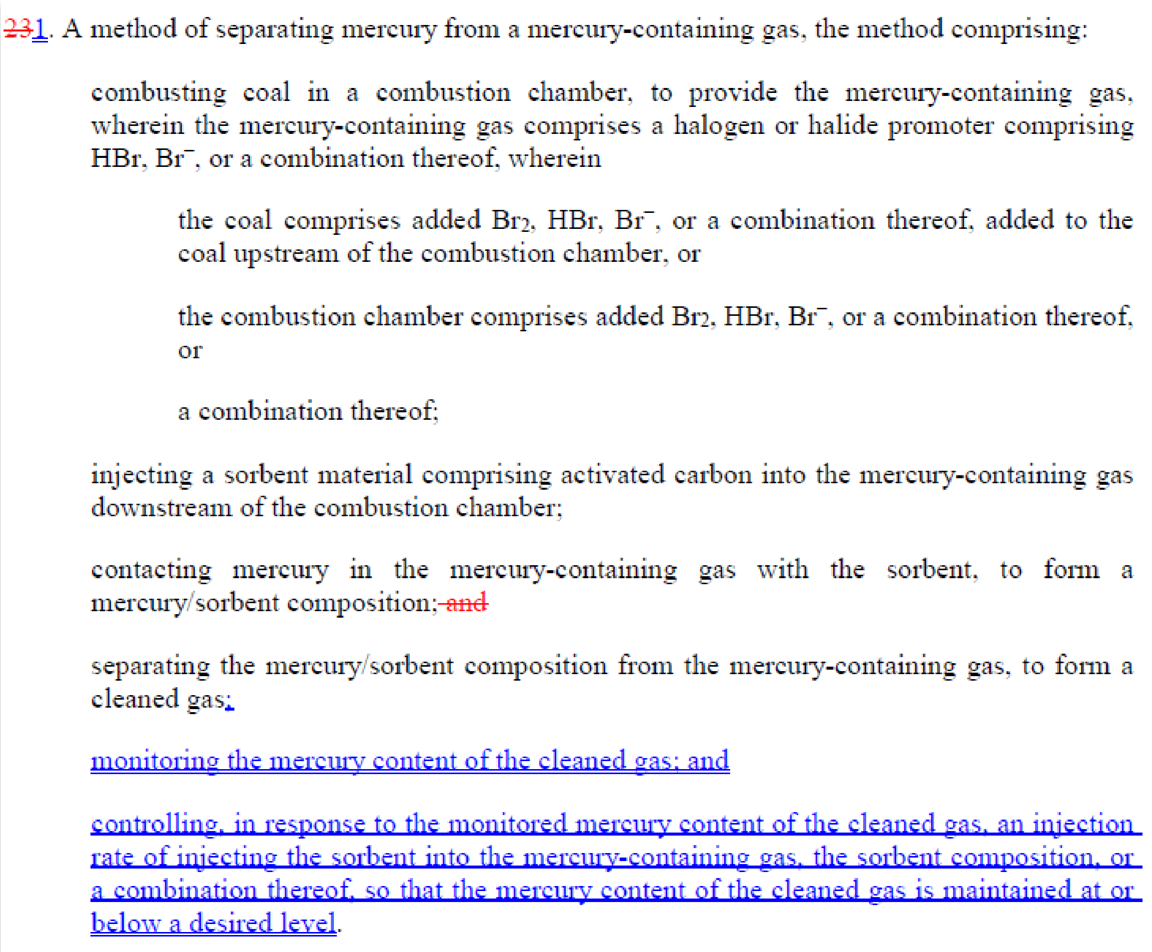
~~28. The method of claim 25, further comprising~~

monitoring the mercury content of the cleaned gas; and

controlling, in response to the monitored 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 bromide compound~~sorbent composition, 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.



~~23~~1. A method of separating mercury from a mercury-containing gas, the method comprising:

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

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;

injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber;

contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition;~~ and~~

separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas;

monitoring the mercury content of the cleaned gas; and

controlling, in response to the monitored mercury content of the cleaned gas, an 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.

Accordingly, my analysis provided for claims 23, 24, 25, and 28 also applies to claim 1.

a. Claim 1: Preamble—"A method of separating mercury from a mercury-containing gas, the method comprising:"

525. The language of the preamble of claim 1 is identical to the preamble of claim 25 (which is identical to the preamble of claims 23 and 24). Accordingly, the explanation I provide above for the preambles of claims 23-25 applies equally to the preamble of claim 1.

b. Claim 1: Element (1)(a)—"combusting coal in a combustion chamber, to provide the mercury-containing gas, wherein"

526. The language of claim element 1(a) is identical to the language of Claim Element 25(a) (which is identical to Claim Elements 23(a) and 24(a)). Accordingly, the explanation I provide above for those claim elements applies equally to claim element 1(a).

c. Claim 1: Element (1)(b)—"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 coal upstream of the combustion chamber, or the combustion chamber comprises added Br_2, HBr, Br^-, or a combination thereof, or a combination thereof;"

527. The language of claim element 1(b) is identical to the language of Claim Element 23(b) (which is similar to Claim Element 24(b) and similar to Claim Element 25(b)). Accordingly, the explanation I provide above for those claim elements applies equally to claim element 1(b).

d. Claim 1: Element (1)(c)—"injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber; contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition;"

528. The language of claim element 1(c) is identical to the language of Claim Element 25(c) (which is identical to Claim Element 23(c) and similar to Claim

Element 24(c)). Accordingly, the explanation I provide above for those claim elements applies equally to claim element 1(c).

e. Claim 1: Element (1)(d)—"separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas;"

529. The language of claim element 1(d) is identical to the language of Claim Element 23(d) (which is identical to the language of Claim Elements 24(d) and 25(d)). Accordingly, the explanation I provide above for those claim elements applies equally to claim element 1(d).

f. Claim 1: Element (1)(e)—"monitoring the mercury content of the cleaned gas; and"

530. The language of claim element 1(e) is identical to the language of claim 28(a) (which is identical to the language of Claim Element 24(e)). Accordingly, the explanation I provide above for those claim elements applies equally to claim element 1(e).

g. Claim 1: Element (1)(f)(1)—"controlling, in response to the monitored mercury content of the cleaned gas, an injection rate of injecting the sorbent into the mercury-containing gas, the sorbent composition, or a combination thereof,"

531. As discussed above for Claim Element 28, this limitation is disclosed by the combinations of Downs-Boiler and Starns (Ground A4) and Downs-Boiler and Mass-EPA (Ground A5). As discussed above for Claim Element 28(a) and

Ground A5, Starns discloses continuously monitoring the mercury content of the cleaned gas and controlling an injection rate of injecting the sorbent into the mercury-containing gas. And as also discussed above for Claim 28(a) and Ground A5, Mass-EPA discloses continuously monitoring the mercury content of the cleaned gas and controlling an injection rate of injecting the sorbent into the mercury-containing gas

h. Claim 1: Element (1)(f)(2)—"so that the mercury content of the cleaned gas is maintained at or below a desired level."

532. The language of claim element 1(f)(2) is identical to the language of Claim Element 28(b). Accordingly, the explanation I provide above for Claim Element 28(b) applies equally to claim element 1(f)(2).

5. <u>Claims Depending from Claim 1</u>

a. Claim 2: "The method of claim 1, comprising removing greater than 70 wt % of the mercury in the mercury-containing gas."

533. Claim 2 would have been obvious over the combination of Downs-Boiler and Starns (Ground A4) and the combination of Downs-Boiler and Mass-EPA (Ground A5). Each of the three references achieve greater than 70 wt% mercury removal, and the combinations would as well. According to Figure 3, reproduced below as annotated, Downs-Boiler indicates that the disclosed method for removing mercury from the flue gas resulted in mercury emissions at the outlet

of the fabric filter of approximately 2 µg/dscm (blue) as compared to an initial value (i.e., the mercury inventory of the system) at the inlet of the fabric filter of approximately 9 µg/dscm (red).[882]

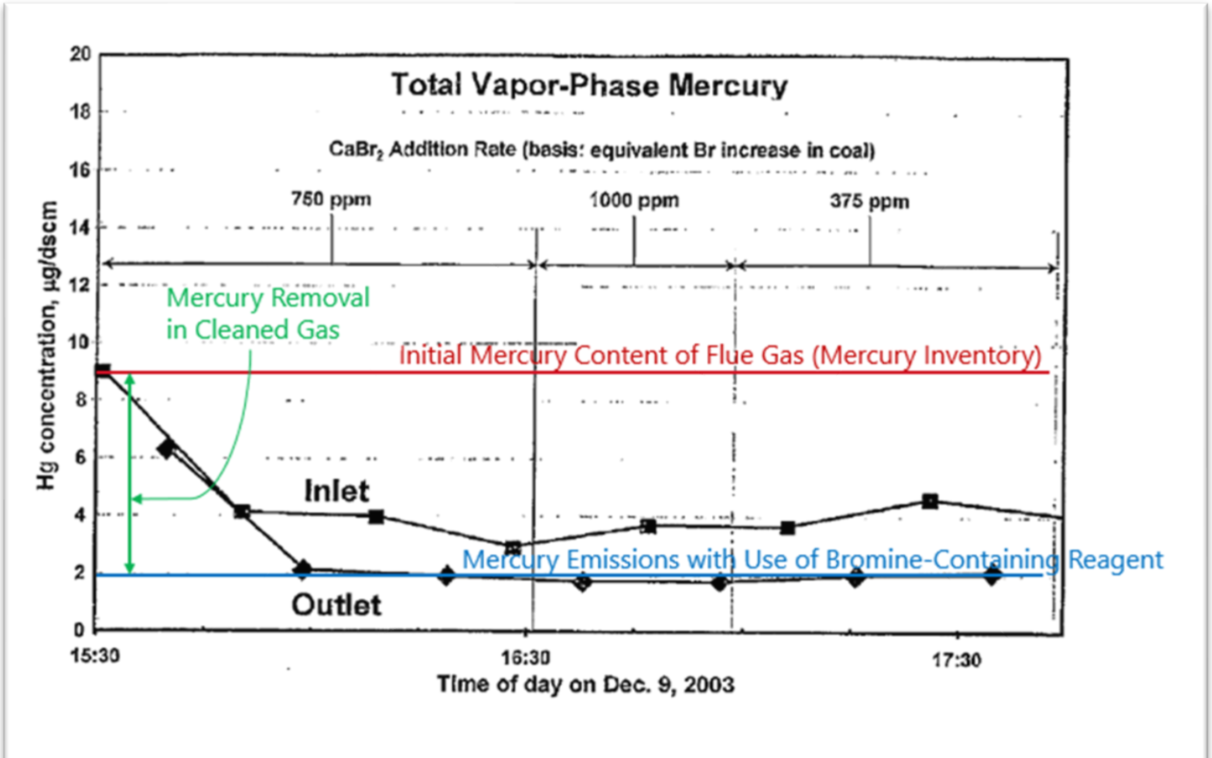


FIG. 3

Therefore, Downs-Boiler resulted in mercury removal of approximately 7 µg/dscm (green). This removal of the mercury in the mercury containing gas (7 µg/dscm) as compared to the mercury inventory of the system (9 µg/dscm) may also be expressed as a percentage: at least 77 wt% of the mercury in the mercury-containing gas was

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[882] EX1006 (Downs-Boiler) Figure 3 (annotated); see also EX1007 (Downs-Boiler-Provisional) Figure 3.

removed—or in other words: removing greater than 70 wt% of the mercury in the mercury-containing gas.

534. Regarding Ground A4, in addition to the disclosure of Downs-Boiler, Starns also discloses removing 70% mercury when using 10 lb/MMacf of activated carbon.[883] When combined with the improved oxidation through the halogenation of Downs-Boiler, the removal would be even greater than the 70%.

535. Regarding Ground A5, in addition to the disclosure of Downs-Boiler, Mass-EPA discloses removing greater than 70% mercury, such as at the Gaston and Brayton Point plants.[884] When combined with the improved oxidation through the halogenation of Downs-Boiler, the removal would be even greater than the 70%.

536. In addition to the mercury-removal percentages disclosed by Downs-Boiler, Starns, and Mass-EPA, Claim 2 would have been obvious to a person of skill in the art for purposes of complying with legal and regulatory requirements. As described in the State of the Art,[885] a POSITA would have known that by 2004, the EPA had already put the industry on notice of upcoming laws and regulations requiring 70% mercury removal, including the EPA's Clean Air Mercury Rule

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[883] EX1008 (Starns) at 20.

[884] EX1009 (Mass-EPA) at 11-12 (Chart 2 and accompanying discussion).

[885] *See* Technology Background and State of the Art, § IX.D – § IX.F.

(CAMR). Downs-Boiler further teaches compliance with EPA standards regulating mercury emissions from coal-fired plants.[886] Notice of these regulations exerted a strong outside impetus on the industry to adjust processes to comply with the regulations' eventual implementation. Through routine process optimization and routine experimentation, a POSITA would have adjusted the rate of addition of bromine-containing species and/or activated carbon injection rate to meet and exceed (for purposes of safety margin) the EPA's proposed rules requiring a 70% removal of mercury.

b. Claim 3: "The method of claim 1, comprising removing greater than 70 wt % of the mercury in the mercury-containing gas on the sorbent."

537. Claim 3 would have been obvious over the combination of Downs-Boiler in view of Starns (Ground A4) and Downs-Boiler in view of Mass-EPA (Ground A5). For example, as described for Claim 2 above, Downs-Boiler discloses removing greater than 77 wt% of the mercury in the flue gas. In addition to the reasons for Claim 2, a POSITA would understand that that the mercury removal on the sorbent alone would meet or exceed 70%. Downs-Boiler discloses that only "25% of the coal-fired power plants in the U.S. are equipped with wet FGD systems"

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[886] EX1006 (Downs-Boiler) ¶[0001]; see also EX1007 (Downs-Boiler-Provisional) ¶[002].

(scrubbers), and discloses "PAC injection systems" (activated carbon) as an alternative to "downstream pollution control systems such as wet [scrubbers] 22 and SDA 24 FGD systems."[887] This impact would be particularly pronounced for coal-fired utility plants using lignite or blends of high volatility coals that would produce minimal unburned carbon (e.g., loss on ignition) particulate in the flue gas stream,[888] resulting in a higher proportion of the mercury in the mercury-containing gas to bind to the sorbent. Downs-Boiler also discloses such a plant that burns "lignite coals," which produces a lower "percentage of oxidized mercury" on account of "low chloride content."[889] Such a plant would require the sorbent in a dry-emission system to remove the mercury.

538. Downs-Boiler notes that "the presence of unburned carbon" is a factor that has "been shown to affect the conversion of elemental mercury to oxidized mercury species" and this unburned carbon (i.e., LOI) would scavenge mercury from the flue gas, thereby affecting the percentage of mercury on the sorbent.[890]

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[887] EX1006 (Downs-Boiler), ¶¶[0007], [0015]; EX1007 (Downs-Boiler-Provisional) ¶¶[009], [0018].

[888] *See* Technology Background and State of the Art, § IX.B.1.

[889] EX1006 (Downs-Boiler) ¶¶[0005], [0020]; see also EX1007 (Downs-Boiler-Provisional) ¶¶[006], [0023].

[890] EX1006 (Downs-Boiler) ¶¶[0005], [0020]; EX1007 (Downs-Boiler-Provisional) ¶¶[006], [0023].

Specifically, Downs-Boiler discloses that power stations burning "lignite coals," which produce a lower "percentage of oxidized mercury" on account of "low chloride content," would benefit from the disclosed Hg control methods.[891] Such plants typically exhibit very low levels of LOI in addition to suffering from very low concentrations of inherent chlorine in their flue gas. Under such circumstances, Hg capture on inherent unburned carbon would have been minimal in plants using western lignite coals and would therefore not have a significant effect on the percentage of mercury on the sorbent.

539. Consequently, adding bromine-containing species to the furnace of coal-fired utility plants burning lignite and other low-rank coals, and that are not configured with a scrubber or a spray dryer absorber while injecting a sorbent ahead of the particle collection device, as Downs-Boiler teaches, ensures that virtually all the Hg captured in a particle collection device would be bound to the sorbent. Furthermore, Downs-Boiler also teaches how to adjust the bromine addition level to achieve highly efficient Hg removal, including greater than 70% removal.

540. The activated carbon injection in Starns (Ground A4) takes place with solely a dry emissions system, and the activated carbon injection is particularly

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[891] EX1006 (Downs-Boiler) ¶[0005]; see also EX1007 (Downs-Boiler-Provisional) ¶[006].

suited as "mercury control technology for coal-fired utility plants that do not have scrubbers for SO_2 control."[892]

541. The activated carbon injection in Mass-EPA (Ground A5) also takes place at units that did not have scrubbers. At the time the Mass-EPA report was issued in December 2002, Massachusetts utilities operated four coal-fired power plants with a total of 10 combustion furnaces. All of these units operated with solely dry emissions systems in which particulates were collected on ESPs.[893] One of these plants, Brayton Point, was the site for field tests whose results, "indicate that the higher the concentration of sorbent injected, the more mercury removed. Removal values range from 0 – 50% at 3 lb/MMacf and 75 – 95% at the highest sorbent injection rate of 20 lb/MMacf."[894] The entire range of removals with the highest ACI concentration are greater than 70 %.

c. Claim 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."

542. Claim 4 would have been obvious over the combination of Downs-Boiler in view of Starns (Ground A4) and Downs-Boiler in view of Mass-EPA

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[892] EX1008 (Starns) p. 2 (Abstract).

[893] EX1009 (Mass-EPA) at 70-71.

[894] EX1009 (Mass-EPA) at 74.

(Ground A5). Claim 4 is merely an attempt to claim the optimum or workable range for a process of combining a particular conventional halogen (bromine) being used in a conventional way (halogens are inherent to coal, and has the dual-benefit of oxidizing mercury and promoting activated carbons) with a conventional sorbent (activated carbon). Nothing about the particular range of 1 g to about 30 g of the halide promoter per 100 g of the sorbent would have led to an unexpected result from what was already known to one of skill in the art.

543. As described in the State of the Art,[895] it was known that the saturation limit of activated carbon for bromine (i.e., how much bromine the activated carbon can actually adsorb at equilibrium), was up to 31 to 38 grams per 100 grams of activated carbon. Given the residence times in flue gas, and other inefficiencies, a person of ordinary skill in the art would have understood that the actual bromine loaded onto activated carbon would have been less than the saturation limit.

544. A POSITA would have recognized that there would be sufficient bromine in the flue gas, according to the processes disclosed by Downs-Boiler, to provide a ratio of between 1 g to 30 g of bromine per 100 g of activated carbon (as described above for Claims 28 and 29). A person of ordinary skill in the art would have been motivated to use near the bromine-saturation limit of the activated carbon

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[895] *See* Technology Background and State of the Art, §IX.C.3.

because, in addition to the enhanced removal of mercury on sorbent with the use of halogens as disclosed by Downs-Boiler,[896] it was known in the art that mercury oxidized by a halide, as "in the form of mercuric chloride, is soluble in water, making it amenable to removal in sulfur dioxide scrubbers," as discussed by Downs-Boiler.[897]

545. Through natural process optimization and routine experimentation, a POSITA would have adjusted the rate of addition of bromine-containing species and/or activated carbon injection rate to achieve halide promoter on the activated-carbon sorbent from about 1 g to about 30 g.[898]

d. Claim 5: "The method of claim 1, wherein the combustion chamber comprises the halogen or halide promoter."

546. Downs-Boiler discloses this limitation in Ground A4 and Ground A5 for the reasons discussed above for Claim Element 25(b) and Claim 27. As described above for Claim Element 25(b), Downs-Boiler discloses a halogen or halide

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[896] EX1006 (Downs-Boiler) ¶¶[0006], [0016]; see also EX1007 (Downs-Boiler-Provisional) ¶¶[0019], [007].

[897] EX1006 (Downs-Boiler) ¶[0003]; see also EX1007 (Downs-Boiler-Provisional) ¶[004].

[898] Patent Owner's expert, Mr. O'Keefe, agrees. EX1092 (O'Keefe Report) at 153 (concluding with regard to claim 4 that "power plants employing bromine additives and activated carbon would necessarily produce a sorbent that is 1 g to 30 g bromine per 100 g of activated carbon.").

promoter (i.e., a bromine-containing reagent).[899] Downs-Boiler further discloses that the bromine-containing reagent may comprise hydrogen bromide (HBr).[900] Downs-Boiler discloses adding "bromine" (Br_2), "hydrogen bromide" (HBr) and aqueous "calcium bromide" to the combustion chamber. According to Downs-Boiler, the bromine promoters may be "fed to the boiler combustion zone 14."[901] Hydrogen bromide (HBr) is expressly disclosed by Claims 1 and 23 of the '114 Patent as examples of "a halogen or halide promoter." Downs-Boiler also states that the purpose of adding the "bromine-containing compounds, added to the coal, or to the boiler combustion furnace" is for "enhancing the overall removal of mercury in downstream pollution control devices." [902] Downs-Boiler indicates that such an embodiment where the combustion chamber comprises the halogen or halide promoter was successfully tested by injecting a solution of the promoter "into the

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[899] EX1006 (Downs-Boiler) ¶[0015]; see also EX1007 (Downs-Boiler-Provisional) ¶[0018].

[900] EX1006 (Downs-Boiler) ¶[0021]; see also EX1007 (Downs-Boiler-Provisional) ¶[0024].

[901] EX1006 (Downs-Boiler) ¶[0022]; see also EX1007 (Downs-Boiler-Provisional) ¶[0025].

[902] EX1006 (Downs-Boiler) ¶[0007]; EX1007 (Downs-Boiler-Provisional) ¶[0013].

combustion chamber 14 through a coal burner."[903] Accordingly, Downs-Boiler discloses that the halogen in the combustion chamber acts as a promoter (e.g., "enhances mercury removal").[904]

e. Claim 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."

547. The language of claim 6 is similar to the language of Claim Element 25(b) and Claim 26, and I refer to my discussion above. Claim 6 has the following changes, as compared to claim 26:

> wherein the coal comprises ~~the~~ added Br_2, HBr, Br-, ~~the bromide compound~~ or a combination thereof, added to the coal upstream of the combustion chamber

Claim 6 is disclosed because, as discussed for claim 26, Downs-Boiler discloses a bromine-containing reagent that may comprise "hydrogen bromide (HBr) or bromine (Br_2)".[905] This bromine-containing reagent is applied to the coal upstream of the combustion chamber.

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[903] EX1006 (Downs-Boiler) ¶[0018]; see also EX1007 (Downs-Boiler-Provisional) ¶[0021].

[904] EX1006 (Downs-Boiler) ¶[0015]; see also EX1007 (Downs-Boiler-Provisional) ¶[0018].

[905] EX1006 (Downs-Boiler) ¶[0021]; see also EX1007 (Downs-Boiler-Provisional) ¶[0024].

f. Claim 7: "The method of claim 1, wherein the promoter is contacted with the sorbent in vapor form, gaseous form, liquid form, or in an organic solvent."

548. Claim 7 would have been obvious over the combination of Downs-Boiler in view of Starns (Ground A4) and Downs-Boiler in view of Mass-EPA (Ground A5). Downs-Boiler explicitly discloses that the promoter (i.e., the bromine-containing reagent) "may be fed to the boiler combustion zone 14 in <u>gaseous</u>, <u>liquid</u>, or <u>solid form</u>."[906] Downs-Boiler also explicitly discloses that the promoter may be in the form of an "<u>aqueous solution</u>."[907]

549. As described for the independent claims, the combination of Downs-Boiler in view of Starns (Ground A4) and the combination of Downs-Boiler in view of Mass-EPA (Ground A5) each injects activated carbon into the mercury-containing flue gas. The boiling point of Br_2 is only 58.8ºC (it is a fuming liquid at room temperature), and the boiling point of hydrogen bromide is -66.38 ºC (i.e., it is a gas at room temperature).[908] Each of these is well below the temperature of the mercury-containing flue gas. As described for Claim 23, for the other species that Downs-

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[906] EX1006 (Downs-Boiler) ¶[0022]; see also EX1007 (Downs-Boiler-Provisional) ¶[0025].

[907] EX1006 (Downs-Boiler) ¶[0019]; see also EX1007 (Downs-Boiler-Provisional) ¶[0022].

[908] EX1036 (CRC Press: March 2005) at 4-53 and 4-65.

Boiler adds to the coal and/or combustion chamber, at least a portion of the Br would have vaporized in the combustion chamber and reacted to form vapor-phase HBr. When bromine-containing species (e.g., HBr) and carbon come into contact with each other, the bromine acts as a promoter.[909]

550. Regarding Ground A4, Starns discloses typical flue gas temperatures of 290 ºF, which is 143 ºC.[910] Regarding Ground A5, Mass-EPA discloses activated carbon injection upstream of ESPs and FFs fall into two classifications, coldside (CS) or hotside (HS), depending on whether they are installed after an air heater, where flue gas temperatures range from 284 to 320ºF (140 to 160°C), or before an air heater, where flue gas temperatures range from 662 to 842ºF (350 to 450°C)."[911] In each of these configurations, the temperatures are well-above the limit at which the mercury-containing gas would be in the gas phase, and the halogen promoters (such as HBr and Br_2) would likewise be vaporized.

551. Regarding Ground A4 and Ground A5, the boiling point of water is around 100 ºC, so a POSITA would have understood, or at the very least found it obvious, that the mercury-containing flue gas (which also contains promoter) would

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[909] *See* Technology Background and State of the Art, §IX.C.3, §IX.G.2.

[910] EX1008 (Starns) at 10.

[911] EX1009 (Mass-EPA) at 26.

be at a temperature well above the boiling point of water and remain in the gas phase. In each combination, the promoter would have remained in the gaseous form as it is transported with the flue gas and eventually contacted the activated-carbon sorbent.

g. Claim 8: "The method of claim 1, further comprising injecting a secondary material into the mercury-containing gas downstream of the combustion chamber."

552. Claim 8 would have been obvious over the combination of Downs-Boiler in view of Starns (Ground A4) and Downs-Boiler in view of Mass-EPA (Ground A5).

553. With respect to Ground A4, Starns discloses activated-carbon that is co-injected with "SO_3 flue gas conditioning."[912] A POSITA would recognize SO_3 as an exemplary secondary material as recited in claim 8 because its impact on Hg removals is being characterized in Starns's test series. Starns's matrix of test conditions in Table 5 contains two tests without SO_3 injection (nos. 1 and 7) and 14 tests with SO_3 injection.

554. With respect to Ground A5, Mass-EPA also discloses SO_3 injection into the mercury-containing flue gas.[913] Mass-EPA further discloses co-injection of not only activated carbon sorbents, but also calcium/lime:

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[912] EX1008 (Starns) at 10.

[913] EX1009 (Mass-EPA) at 39-40.

> In one study (Ref. 28), activated carbon was co-injected with either sodium carbonate or lime for SO_2 control. With either of these sorbents, an improvement in the adsorption of gaseous Hg by the activated carbon was reported.[914]
>
> Increased removal of mercury from gas has been demonstrated by co-injection of activated carbon and calcium-based sorbents in spray dryer adsorber systems in full-scale coal-fired power plants. [915]
>
> In addition to using sorbents with higher mercury adsorption capacity and/or lower costs (such as composite PAC-lime sorbents or impregnated activated carbons)… could improve the cost-effectiveness of PAC injection-based technologies.[916]

A person of ordinary skill in the art would recognize that alkaline sorbents, among many other options, are secondary materials that can be injected into flue gas to enhance the performance of ACI in removing Hg.

555. In addition, and with respect to Ground A5, Mass-EPA discloses injecting "[m]odified activated carbons (i.e., doped with sulfur, iron, chlorine, and iodine."[917] The modified activated carbon with chlorine and iodine is a compound derived from a halogen.

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[914] EX1009 (Mass-EPA) at 37.

[915] EX1009 (Mass-EPA) at 32.

[916] EX1009 (Mass-EPA) at 52.

[917] EX1009 (Mass-EPA) at 33.

h. Claim 9: “The method of claim 8, wherein the secondary material comprises a halogen, a compound derived from a halogen, a hydrohalide, a compound comprising a Group V or Group VI element and a molecular halogen, or a combination thereof.”

556. Claim 9 would have been obvious over the combination of Downs-Boiler in view of Mass-EPA (Ground A5). As described for Claim 8 (Ground A5), Mass-EPA discloses injecting “[m]odified activated carbons (i.e., doped with sulfur, iron, chlorine, and iodine).”[918] The chlorine and iodine are each halogens.

557. Mass-EPA also discloses injecting “[m]odified activated carbons (i.e., doped with sulfur, iron, chlorine, and iodine.”[919] The modified activated carbon with chlorine and iodine is a compound derived from a halogen.

i. Claim 10: “The method of claim 1, wherein the sorbent material injected into the mercury-containing gas further comprises a non-carbon sorbent material.”

558. Claim 10 would have been obvious over the combination of Downs-Boiler in view of Mass-EPA (Ground A5). With respect to Ground A5, Mass-EPA discloses co-injection of not only activated carbon sorbents, but also calcium-based sorbents and other non-carbon sorbents:

> In one study (Ref. 28), activated carbon was co-injected with either sodium carbonate or lime for SO_2 control. With either of

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[918] EX1009 (Mass-EPA) at 33.

[919] EX1009 (Mass-EPA) at 33.

> these sorbents, an improvement in the adsorption of gaseous Hg by the activated carbon was reported.[920]
>
> Increased removal of mercury from gas has been demonstrated by co-injection of activated carbon and calcium-based sorbents in spray dryer adsorber systems in full-scale coal-fired power plants.[921]
>
> Various types of sorbents have been under investigation. These include various types of activated carbon, calcium-based and sodium-based (trona) sorbents, various clays and zeolites, alkaline-earth sulfides, as well as lime and lime-silica multi-pollutant sorbents. Activated Carbon and calcium-based sorbents have been the most actively researched and tested sorbents.[922]

The "calcium-based sorbents" are examples of non-carbon sorbent material. Calcium-based sorbents and other alkaline materials adsorb other constituents from the flue gas (e.g., SO_3), which would otherwise compete with mercury for the active binding sites on activated-carbon sorbent.

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[920] EX1009 (Mass-EPA) at 37.

[921] EX1009 (Mass-EPA) at 32.

[922] EX1009 (Mass-EPA) at 32.

j. Claim 11: "The method of claim 10, wherein the non-carbon sorbent material comprises at least one of a porous felsic material, a vesicular felsic material, a porous basaltic material, a vesicular basaltic material, a clay-based compound, an alkaline compound, a calcium hydroxide compound, a sodium acetate compound, and a bicarbonate compound."

559. Claim 11 would have been obvious over the combination of Downs-Boiler in view of Mass-EPA (Ground A5). As discussed for Claim 10, Mass-EPA discloses co-injecting lime (a calcium hydroxide compound), alkaline-earth sulfides (an alkaline compound), and various clays and zeolites (clay-based compound).

k. Claim 12: "The method of claim 1, wherein the activated carbon comprises powdered activated carbon, granular activated carbon, or a combination thereof."

560. This limitation is disclosed by Downs-Boiler (Ground A4 and Ground A5). As discussed above for Claim Element 25(c), Downs-Boiler discloses the use of a "sorbent injection system" for the purpose of injecting a "carbonaceous sorbent" including at least "powdered activated carbon (PAC), carbons and chars produced from coal and other organic materials, and unburned carbon produced by the combustion process itself."[923]

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[923] EX1006 (Downs-Boiler) ¶[0025]; see also EX1007 (Downs-Boiler-Provisional) ¶[0028].

561. For Ground A4, the activated carbon injected by Starns is "powdered activated carbon," which is also abbreviated as "PAC": "The most mature, retrofit technology available today is the injection of sorbents such as powdered activated carbon (PAC) into the flue gas upstream of the particle control equipment."[924]

562. For Ground A5, Mass-EPA discussed powdered activated carbon (abbreviated as "PAC") throughout the reference, including how "one mercury-specific control technology (powdered activated carbon injection) has the potential for commercialization in the near future."[925]

l. Claim 13: "The method of claim 1, wherein the sorbent material injected into the mercury-containing gas is substantially free of halogen and halide promotion."

563. Claim 13 would have been obvious over the combination of Downs-Boiler in view of Starns (Ground A4) and Downs-Boiler in view of Mass-EPA (Ground A5). Downs-Boiler acknowledges that the "removal of elemental mercury from coal combustion gases generated by electric utility plants through the application of a <u>conventional PAC injection process</u>" is well known and understood in the industry but concedes that that use of these systems is "very expensive" when

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[924] EX1008 (Starns) at 2.

[925] EX1009 (Mass-EPA) at 22; *see also* p. 32 ("Powdered Activated Carbon … has been the most extensively studied sorbent for mercury adsorption.").

not used in combination with the disclosed invention.[926] These "conventional" PAC injection processes referred to by Downs-Boiler are the injection of a powdered activated carbon (PAC) sorbent that is untreated (i.e., substantially free of halogen or halide promotion) prior to injection. Downs-Boiler proposes enhancing the mercury removal ability of such a conventional PAC to make it less cost-prohibitive by "utilizing a sorbent injection system in conjunction with the present invention. Such carbonaceous sorbents include, but are not limited to, powdered activated carbon (PAC)."[927] Further, because Down-Boiler does not characterize the sorbent as having been pre-brominated or otherwise impregnated with a halogen promoter prior to injection, a POSITA would have understood the disclosure of Downs-Boiler to naturally refer to sorbent material that is substantially free of halogen and halide promotion.

564. In addition to the disclosure of Downs-Boiler, for Ground A4, Starns discloses Norit "Darco FGD":

> At each site, at least two sorbents are evaluated during the parametric tests. A standard powdered activated carbon (FGD),

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[926] EX1006 (Downs-Boiler) ¶[0016]; see also EX1007 (Downs-Boiler-Provisional) ¶[0019].

[927] EX1006 (Downs-Boiler) ¶[0025]; see also EX1007 (Downs-Boiler-Provisional) ¶[0028].

> which is a lignite-derived sorbent supplied by Norit Americas Inc., is tested in all cases as the benchmark sorbent.[928]

For Ground A5, the same activated carbon was used: "Norit FGD," specifically "Norit America's 'Darco FGD.'"[929] A POSITA would have recognized that the Norit Darco FGD is substantially free of halogen and halide promotion. Articles dating back to at least 1998 confirm that the chemical composition of "Norit Darco FGD" does not have halogens.[930]

m. Claim 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."

565. Claim 14 would have been obvious over the combination of Downs-Boiler in view of Starns (Ground A4). A POSITA would have been motivated, and would have had a reasonable expectation of success, to try pre-halogenating the activated carbon prior to injecting it into the mercury-containing flue gas. For example, it was well-known in the art since the 1930s to remove mercury vapors by injecting pre-halogenated sorbents into a mercury-containing flue gas.[931]

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[928] EX1008 (Starns) at 3.

[929] EX1009 (Mass-EPA) at 73, 74.

[930] EX1048 (Carey) at 1169 (Table 1, discussing chemical analysis of Norit FGD).

[931] Technology Background and State of the Art, §§IX.C, IX.G (including EX1029 (Stock)).

566. Claim 14 would have also been obvious over the combination of Downs-Boiler in view of Mass-EPA (Ground A5). Mass-EPA discloses two alternatives for the powdered activated carbon: "activated carbon (or the impregnated activated carbon)."[932] Mass-EPA explains that exemplary forms of the impregnated activated carbon are "chlorine-impregnated activated carbon."[933] Mass-EPA also discloses "[m]odified activated carbons (i.e., doped with … chlorine and iodine") as an alternative that "can provide higher mercury adsorption capacity, but often have higher production costs."[934] Chlorine and iodine are each types of halogens, and the activated carbons with these halogens is promoted[935]

567. For Ground A4 and Ground A5, a POSITA would have been motivated to at least try such a pre-halogenated sorbent in conjunction with the process of Downs-Boiler in order to further enhance mercury removal, particularly for coals with higher native mercury content (or lower native halogen content and/or lower unburned carbon in fly ash) where a greater percentage of elemental mercury makes removal more troublesome. Indeed, Downs-Boiler recognizes the shortcoming of

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[932] EX1009 (Mass-EPA) at 32.

[933] EX1009 (Mass-EPA) at 34 & n.44.

[934] EX1009 (Mass-EPA) at 33.

[935] Technology Background and State of the Art, SectionIX.C.32.

conventional PAC for removal of elemental mercury, noting that "PAC injection removes both oxidized and elemental mercury species, although removal efficiencies are higher for the oxidized form."[936] Employing a pre-halogenated promoted sorbent could overcome the propensity of PAC to favor reacting with the oxidized form of mercury, thereby more-uniformly removing both elemental and oxidized forms of mercury from the flue gas—reducing the total mercury emissions even further.

n. Claim 15: "The method of claim 1, wherein the combustion chamber comprises a boiler."

568. This claim is disclosed by Downs-Boiler (Ground A4 and Ground A5). Downs-Boiler discloses a combustion chamber (i.e. a "combustion furnace 14") that comprises a "boiler 12."[937] This is also shown in Figures 2 and 4-6 of Downs-Boiler.[938] Figure 5 is copied below.

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[936] EX1006 (Downs-Boiler) ¶[0004]; see also EX1007 (Downs-Boiler-Provisional) ¶[005].

[937] EX1006 (Downs-Boiler) ¶[0015]; see also EX1007 (Downs-Boiler-Provisional) ¶[0018].

[938] EX1006 (Downs-Boiler) Figures 2, 4-6; see also EX1007 (Downs-Boiler-Provisional) Figures 2, 4-6.

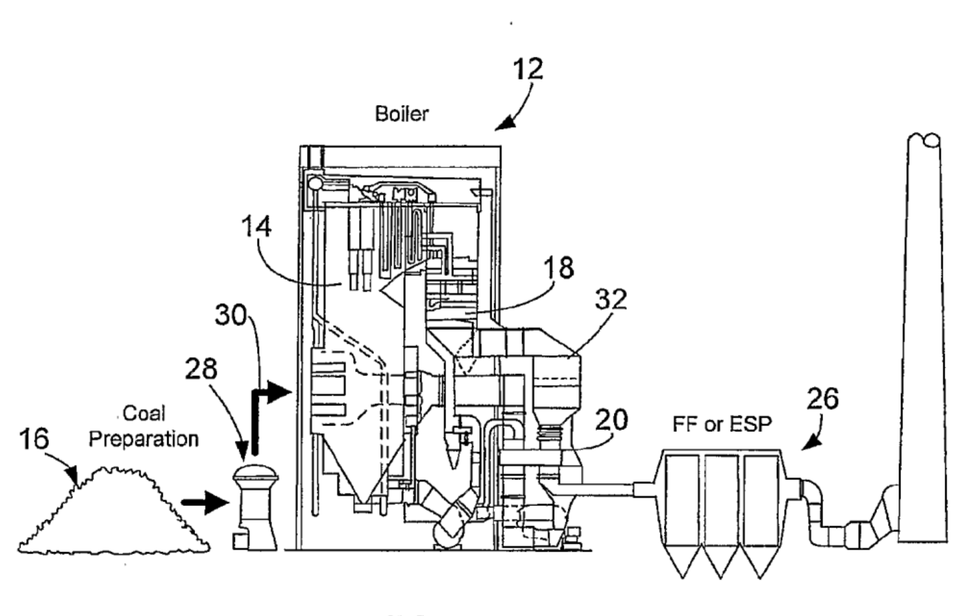

FIG. 5

o. Claim 16: "The method of claim 1, wherein the mercury-containing gas is a flue gas."

569. This claim is disclosed by Downs-Boiler (Ground A4 and Ground A5). Downs-Boiler specifically describes various forms of mercury as being present within a flue gas:[939]

> Mercury appears in coal combustion <u>flue gases</u> in both solid and gas phases (particulate-bound mercury and vapor-phase mercury, respectively). The so called particulate-bound mercury is really vapor-phase mercury adsorbed onto the surface of ash or carbon particles. Due to the high volatility of mercury and many of its compounds, most of the mercury found in flue gases is vapor-phase mercury. Vapor-phase mercury can appear as elemental mercury (elemental, metallic mercury vapor) or as

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[939] EX1006 (Downs-Boiler) ¶[0002]; see also EX1007 (Downs-Boiler-Provisional) ¶[003].

> oxidized mercury (vapor-phase species of various compounds of mercury).

The invention taught by Downs-Boiler promises an effective low-cost solution for "mercury removal" from the flue gases "at coal-fired electric plants."[940] The preamble of claim 1 of Downs-Boiler also identifies "a flue gas" as being such a mercury-containing gas from which to remove mercury.[941]

p. Claim 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."

570. This limitation is obvious over Downs-Boiler. Downs-Boiler discloses a coal-fired utility boiler with a "particulate collector 26 (FF or ESP) (FIG. 4), a particulate collector 26 (FF or ESP) (FIG. 5), or a wet 22 FGD and particulate collector 26 (FF or ESP) (FIG. 6)."[942] Though the particular figures of Downs-Boiler illustrate a cold-side ESP, Downs-Boiler also notes that alternative embodiments are compatible with the specific embodiments disclosed.[943] A POSITA would have

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[940] EX1006 (Downs-Boiler) ¶[0016]; see also EX1007 (Downs-Boiler-Provisional) ¶[0019].

[941] EX1006 (Downs-Boiler) Claim 1; see also EX1007 (Downs-Boiler-Provisional) Claim 1.

[942] EX1006 (Downs-Boiler) Figures 4-6, ¶[0023]; see also EX1007 (Downs-Boiler-Provisional) Figures 4-6, ¶[004].

[943] EX1006 (Downs-Boiler) ¶[0027]; see also EX1007 (Downs-Boiler-Provisional) ¶[0029].

known that there are a finite number of options (really, just two) categories of ESPs: hot-side ESP and cold-side ESP. A cold-side ESP is located downstream from the air-preheater, whereas a hot-side ESP is located upstream of the air-preheater. One such alternative embodiment would have been to use a hot-side electrostatic precipitator (HESP) (i.e., an ESP upstream of the air pre-heater) as a particulate collector, in which the sorbent injection would occur upstream of both the HS-ESP and the air preheater.

571. Regardless of the configuration of the pollution control devices in the flue gas system, Downs-Boiler discloses that the sorbent (e.g., a conventional PAC injection system) should be injected upstream of the particulate collector such that the "sorbent, and its burden of adsorbed mercury, are subsequently removed from the flue gases <u>in a downstream particulate collector.</u>"[944] A POSITA would have known that for a coal-fired utility boiler configured with a hot-side ESP that the sorbent would necessarily be injected upstream of the hot-side ESP, and that therefore the sorbent injection into the mercury-containing gas (i.e., the flue gas) would occur upstream of the air pre-heater.

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[944] EX1006 (Downs-Boiler) ¶[0004]; see also EX1007 (Downs-Boiler-Provisional) ¶[005].

i. Ground A4 (Downs-Boiler and Starns)

572. This claim would have further been obvious over Downs-Boiler in view of Starns. Starns discloses that at one of the sites (Gaston), a "hotside electrostatic precipitator" was used.[945] Thus, it would have been at least obvious to try a hotside ESP when combining Downs-Boiler and Starns, and with such a configuration, the activated carbon would have been injected upstream of the air preheater. Starns recommends "using activated carbon injection upstream of an ESP."[946] A POSITA would have been motivated, as Starns suggests, to use activated carbon injection between the combustion chamber (furnace) and a hotside ESP (electrostatic precipitator) in Downs-Boiler.[947]

ii. Ground A5 (Downs-Boiler and Mass-EPA)

573. This claim would have been further obvious over Downs-Boiler in view of Mass-EPA. The Massachusetts EPA tabulated an assortment of approaches "demonstrated or under investigation to control mercury" in Table 1.[948] The Mass-EPA recognized that devices already present for controlling other pollutants (such

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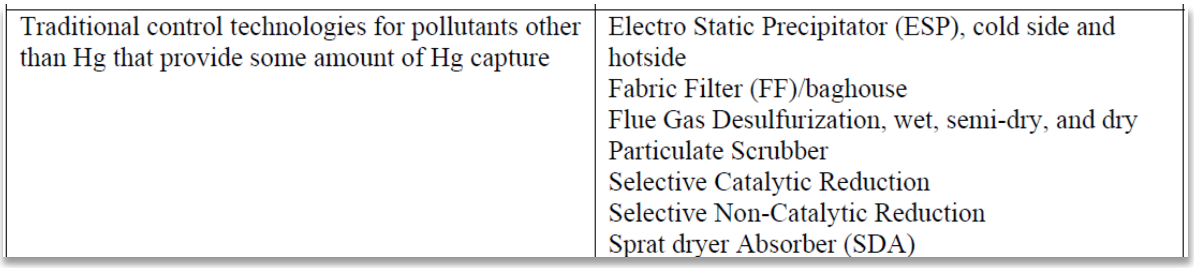
[945] EX1008 (Starns) at 3.

[946] EX1008 (Starns) at 20.

[947] EX1006 (Downs-Boiler) ¶[0004]; see also EX1007 (Downs-Boiler-Provisional) ¶[005].

[948] EX1009 (Mass-EPA) at 7.

as SOx or NOx) can also be useful to provide some mercury capture, including "Electro Static Precipitator (ESP), cold side and hotside."[949]



Traditional control technologies for pollutants other than Hg that provide some amount of Hg capture	Electro Static Precipitator (ESP), cold side and hotside Fabric Filter (FF)/baghouse Flue Gas Desulfurization, wet, semi-dry, and dry Particulate Scrubber Selective Catalytic Reduction Selective Non-Catalytic Reduction Sprat dryer Absorber (SDA)

574. A POSITA would readily have known that, as disclosed in Mass-EPA, a hot-side ESP is located upstream of an air preheater.

> ESPs and FFs fall into two classifications, coldside (CS) or hotside (HS), depending on whether they are installed after an air heater, where flue gas temperatures range from 284 to 320ºF (140 to 160°C), or before an air heater, where flue gas temperatures range from 662 to 842ºF (350 to 450°C). Currently available data indicate that mercury capture in HS-ESPs is very low.

575. In the above quote, the "air heater" is another term for the air pre-heater. Mass-EPA suggests adding activated carbon injection, "incorporate retrofit PAC injection-based technologies on various existing coal-fired utility boiler plant pollution control systems," to improve the efficiency of mercury removal up to 60-90%, depending on the injection rate.[950] Mass-EPA teaches injecting activated

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[949] EX1009 (Mass-EPA) at 7.

[950] EX1009 (Mass-EPA) at 50.

carbon "upstream" of an ESP, [951] which means the activated carbon can also be injected upstream of the air preheater.

q. Claim 18: "The method of claim 1, wherein the injection of the sorbent material into the mercury-containing gas occurs upstream of a particulate separator or a scrubber."

576. Downs-Boiler discloses this limitation. As illustrated by Figures 4-6 of Downs-Boiler, representative Figure 6 reproduced below as annotated, Downs-Boiler describes a coal-fired electric utility plant that can have a number of downstream pollution control devices including particulate collection systems (e.g., a fabric filter (FF) system and/or an electrostatic precipitator (ESP) system) (purple) and a scrubber (e.g., wet flue gas desulfurization (FGD) system) (yellow).[952]

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[951] EX1009 (Mass-EPA) at 53, 54.

[952] EX1006 (Downs-Boiler) Figure 6 (annotated; see also EX1006 (Downs-Boiler) Figures 4-5; EX1007 (Downs-Boiler-Provisional) Figures 4-6.

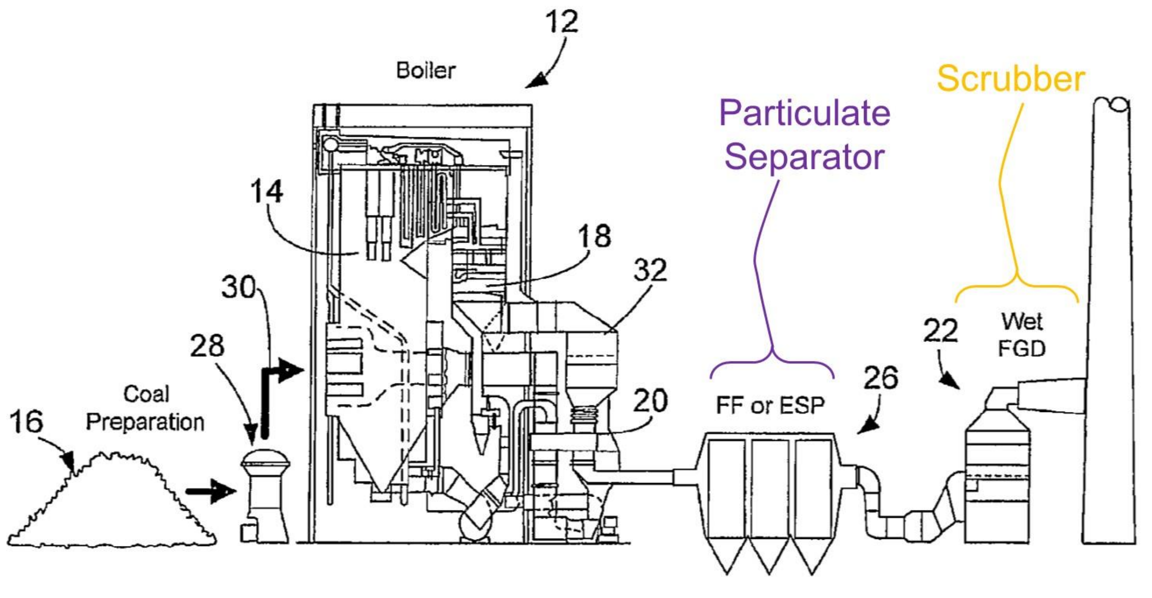

FIG. 6

The use of the bromine-containing reagent as disclosed by Downs-Boiler "thereby enhance[es] the overall removal of mercury in <u>downstream pollution control devices.</u>"[953] Specifically, Downs-Boiler explains that a particular advantage of the disclosed invention is that it "enhances removal of mercury across <u>particulate collectors</u> 26 such as fabric filters (FF) and electrostatic precipitators (ESP)."[954] As further explained by Downs-Boiler, the upstream injection of a sorbent means that the "sorbent, and its burden of adsorbed mercury, are subsequently removed from

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[953] EX1006 (Downs-Boiler) ¶[0007]; see also EX1007 (Downs-Boiler-Provisional) ¶[009].

[954] EX1006 (Downs-Boiler) ¶[0015]; see also EX1007 (Downs-Boiler-Provisional) ¶[0018].

the flue gases <u>in a downstream particulate collector.</u>"[955] Regardless of whether a hot-side ESP or a cold-side ESP is used, the activated-carbon sorbent would be injected upstream of either ESP, so that it could be "subsequently removed" by that ESP.

577. This claim would have also been obvious to a POSITA further in view of Starns (Ground A4) and Mass-EPA (Ground A5). As described above for Claim 17, each of the three references discloses an electrostatic precipitator (ESP), and Starns (Ground A4) and Mass-EPA (Ground A5) each specify that the activated carbon sorbent is injected upstream of the ESP. An ESP is an example of a particulate separator.

578. With respect to Ground A4, Starns states that the activated-carbon sorbent is carried "from the feeders to distribution manifolds located on the <u>ESP inlet</u> duct, feeding the injection probes"[956] further demonstrating that the injection of sorbent into the mercury-containing gas occurs upstream of a particulate separator.

579. With respect to Ground A5, Mass-EPA refers to the "injection of a sorbent into the exhaust system and <u>subsequent</u> collection of the particulates in a PM

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[955] EX1006 (Downs-Boiler) ¶[0004]; see also EX1007 (Downs-Boiler-Provisional) ¶[005].

[956] EX1008 (Starns) at 7.

[particulate matter] control device."[957] This again demonstrates that the sorbent injection into the mercury-containing gas occurs upstream of a particulate separator.

r. Claim 19: "The method of claim 1, wherein the coal comprises added halide sorbent enhancement additive."

580. Downs-Boiler discloses this limitation in Ground A4 and Ground A5. As I explain above regarding Claim Element 25(b) and claim 26, Downs-Boiler discloses a bromine-containing reagent. Downs-Boiler also discloses that the bromine-containing reagent may comprise "alkali metal and alkaline earth metal bromides, hydrogen bromide (HBr) or bromine (Br_2)."[958] A POSITA would also have understood that these specific bromine-based chemicals are all "halides," except for Br_2 (which is a halogen).

581. As disclosed by Downs-Boiler, these halides are applied to the coal such that the coal comprises added halogen. Downs-Boiler teaches that a "bromine containing reagent 10 is added to the boiler 12 combustion furnace 14, either directly or by <u>premixing with the incoming coal 16.</u>"[959] According to the preferred

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[957] EX1009 (Mass-EPA) at 32.

[958] EX1006 (Downs-Boiler) ¶[0021]; see also EX1007 (Downs-Boiler-Provisional) ¶[0024].

[959] EX1006 (Downs-Boiler) ¶[0015]; see also EX1007 (Downs-Boiler-Provisional) ¶[0018].

embodiment of Downs-Boiler, "an aqueous solution of calcium bromide is sprayed onto the crushed coal 16 before the coal 16 is pulverized for combustion. The aqueous solution is easily handled and metered onto the coal 16" such that the "coal pulverizers 28 intimately mix the bromide reagent 10 with the coal 16, and the pulverized coal conveying system 30 to the several coal burners (not shown) ensures an even distribution of the reagent 10 across the boiler furnace 14."[960]

582. Downs-Boiler further instructs that "mercury removal may be further enhanced by utilizing a sorbent injection system in conjunction with the present invention."[961] Downs-Boiler explains that the halogen-based bromine-containing reagent is a sorbent (e.g., PAC) enhancement additive because it "enhances the removal of mercury across a PAC injection process, due to the higher reactivity of oxidized mercury with PAC."[962]

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[960] EX1006 (Downs-Boiler) ¶[0019], Figure 2; see also EX1007 (Downs-Boiler-Provisional) ¶[0022], Figure 2.

[961] EX1006 (Downs-Boiler) ¶[0025]; see also EX1007 (Downs-Boiler-Provisional) ¶[0028].

[962] EX1006 (Downs-Boiler) ¶[0016]; see also EX1007 (Downs-Boiler-Provisional) ¶[0019].

s. Claim 20: "The method of claim 1, wherein the combustion chamber comprises added Br_2, HBr, Br^-, or a combination thereof."

583. Downs-Boiler discloses this limitation in Ground A4 and Ground A5. The language of claim 20 is similar to the language of Claim 27, and I refer to my discussion of that claim. Claim 20 has the following changes, as compared to claim 27:

> wherein the combustion chamber comprises ~~the~~ added Br_2, HBr, Br-, ~~the bromide compound~~, or a combination thereof."

As discussed regarding claim 27, Downs-Boiler explains that the bromine-containing reagent may comprise an "hydrogen bromide (HBr) or bromine (Br_2)," as it can be added directly to the combustion chamber or added to the coal (and then fed to the combustion chamber).[963]

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[963] EX1006 (Downs-Boiler) ¶[0021]; see also EX1007 (Downs-Boiler-Provisional) ¶[0024].

t. Claims 21-22

Claim 21: "The method of claim 1, wherein the coal comprises added sorbent enhancement additive that comprises Br^-."

Claim 22: "The method of claim 21, wherein the sorbent enhancement additive comprises a bromide compound."

584. Downs-Boiler discloses this limitation in Ground A4 and Ground A5. As I explain regarding claim 25(b) and claim 26, Downs-Boiler describes adding to the coal bromine-containing reagents including "alkali metal and alkaline earth metal bromides, hydrogen bromide (HBr) or bromine (Br_2)," and "an aqueous solution of calcium bromide" ($CaBr_2$).[964] HBr and calcium bromide are all bromide compounds, and calcium bromide and hydrogen bromide dissociate in water to form Br^- ions.

585. As disclosed by Downs-Boiler, these bromide ions (Br^-) in the aqueous solution are applied to the coal such that the coal would comprise added bromide ions (Br^-). Downs-Boiler teaches that a "bromine containing reagent 10 is added to the boiler 12 combustion furnace 14, either directly or by <u>premixing with the</u>

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[964] EX1006 (Downs-Boiler) ¶¶[0018]-[0019], [0021], Figure 2; see also EX1007 (Downs-Boiler-Provisional) ¶[0021-22, 0024], Figure 2.

incoming coal 16."[965] According to the preferred embodiment of Downs-Boiler, "an aqueous solution of calcium bromide is sprayed onto the crushed coal 16 before the coal 16 is pulverized for combustion. The aqueous solution is easily handled and metered onto the coal 16" such that the "coal pulverizers 28 intimately mix the bromide reagent 10 with the coal 16, and the pulverized coal conveying system 30 to the several coal burners (not shown) ensures an even distribution of the reagent 10 across the boiler furnace 14."[966]

586. Downs-Boiler explains that the bromine-containing reagent (e.g., the bromide ions (Br^-) in the aqueous solution of calcium bromide ($CaBr_2$) in water) is a sorbent enhancement additive attributable to the fact that it "enhances the removal of mercury across a PAC injection process, due to the higher reactivity of oxidized mercury with PAC."[967]

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[965] EX1006 (Downs-Boiler) ¶[0015]; see also EX1007 (Downs-Boiler-Provisional) ¶[0018].

[966] EX1006 (Downs-Boiler) ¶[0019], Figure 2; see also EX1007 (Downs-Boiler-Provisional) ¶[0022], Figure 2.

[967] EX1006 (Downs-Boiler) ¶[0016]; see also EX1007 (Downs-Boiler-Provisional) ¶[0019].

XVI. GROUND B1: OBVIOUSNESS OVER SJOSTROM IN VIEW OF ECKBERG

587. It is my opinion that Sjostrom in view of Eckberg render obvious each of claims 1-9 and 12-30 of the '114 Patent.

A. REASONS TO COMBINE SJOSTROM WITH ECKBERG

588. A person of skill in the art would have been motivated to combine Sjostrom and Eckberg, and have a reasonable expectation of success in applying the teachings of Eckberg to Sjostrom, because both references are directed towards the same goal of removing mercury from combustion-fuel gases (as indicated by the titles of each reference). Both references teach the use of bromine-based halogens in conjunction with activated carbon to improve mercury removal from flue gas emission leaving coal-fired power plants. The title of Sjostrom is "Full Scale Evaluations of Mercury Control Technologies with PRB Coals."[968] Sjostrom provides an overall process schematic showing activated-carbon sorbents for mercury removal in coal-fired flue gas.[969] Sjostrom discusses that activated carbon was a well-known sorbent for mercury control and discloses suitable ranges for sorbent injection rate.[970] Sjostrom teaches adding halogen-containing reagents

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[968] EX1010 (Sjostrom) at 1.

[969] EX1010 (Sjostrom) at 4.

[970] EX1010 (Sjostrom) at 10, 11, 16.

(including bromine-containing and iodine-containing) onto coal, injecting them into the combustion chamber, and/or injecting them with the sorbent, but does not expressly describe the specific bromine-containing or iodine-containing chemical to use or the quantity to add.[971]

589. A POSITA would have been motivated to look to the teachings of Eckberg to provide these implementation details, for example, to be able to implement the system described in Sjostrom. The title of Eckberg is "Mercury Control Evaluation of Halogen Injection into a Texas Lignite-Fired Boiler."[972] Eckberg includes a similar process schematic as Sjostrom that shows injection of halogens into a coal-fired boiler for mercury removal.[973] Eckberg tells a POSITA the type of bromine to be used (aqueous solution of 52 wt% calcium bromide, $CaBr_2$), the bromine:coal weight ratio (0.09%), the bromine liquid feed rate (1.6 gpm), and the estimated gas concentration of HBr in the flue gas (50 ppm).[974]

590. A POSITA would be further motivated to combine the references, and have a reasonable expectation of success, because both references were presented at

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[971] EX1010 (Sjostrom) at 4.

[972] EX1011 (Eckberg) at 1.

[973] EX1011 (Eckberg) at 5.

[974] EX1011 (Eckberg) at 3, 9, 14, 15.

the 2005 EUEC.[975] In fact, both references were originally presented one after the other during the same "A3" session of the 2005 EUEC on Tuesday, January 25, 2005 from 7:30-9:30 am.[976] Namely, Sjostrom was presented in the A3b slot and Eckberg was presented in the A3c slot.[977] Further, both presentations included a common author—Dr. Ramsay Chang, Ph.D.—and shared a common partner, namely EPRI.[978] Thus, a POSITA attending the conference, or reading the materials after the POSITA received the CD mailed by the EUEC, would have understood that the two presentations included related material and would have benefited one another. Moreover, a POSITA would have been likely to see the material in Sjostrom and Eckberg sequentially, thereby increasing the likelihood that a POSITA would have viewed the two references as interoperable with each other.

591. As noted above, Sjostrom described testing mercury removal from flue gas of coal-fired power plants involving sorbent injection, addition of halogens, and combining sorbents with halogens, as detailed below.[979]

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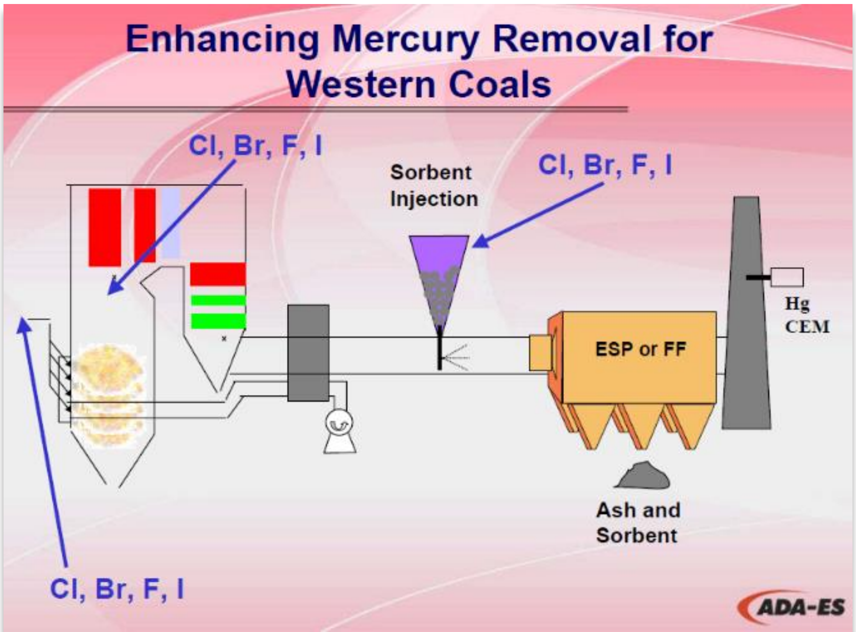
[975] EX1030 (EUEC Handout) at 23.

[976] EX1030 (EUEC Handout) at 23.

[977] EX1030 (EUEC Handout) at 23.

[978] EX1030 (EUEC Handout) at 23.

[979] EX1010 (Sjostrom) at 4.



Enhancing Mercury Removal for Western Coals

Sjostrom demonstrates that activated-carbon sorbent injection was a well-known way of treating mercury emissions in flue gas.[980] Sjostrom also teaches that halogens (e.g., "Cl, Br, F, I") may be injected within the process in multiple locations.[981] A POSITA would have understood that the "Cl, Br, F, I" of Sjostrom referred generally to the addition of chlorine, bromine, fluorine, and iodine in any form, rather than the pure elemental form alone. In fact, a POSITA would have understood that the pure elemental forms of these elements are not readily obtainable and would not have been strong candidates for injection in the system of Sjostrom. Sjostrom includes numerous charts detailing the "Hg Removal (%)" and "Hg Removal Efficiency (%)"

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[980] EX1010 (Sjostrom) at 10-11.

[981] EX1010 (Sjostrom) at 4.

achieved throughout the testing performed on coal flue gas.[982] Sjostrom also shows activated-carbon sorbents that are treated with halogen additives are more effective at removing mercury from flue gas than untreated sorbent alone.[983]

592. Although Sjostrom provides overall process descriptions and sorbent injection rates, and also diagrams and highlights the improved results of halogens used in combination with activated-carbon sorbents, Sjostrom does not expressly describe the specific chemicals used for the halogen injection or the specific injection rates. A person of skill in the art would have looked to the Eckberg reference to further tune implementation of a system like that of Sjostrom, because it expressly describes the chemical formula of the halogen (adding calcium bromide, $CaBr_2$), onto the coal or into the combustion chamber and having it react to provide HBr in the flue gas, as well as the flow rate of calcium bromide, the resulting bromine:coal ratio, and the resulting concentration of HBr in the flue gas in such a system. Specifically, Eckberg teaches injection of "$CaCl_2$ (25 wt%)" or "$CaBr_2$ (52 wt%)" into the combustion chamber.[984] As a result of this injection, the bromine is

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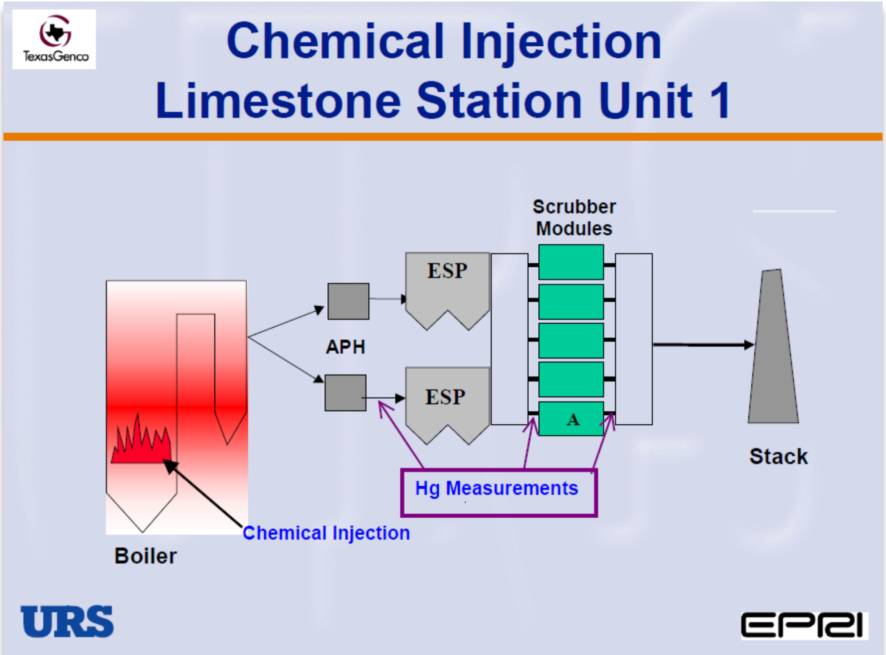
[982] EX1010 (Sjostrom) at 8, 15-17, 20, and 21.

[983] EX1010 (Sjostrom) at 16.

[984] EX1011 (Eckberg) at 9.

provided at a 0.09 weight % (relative to coal), which dissociates and further reacts in the gas phase to provide 50 ppm HBr in the flue gas.[985]

593. Like Sjostrom, Eckberg also teaches enhancing mercury removal through halogen injection into a boiler. Eckberg describes several testing objectives including "[i]ncreas[ing] mercury oxidation in flue gas derived from Texas lignite" and "[e]nhanc[ing] mercury removal across wet scrubbers."[986] As shown in the figure below, and similar to Sjostrom, Eckberg describes testing the mercury removal effects of halogen injection directly into a coal-fired boiler.[987]



Chemical Injection
Limestone Station Unit 1

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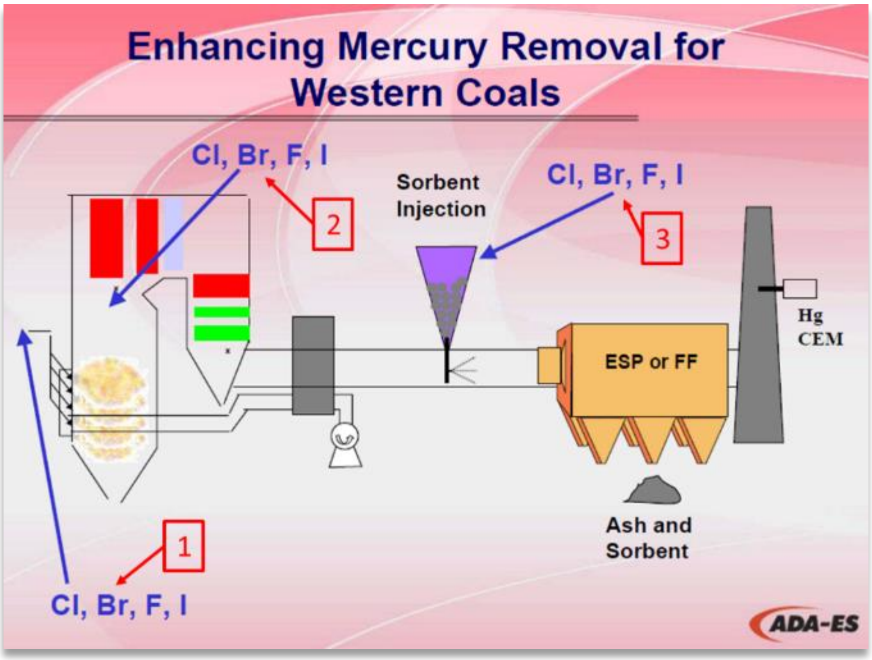
[985] EX1011 (Eckberg) at 9.

[986] EX1011 (Eckberg) at 3.

[987] EX1011 (Eckberg) at 5.

As discussed below, a POSITA would have been motivated to apply the teachings of Eckberg to Sjostrom because it would have provided well-known chemical substances that could be used as the "Br" identified in the figures of Sjostrom.

594. Eckberg describes a similar location as Sjostrom for adding halogens into the overall system, namely directly within the boiler. Sjostrom describes testing mercury removal from flue gas of coal-fired power plants involving sorbent injection, halogen addition, and a combination of the two.[988] Specifically, the annotated figure below shows that Sjostrom teaches adding halogens in at least three locations.[989]



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[988] EX1010 (Sjostrom) at 4.

[989] EX1010 (Sjostrom) at 4 (annotations in red).

Location 2 of Sjostrom teaches Br into the boiler,[990] the same location as in Eckberg.

595. A POSITA would have a reasonable expectation of success applying Eckberg's teachings regarding the specific type, concentration, and rate of addition of bromine-containing species to the overall system of Sjostrom to create an operational system, because in combining Sjostrom with Eckberg, no modifications would need to be made to the overall process equipment, operating conditions, or activated-carbon sorbent used in Sjostrom. Eckberg describes a nearly identical system operating at similar conditions. Indeed, both references teach mercury removal for the same types of coal, Powder River Basin (abbreviated PRB and also referred to as western subbituminous) and Texas Lignite.[991] Thus, a POSITA would have had a reasonable expectation of success in using the salt solutions of Eckberg in the system of Sjostrom.

596. A POSITA would have seen the overall process goals and schematics and would have understood that applying the specific teachings of Eckberg to implement the system of Sjostrom would have been readily achievable because of the overall similarities between the references. Both references apply halogen

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[990] EX1010 (Sjostrom) at 4 (annotations in red).

[991] EX1010 (Sjostrom) at 3-8; EX1011 (Eckberg) at 2, 6.

addition to coal-plants to remove mercury from flue gas.[992] Both references include similar surrounding equipment, such as boilers, air pre-heaters, and an ESP or other particulate matter control devices.[993]

597. Thus, applying implementation details from Eckberg into the teachings of Sjostrom would be a simple substitution of one known element (the "Br" in Sjostrom) for another known element (the $CaBr_2$ in Eckberg) to obtain predictable results of at least 70% mercury removal. Both references use known techniques (halogen/halide promotion) to improve known materials (activated carbon) in the same way. Both Sjostrom and Eckberg are in the same field of endeavor, as they were presented one right after the other at the 2005 EUEC. In combining Sjostrom with Eckberg, no modifications would need to be made to the overall process equipment, operating conditions, or activated carbon sorbent used in Sjostrom.

B. INDEPENDENT CLAIM 1

1. Claim 1: Preamble—"A method of separating mercury from a mercury-containing gas, the method comprising:"

598. The preamble is disclosed by Sjostrom. Sjostrom teaches separating mercury from a mercury-containing gas. The title of Sjostrom is "Full Scale

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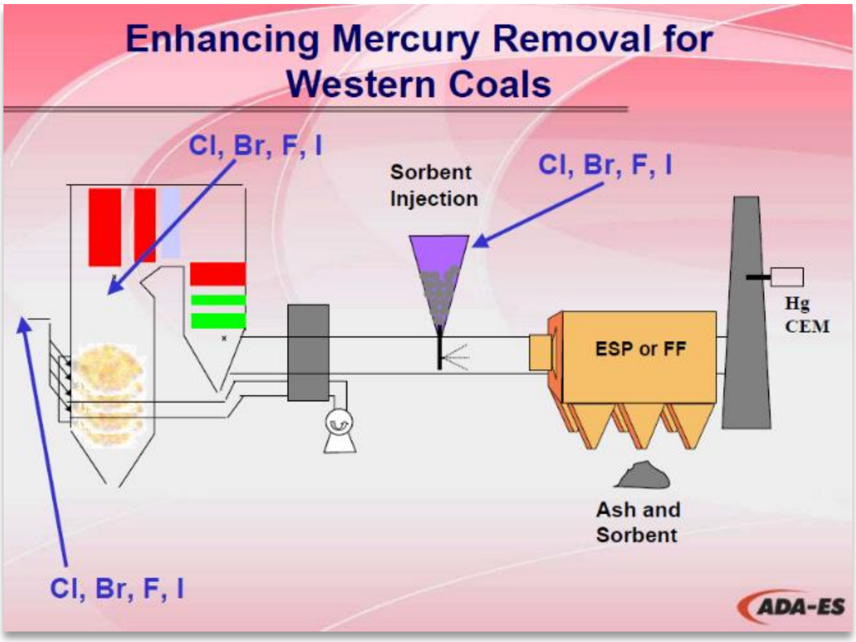
[992] EX1010 (Sjostrom) at 4; EX1011 (Eckberg) at 2, 9.

[993] EX1010 (Sjostrom) at 4; EX1011 (Eckberg) at 5.

Evaluations of <u>Mercury Control Technologies</u> with PRB Coals."[994] Specifically, Sjostrom described various mercury control tests conducted at several coal-fired power plants.[995] Sjostrom described testing mercury removal from flue gas of coal-fired power plants involving sorbent injection and halogen addition, as detailed below.[996]



Enhancing Mercury Removal for Western Coals

Sjostrom includes numerous charts detailing the "Hg Removal (%)" and "Hg Removal Efficiency (%)" achieved throughout the testing performed on coal flue

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[994] EX1010 (Sjostrom) at 1.

[995] EX1010 (Sjostrom) at 12, 18.

[996] EX1010 (Sjostrom) at 4.

gas in order to reduce mercury emissions.[997] This annotated figure in Sjostrom specifically shows that particulate matter, including the mercury-sorbent composition, would have been separated and removed from the flue gas by the ESP or FF, because a POSITA would have understood that it was well-known to use an ESP or FF to remove such solid materials.[998] The pile removed from the ESP or FF is labeled "Ash and Sorbent," which also contains mercury that was removed from the flue gas.

2. Claim 1: Element (1)(a)—"combusting coal in a combustion chamber, to provide the mercury-containing gas, wherein"

599. This limitation is disclosed by Sjostrom. This limitation is also obvious over Sjostrom in view of Eckberg. As discussed above, Sjostrom described various mercury control tests conducted at coal-fired power plants.[999] These plants combust coal in a coal-fired boiler (e.g., combustion chamber) as shown in the annotated figure below.[1000]

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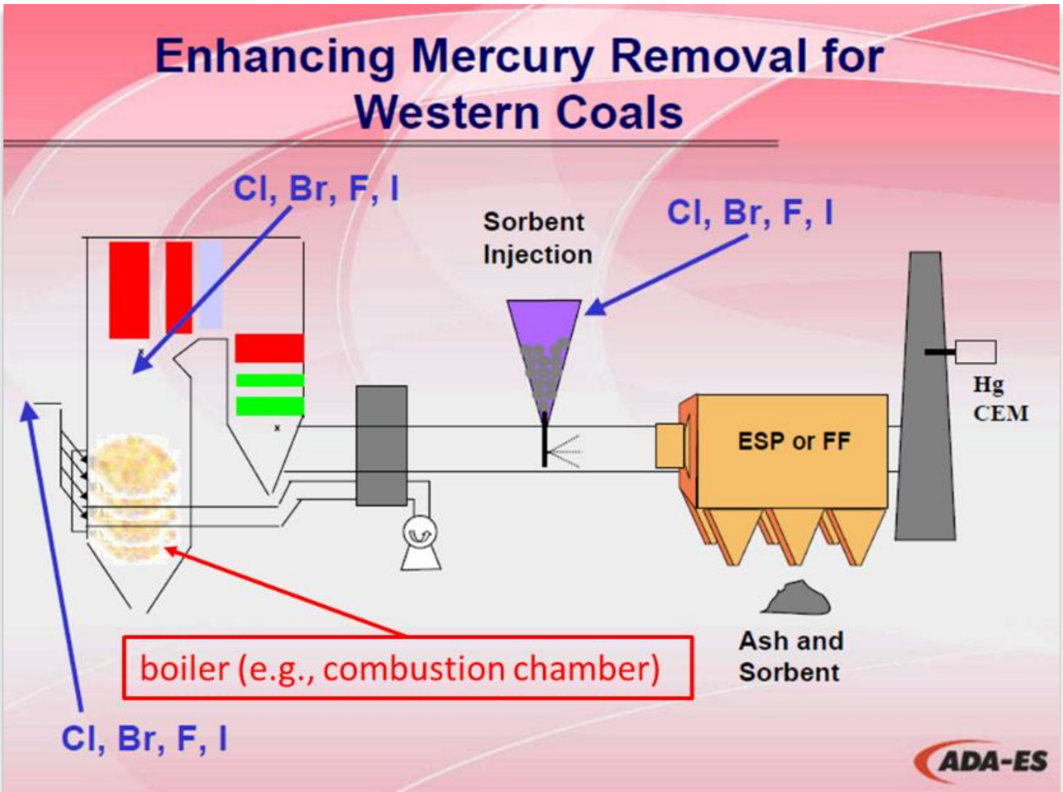
[997] EX1010 (Sjostrom) at 8, 15-17, 20, and 21.

[998] *See* Technology Background and State of the Art, § IX.B.5.a.

[999] EX1010 (Sjostrom) at 12, 18.

[1000] EX1010 (Sjostrom) at 4 (annotations in red).



Enhancing Mercury Removal for Western Coals

A POSITA would have understood that this unit was a boiler based on the image used to represent the unit in the drawing, which was a common and routine way to represent a coal-combustion chamber (boiler). Sjostrom explains that at the time of testing, two of the coal-fired power plants combusted PRB (Powder River Basin) coal having a mercury content of "0.04 – 0.1 ppm-dry."[1001] Relying only on existing equipment at these plants, Sjostrom shows that the outlet mercury content of the flue

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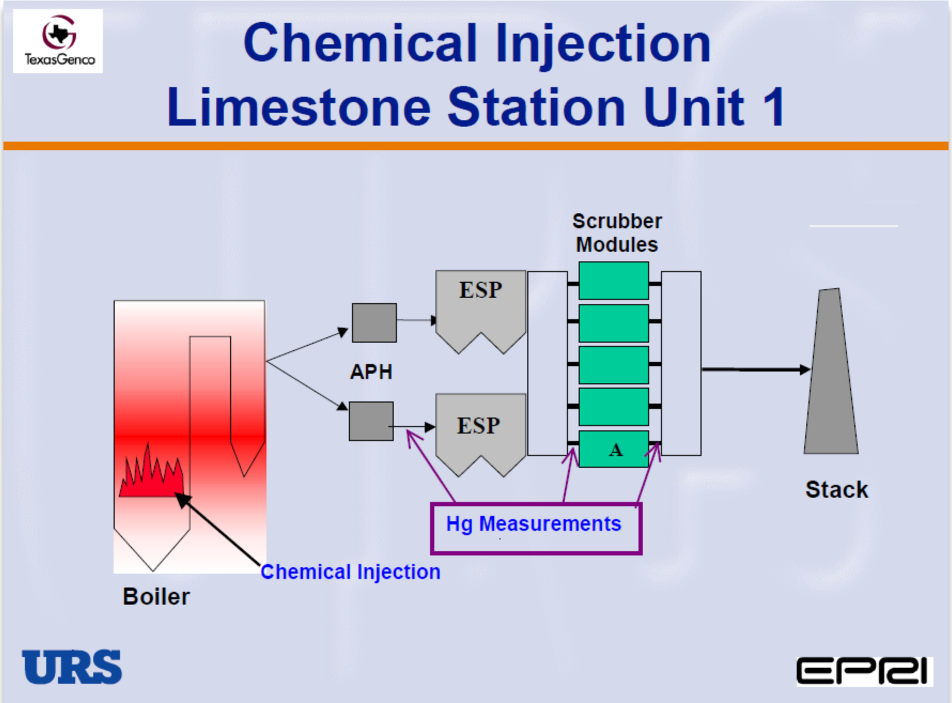
[1001] EX1010 (Sjostrom) at 12, 18.

gas was 11.2 μg/dncm.[1002] Thus, Sjostrom discloses combusting coal in a combustion chamber (e.g., boiler) to form a mercury containing flue gas stream.

600. This limitation is further obvious over Eckberg. As shown in the figure below, Eckberg explicitly describes combusting coal in a boiler.[1003]



Chemical Injection
Limestone Station Unit 1

The image in Eckberg identified as a "boiler" is substantially similar to the image found in Sjostrom. Thus, Sjostrom in view of Eckberg discloses combusting coal in a combustion chamber (e.g., boiler) to form a mercury containing flue gas stream.

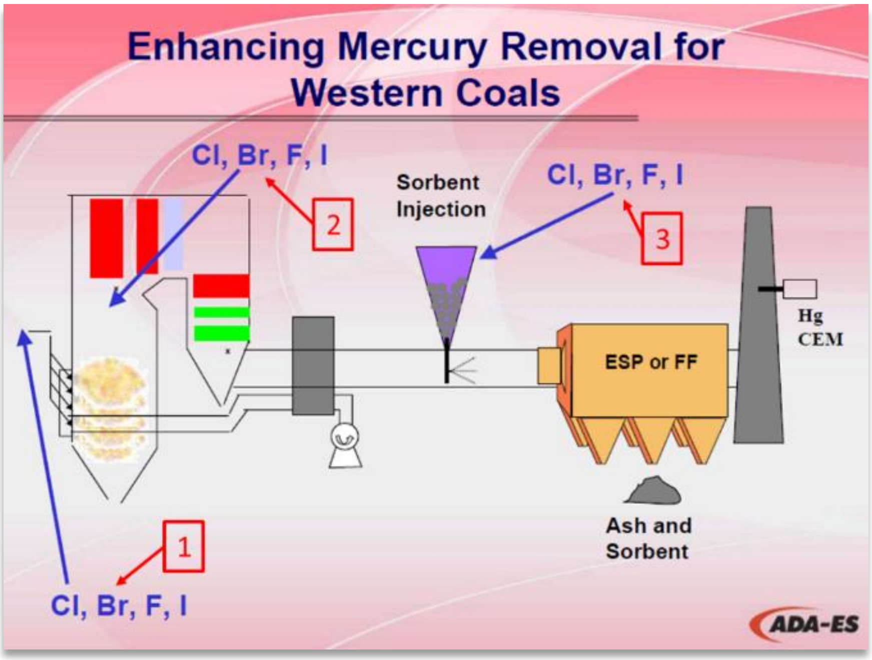
[1002] EX1010 (Sjostrom) at 3.

[1003] EX1011 (Eckberg) at 5.

3. Claim 1: Element (1)(b)—"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 coal upstream of the combustion chamber, or the combustion chamber comprises added Br_2, HBr, Br^-, or a combination thereof, or a combination thereof;"

601. This limitation is disclosed by Sjostrom. This limitation is also obvious over Sjostrom in view of Eckberg.

602. The annotated figure below shows that Sjostrom teaches injection of bromine in at least three locations throughout the coal-combustion process.[1004]



Enhancing Mercury Removal for Western Coals

[1004] EX1010 (Sjostrom) at 4 (annotations in red).

Location 1 of Sjostrom renders obvious injecting bromine upstream of the combustion chamber, such as by adding it to the coal entering the boiler.[1005] Though there are multiple places upstream of a boiler, it would have at least been obvious to add the halogens to the coal itself, because Sjostrom discloses not only the figure, but also mentions of "coal additives."[1006] Location 2 of Sjostrom discloses injecting bromine directly into the boiler.[1007] Location 3 of Sjostrom discloses adding bromine to the activated-carbon sorbent that is injected into the flue gas.[1008] At least Location 1 and Location 2 satisfy the claim limitation.

603. A POSITA would have found it obvious that the "Br" of Sjostrom would be a widely available bromine-containing material, such as an aqueous solution of a bromide salt, such as $CaBr_2$, for Location 1 and Location 2 (or HBr for Location 2). Further, Sjostrom teaches the addition of "KNX (Alstom Power)."[1009] KNX was a known aqueous solution of a bromide salt additive developed for enhanced mercury control. A POSITA would have found it obvious that an aqueous

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[1005] EX1010 (Sjostrom) at 4 (annotations in red).

[1006] EX1010 (Sjostrom) at 23, 25.

[1007] EX1010 (Sjostrom) at 4 (annotations in red).

[1008] EX1010 (Sjostrom) at 4 (annotations in red).

[1009] EX1010 (Sjostrom) at 23.

bromide salt solution, such as $CaBr_2$, would dissociate to form Br^- ions. As discussed above, Location 1 of Sjostrom renders obvious adding bromine-containing species upstream of the combustion chamber, such as by adding it to the coal entering the boiler.[1010] Thus, Sjostrom renders obvious wherein the coal comprises added Br_2, HBr, Br^-, or a combination thereof, added to the coal upstream of the combustion chamber.

604. As discussed above, Location 2 of Sjostrom teaches adding bromine-containing species into the combustion chamber.[1011] A POSITA would have understood the "Br" addition of Sjostrom would also have entered the mercury-containing flue gas. Specifically, a POSITA would have understood the "Br" added at either Location 1 before the combustion chamber or Location 2 within the combustion chamber would have resulted in "Br" entering the flue gas stream.

605. A POSITA would have understood that at combustion temperatures found within the boiler, at least a portion of the Br injected at either Location 1 or Location 2 would have vaporized and reacted to form HBr in the combustion chamber, leaving the boiler as HBr in the vapor phase. The boiling point of Br_2 is only 58.8ºC (it is a fuming liquid at room temperature), and the boiling point of

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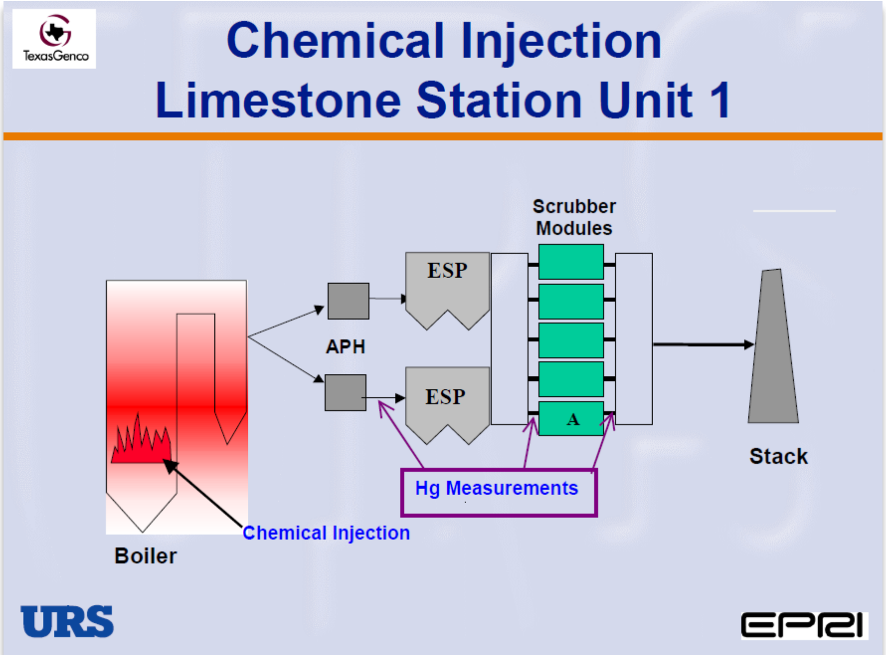
[1010] EX1010 (Sjostrom) at 4 (annotations in red).

[1011] EX1010 (Sjostrom) at 4 (annotations in red).

hydrogen bromide is -66.38ºC (i.e., it is a gas at room temperature).[1012] Thus, Sjostrom discloses wherein the mercury-containing gas comprises a halogen or halide promoter comprising HBr, or a combination thereof.[1013]

606. The identification of the specific bromine-containing ingredient is also obvious over Eckberg. As shown in the figure below, Eckberg teaches "chemical injection" to the boiler.[1014]



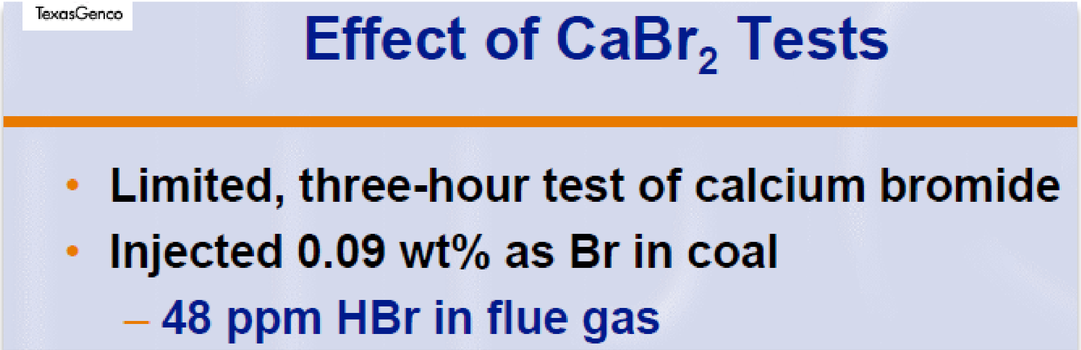
Chemical Injection
Limestone Station Unit 1

[1012] EX1036 (CRC Press: March 2005) at 4-53 and 4-65.

[1013] Named inventor of the Challenged Patent, Dr. Olson, acknowledged that this would result in in-flight promotion downstream of the furnace. EX1095 (Olson) at 231:3-9, 98:23-100:3.

[1014] EX1011 (Eckberg) at 5.

Specifically, Eckberg teaches injection of "$CaBr_2$ (52 wt%)" into the boiler.[1015] A POSITA would have understood that calcium bromide was an example of a "bromide compound." Eckberg confirms that when calcium bromide ($CaBr_2$) is combusted, the mercury-containing gas contains hydrogen bromide (HBr):[1016]



TexasGenco

Effect of $CaBr_2$ Tests

- **Limited, three-hour test of calcium bromide**
- **Injected 0.09 wt% as Br in coal**
  - **48 ppm HBr in flue gas**

607. As described above in the "Reasons to Combine" section, a POSITA would have been motivated, and expected a reasonable chance of success, to apply the teachings of Eckberg (e.g., the injection of $CaBr_2$) to the combustion chamber of Sjostrom. A POSITA would have been motivated to supplement the system of Sjostrom ("Br") with the teachings of Eckberg (aqueous solution of $CaBr_2$), at least because calcium bromide was a widely obtainable and relatively cheap form of bromine.

[1015] EX1011 (Eckberg) at 9.

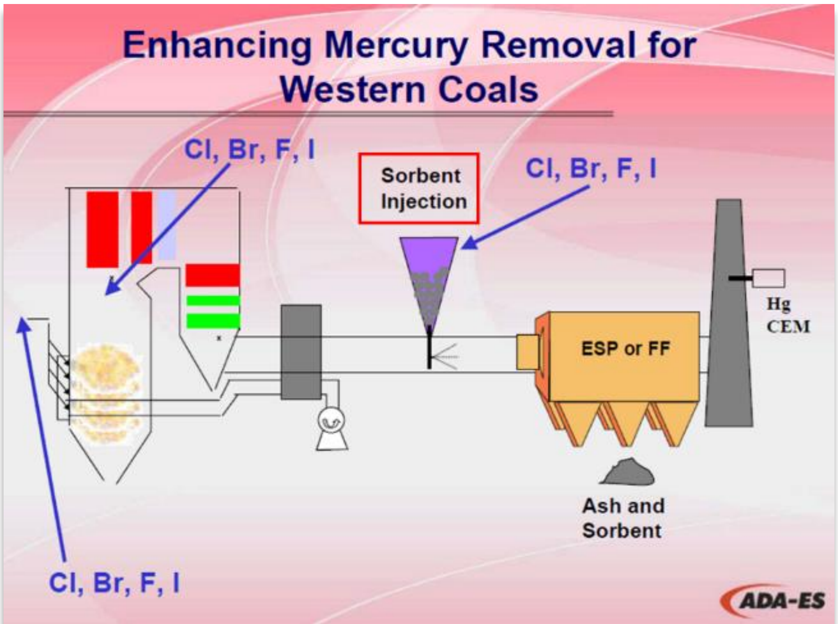
[1016] EX1011 (Eckberg) at 14.

4. <u>Claim 1: Element (1)(c)—"injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber; contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition;"</u>

608. This limitation is disclosed by Sjostrom.

a. Injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber

609. As shown in the annotated figure below, Sjostrom described certain tests involving sorbent injection downstream of the boiler.[1017]



Enhancing Mercury Removal for Western Coals

As shown in the above figure, the "Sorbent Injection" occurs downstream from a combustion chamber, and thus into the mercury-containing gas. Sjostrom refers to

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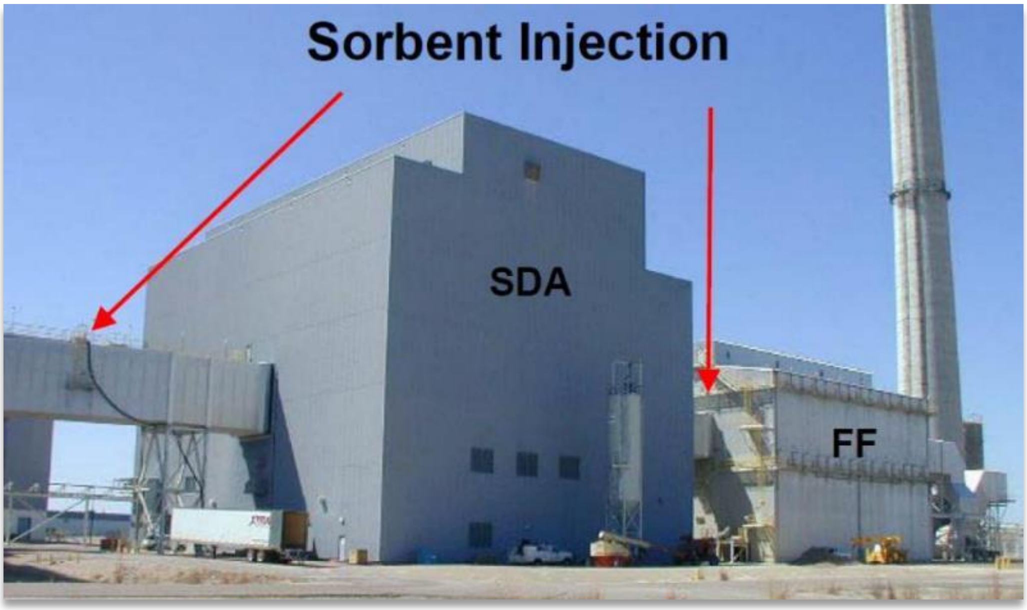
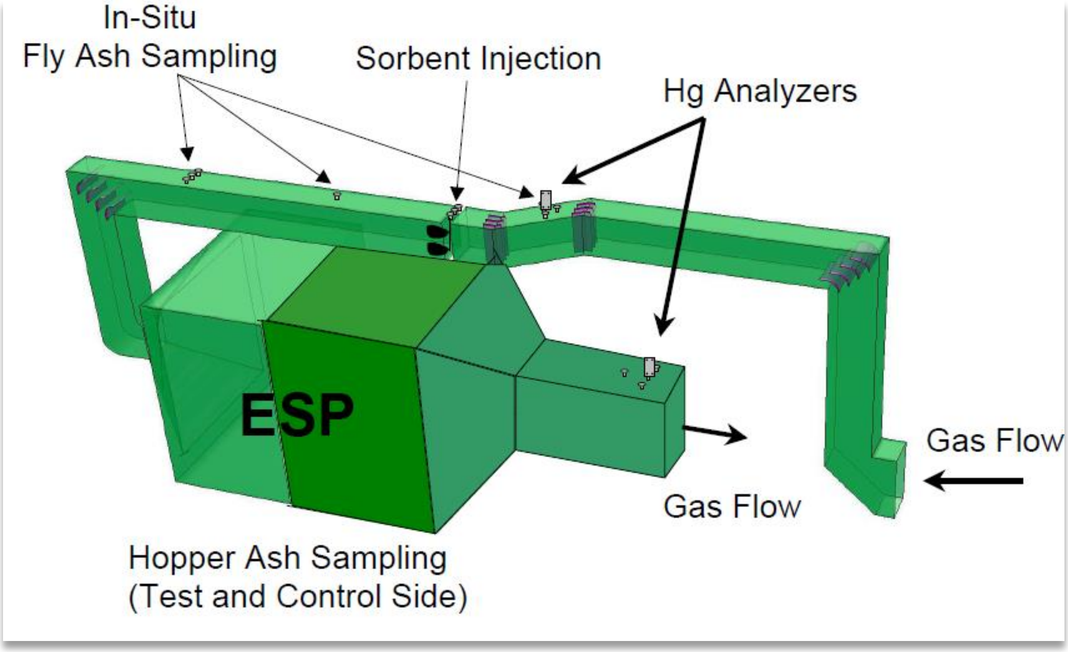
[1017] EX1010 (Sjostrom) at 4 (annotations in red).

"Sorbent Injection Rate."[1018] A photo of the sorbent injection is below (annotations in original):



EX1010, 13. A schematic of "sorbent injection" into mercury-containing gas ("gas flow") is also provided:

[1018] EX1010 (Sjostrom) at 32.



EX1010, 19. Specifically, Sjostrom described that the type of sorbent being injected into the mercury-containing flue gas is activated carbon ("activated carbon injection to improve mercury control"),[1019] which Sjostrom abbreviates as "ACI."[1020] The specific brand of ACI is "DARCO FGD."[1021] A POSITA would have understood that Norit DARCO FGD was a well-known type of activated carbon used for mercury capture.[1022]

[1019] EX1010 (Sjostrom) at 10.

[1020] EX1010 (Sjostrom) at 11.

[1021] EX1010 (Sjostrom) at 10, 11, 16.

[1022] Technology Background and State of the Art, §IX.G.2.

b. Contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition

610. The mercury in the flue gas is adsorbed, and thus contacted, with the sorbent to form a mercury/sorbent composition. A POSITA would have understood that Norit DARCO FGD and related materials were referred to as a "sorbent" by Sjostrom, specifically because they adsorbed (and thus contacted) materials in the gas phase. It was a well-known use of activated carbon for adsorbing and thus removing mercury from the flue-gas stream. Upon adsorption, the mercury and activated carbon in the flue gas would form a mercury/sorbent composition.[1023] Specifically, a POSITA would have understood that "sorbents" are used in a process called adsorption by which adsorbate (e.g., atoms, ions, or molecules) in a fluid (typically a gas) are bound to the surface of a sorbent, and thus by definition the sorbent is "contacting mercury in the mercury-containing gas" and forming a mercury-sorbent composition, as per Claim Element 1(c).

611. In addition, a person of skill in the art would have understood that the scope of a "mercury/sorbent composition" is broad enough to encompass a "mercury/sorbent/bromine" composition, because, for example, independent claim 25 of the '114 Patent recites a "mercury/sorbent composition" and its dependent

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[1023] Technology Background and State of the Art, §IX.C.3, §IX.G.2.

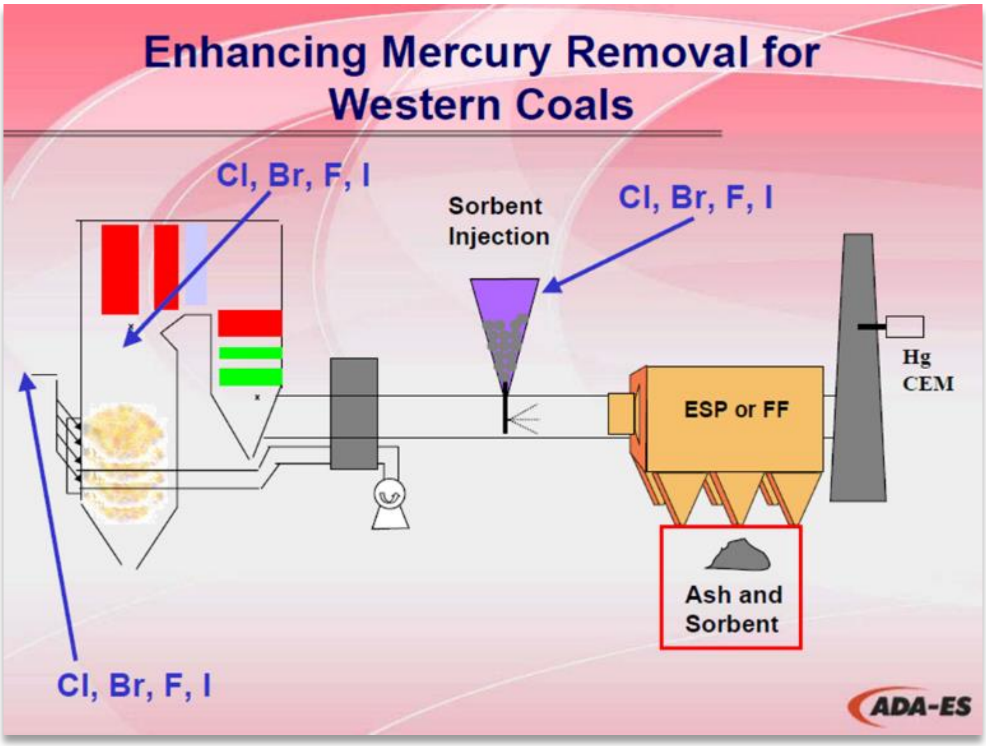
claim 30 recites that "the mercury/sorbent composition comprises the element bromine, the sorbent material, and mercury."[1024] Further, through enhanced reactivity between mercury and activated carbon because of the halogens (bromine), a POSITA would have known that the sorbent/halogen complex would have been referred to as a "promoted" sorbent.

5. **<u>Claim 1: Element (1)(d)—"separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas;"</u>**

612. This limitation is disclosed by Sjostrom. As shown in the annotated figure below, Sjostrom describes passing the flue gas through an electrostatic precipitator (ESP) or fabric filter (FF) after the bromine and sorbent injection.[1025]

[1024] EX1001 ('114 Patent) at Claims 25, 30.

[1025] EX1010 (Sjostrom) at 4 (annotations in red).



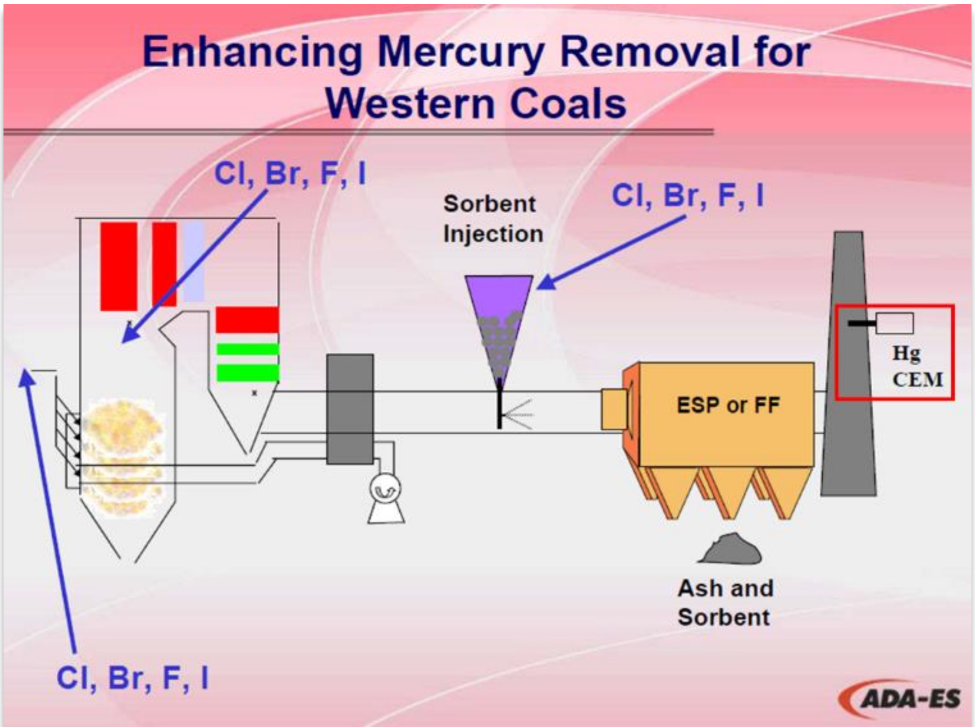
Enhancing Mercury Removal for Western Coals

This annotated figure in Sjostrom specifically shows that the mercury-sorbent composition would have been removed by the ESP or FF (pile of "Ash and Sorbent"). As described for Element 1(c), a POSITA would have known, or at least found it obvious, that the sorbent is a mercury/sorbent composition after it is introduced into the mercury-containing gas. Further, a POSITA would have understood that it was well-known that the ESP or FF would have removed solid material, including the mercury/sorbent composition.[1026] Thus, Sjostrom teaches "separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas."

[1026] *See* Technology Background and State of the Art, §IX.B.5.a.

6. Claim 1: Element (1)(e)—"monitoring the mercury content of the cleaned gas; and"

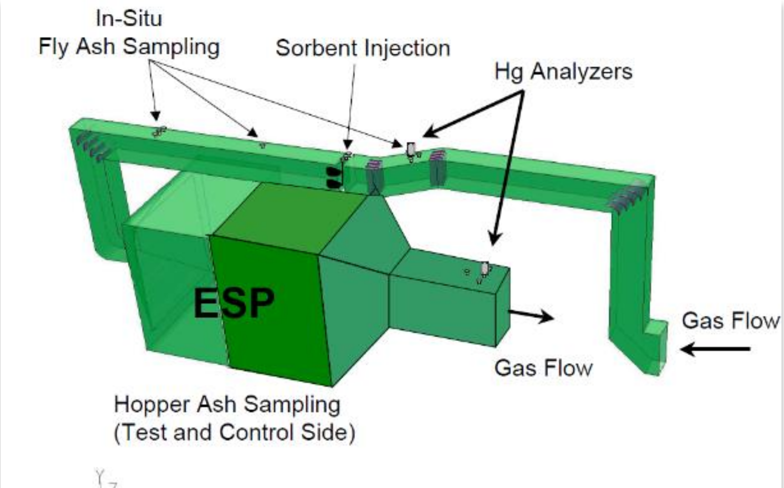
613. This limitation is disclosed by Sjostrom. As shown in the annotated figure below, Sjostrom describes passing the treated flue gas through a stack with an attached Hg CEM (which stands for Continuous Emissions Monitor) attached.[1027] As shown in the figure below, sorbent injection is applied, and then the "ash and sorbent" (i.e., including the mercury/sorbent composition) is removed in the electrostatic precipitator (ESP) or fabric filter (FF). At this point, the cleaned gas is measured downstream by the Hg CEM.



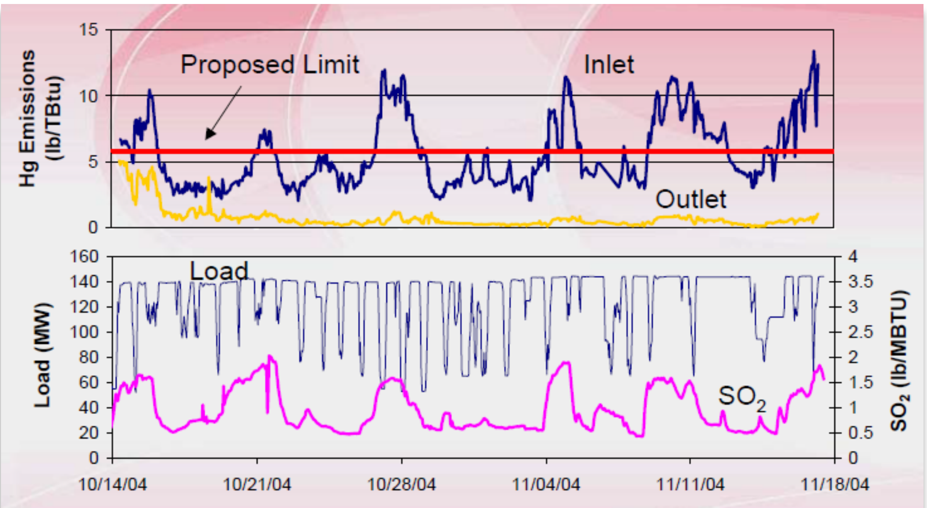
Enhancing Mercury Removal for Western Coals

[1027] EX1010 (Sjostrom) at 4 (annotations in red).

Further, Sjostrom discusses taking Hg measurements at both the inlet and outlet of the ESP as shown below.[1028]



Sjostrom includes the chart below showing the Hg emissions as measured at the inlet and outlet of the ESP.[1029]



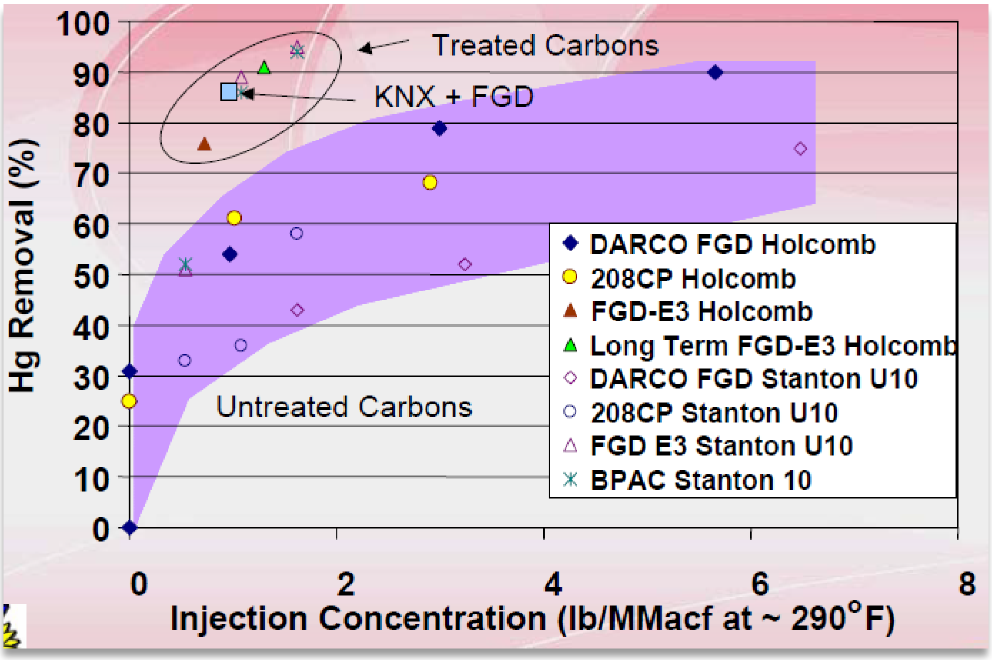
[1028] EX1010 (Sjostrom) at 19.

[1029] EX1010 (Sjostrom) at 22.

Thus, Sjostrom discloses monitoring the mercury content of the cleaned gas.

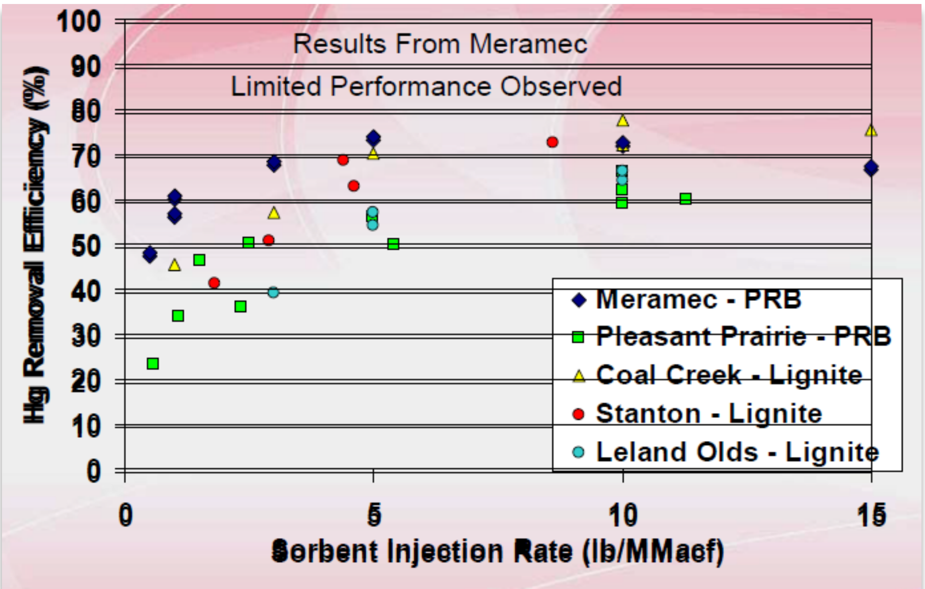
7. Element (1)(f)(1)—"controlling, in response to the monitored mercury content of the cleaned gas, an injection rate of injecting the sorbent into the mercury-containing gas, the sorbent composition, or a combination thereof,"

614. These limitations are disclosed by Sjostrom. Sjostrom includes numerous charts of measured mercury removals (100% – outlet mercury content) for various injection rates of activated-carbon sorbents. For example, the below chart shows the effects of activated carbon injection rates for testing using the system of Sjostrom.[1030]



[1030] EX1010 (Sjostrom) at 16.

Similarly, the below chart shows the effects of activated carbon injection rates for testing using the system of Sjostrom.[1031]



615. The fact that there is a graph that has datapoints for different sorbent injection rates (the independent variable) and associated Hg removal percentages (the dependent variable) means that a POSITA would have understood that there is a relationship between the Hg removal % and the sorbent injection rate. Given that, and a target Hg removal rate, a POSITA would have understood that the sorbent injection rate would be adjusted to result in a target removal %.

616. As discussed previously, a POSITA would have known that activated carbon was expensive, especially relative to costs of components such as "Br" in the

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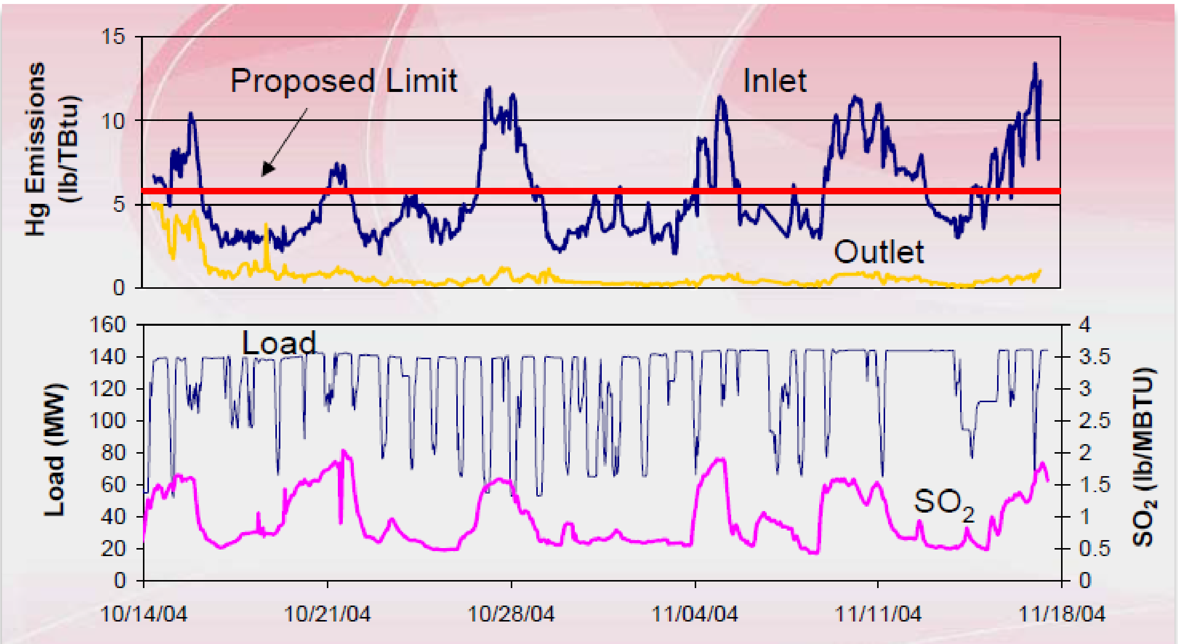
[1031] EX1010 (Sjostrom) at 20.

form of HBr or an aqueous bromide salt solution. A POSITA would have understood that injecting too much activated carbon would have increased the costs of the mercury removal process, and injecting too little activated carbon may lead to mercury emissions rising above actionable levels. A POSITA viewing the charts of Sjostrom showing mercury removal versus sorbent injection rate would have been motivated to use the charts to control the sorbent injection rate at a level that minimized costs while reaching mercury removal targets.

8. <u>Element (1)(f)(2)—"so that the mercury content of the cleaned gas is maintained at or below a desired level."</u>

617. The below figure from Sjostrom shows that the testing focused on a "Proposed Limit" (shown in the red line below)[1032]

[1032] EX1010 (Sjostrom) at 22.



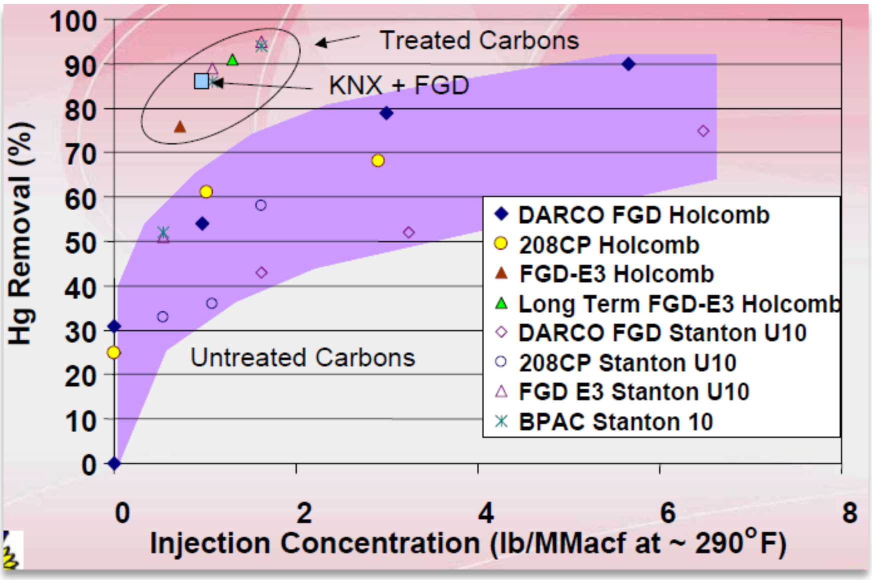
Thus, Sjostrom teaches maintaining the mercury content of the cleaned gas "at or below a desired level" (e.g., the 'Proposed Limit."). A POSITA would have been motivated to control the activated carbon injection rate to reach this desired level while minimizing the amount of activated carbon injected. Thus, Sjostrom discloses controlling the system so that the mercury content of the cleaned gas is maintained at or below a desired level.

C. CLAIMS DEPENDING FROM CLAIM 1

1. Claim 2: "The method of claim 1, comprising removing greater than 70 wt % of the mercury in the mercury-containing gas."

618. This limitation is disclosed by Sjostrom. Sjostrom includes numerous charts showing greater than 70% by weight removal of mercury from the flue gas. For example, the below chart shows the mercury removal from testing at a plant

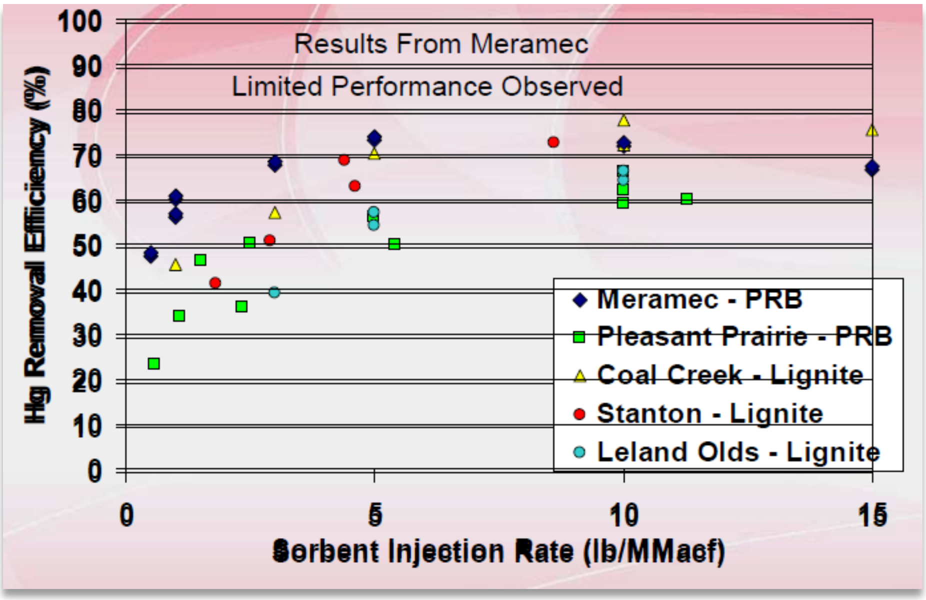
using the system of Sjostrom, achieving more than 90% Hg removal (using treated carbons) and almost 90% Hg removal (using KNX + FGD).[1033]



Similarly, the below chart shows the mercury removal from testing at plants using the system of Sjostrom.[1034]

[1033] EX1010 (Sjostrom) at 16.

[1034] EX1010 (Sjostrom) at 20.



As can be seen in the above graphs, Sjostrom achieved greater than 70 % mercury removal.

2. <u>Claim 3: "The method of claim 1, comprising removing greater than 70 wt % of the mercury in the mercury-containing gas on the sorbent."</u>

619. This limitation is obvious over Sjostrom. For example, as described for Claim 2 above, Sjostrom discloses removing more than 90% of the mercury from the mercury-containing gas. In the plant setup for which the halogens are added to the coal, the combustion chamber, or both, there is only dry emission-control equipment, such as the ESP or FF.[1035] Such plants with "solely" a dry emission control system, and without a scrubber, would be dependent on the activated carbon

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[1035] EX1010 (Sjostrom) at 4.

for mercury removal. The Hg removals on sorbents alone would meet or exceed the 70% removal threshold under the configurations disclosed by Sjostrom.

620. A person of ordinary skill in the art would have understood that such plants that burn lignite and subbituminous coal (as described in Sjostrom and Eckberg) typically have very low concentrations of inherent chlorine in their flue gas as well as very low LOI levels in their fly ash. Under such circumstances, Hg capture on inherent unburned carbon is minimal. Consequently, a person of ordinary skill in the art would have understood that adding bromine to the furnace of a plant firing high-volatility coals and with "solely" a dry emission control system, and without a scrubber, while injecting a sorbent ahead of the particle collection device, as Sjostrom teaches, ensures that virtually all the Hg captured in a particle collection device would be bound to the sorbent.

621. As described in the State of the Art,[1036] a person of skill in the art would have known that by 2004, the EPA had already put the industry on notice of upcoming laws and regulations requiring 70% mercury removal, such as the EPA's Clean Air Mercury Rule (CAMR). Notice of these regulations exerted a strong outside impetus on the industry to adjust processes to comply with the regulations' eventual implementation. Through routine process optimization and routine

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[1036] Technology Background and State of the Art, §IX.D – §IX.F.

experimentation, a person of ordinary skill in the art would have adjusted the bromine injection rate and/or activated carbon injection rate to meet and exceed (for purposes of safety margin) the EPA's proposed rules requiring a 70% removal of mercury.

3. Claim 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."

622. This limitation is obvious over Sjostrom in view of Eckberg. Claim 4 is merely an attempt to claim the optimum or workable range for a process of combining a particular conventional halogen (bromine) being used in a conventional way (halogens are inherent to coal, and both oxidize mercury and promote activated carbon) with a conventional sorbent (activated carbon). Nothing about the particular range of 1 g to about 30 g of the halide promoter per 100 g of the sorbent would lead to an unexpected result from what was already known to one of skill in the art.

623. As described in the State of the Art,[1037] it was known that the saturation limit of activated carbon for bromine (i.e., how much bromine the activated carbon can actually adsorb at equilibrium), was up to 31 to 38 grams per 100 grams of activated carbon. Given the residence times in flue gas, and other inefficiencies, a

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[1037] *See* Technology Background and State of the Art, § IX.C.3.

person of ordinary skill in the art would have understood that the actual bromine loaded onto activated carbon would have been less than the saturation limit.

624. A person of ordinary skill in the art would have recognized that there would be sufficient bromine in the flue gas, according to Sjostrom's processes, to provide a ratio of between 1 g to 30 g of bromine per 100 g of activated carbon. For example, Sjostrom teaches mercury-removal results similar to Eckberg, using an injection rate of 1 lb/MMacf activated carbon (FGD) at 290 °F in connection with an unspecified quantity of KNX (bromine).[1038] Eckberg discloses a bromine concentration in the flue gas for a nearly identical system was 48 ppm or 50 ppm that results in "81% overall removal" of mercury.[1039] A person of ordinary skill in the art would have been motivated to take advantage of the saturation limits of activated carbon, and seek to load the activated carbon with up to nearly its saturation limit, because it was known in the art that halides "improve[d] Hg capture both by conversion of the Hg^0 to the more easily removed Hg^{2+} forms and by enhancing the reactivity of Hg^0 with activated carbons."[1040]

[1038] EX1010 (Sjostrom) at 16.

[1039] EX1011 (Eckberg) at 9, 14.

[1040] EX1062 (Crocker) at 2-3.

625. Through routine process optimization and routine experimentation, a person of ordinary skill in the art would have adjusted the bromine injection rate and/or activated carbon injection rate to achieve halide promoter on the activated-carbon sorbent from about 1 g to about 30 g.[1041]

4. Claim 5: "The method of claim 1, wherein the combustion chamber comprises the halogen or halide promoter."

626. This limitation is obvious over Sjostrom and Eckberg. As discussed above for Claim Element 1(b), Sjostrom in view of Eckberg discloses wherein the combustion chamber comprises added halogen or halide promoter (such as HBr). A POSITA would have understood that HBr was a known halogen or halide promoter.[1042]

5. Claim 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."

627. This limitation is rendered obvious by Sjostrom and Eckberg. This limitation is the same as one of the elements found in Claim Element 1(b). As discussed above for Claim Element 1(b), Sjostrom and Eckberg render obvious wherein the coal comprises added Br_2, HBr, Br^-, or a combination thereof, added to

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[1041] Patent Owner's expert agrees that such a ratio would necessarily be produced at bromine plants employing bromine additives and activated carbon. EX1092 (O'Keefe Report) at 153.

[1042] Technology Background and State of the Art, §IX.C.3, § IX.G.2.

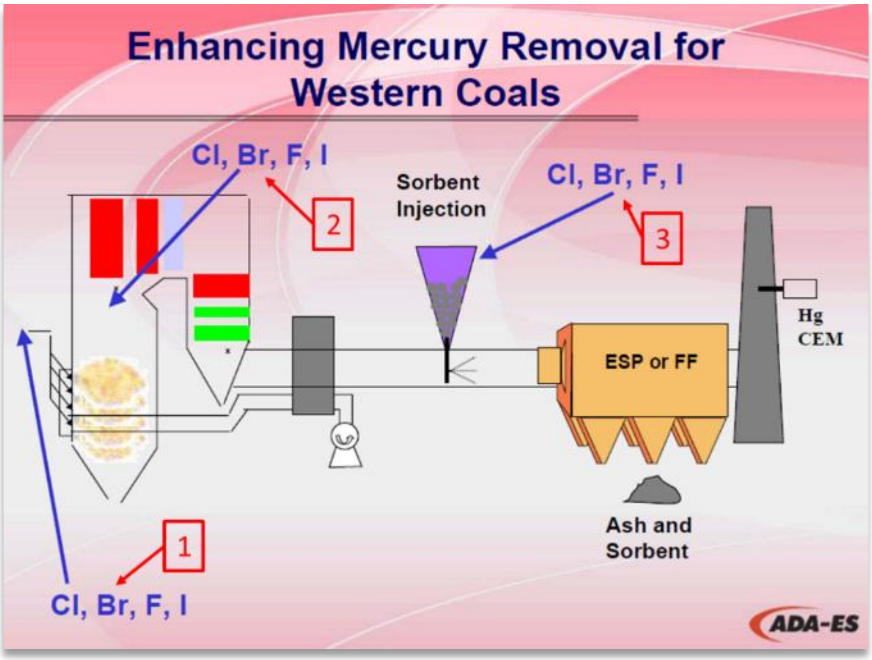
the coal upstream of the combustion chamber. Eckberg discloses aqueous calcium bromide to the coal, which dissociates in water to form bromide ions (Br-).

6. Claim 7: "The method of claim 1, wherein the promoter is contacted with the sorbent in vapor form, gaseous form, liquid form, or in an organic solvent."

628. This limitation is obvious over Sjostrom in view of Eckberg for the reasons stated above for Element 1(b). Sjostrom described testing mercury removal from flue gas of coal-fired power plants involving sorbent injection, halogen injection, and both sorbent and halogen injection.[1043] Specifically, the annotated figure below and accompanying text shows that Sjostrom teaches injection of bromine in at least three locations throughout the coal-combustion process.[1044]

[1043] EX1010 (Sjostrom) at 4.

[1044] EX1010 (Sjostrom) at 4 (annotations in red).



629. Location 1 of Sjostrom renders obvious injecting bromine upstream of the combustion chamber, such as by adding it to the coal entering the boiler.[1045] Though there are multiple places upstream of a boiler, it would have at least been obvious to add the halogens to the coal itself, because Sjostrom discloses not only the figure, but also mentions "coal additives."[1046] Location 2 of Sjostrom discloses injecting bromine into the boiler.[1047] A POSITA would have found it obvious that the "Br" of Sjostrom would be a widely available bromine-containing material, such as HBr or an aqueous solution of a bromide salt, such as $CaBr_2$, for Location 1 and

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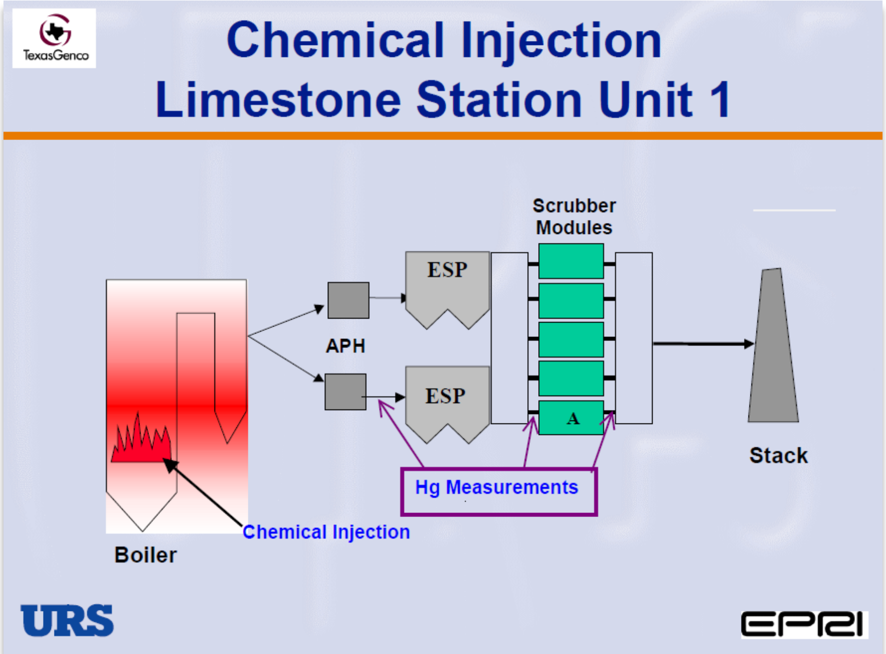
[1045] EX1010 (Sjostrom) at 4 (annotations in red).

[1046] EX1010 (Sjostrom) at 23, 25.

[1047] EX1010 (Sjostrom) at 4 (annotations in red).

Location 2. Further, Sjostrom teaches the addition of "KNX (Alstom Power)."[1048] KNX was a known aqueous solution of a bromide salt additive developed for enhanced mercury control.

630. As shown in the figure below, Eckberg teaches "chemical injection" to the boiler.[1049]



Chemical Injection
Limestone Station Unit 1

[1048] EX1010 (Sjostrom) at 23.

[1049] EX1011 (Eckberg) at 5.

Specifically, Eckberg teaches injection of "$CaBr_2$ (52 wt%)" into the boiler.[1050] Further, Eckberg explains that the $CaBr_2$ salt is injected at a "Liquid Salt Feed Rate (gpm)."[1051]

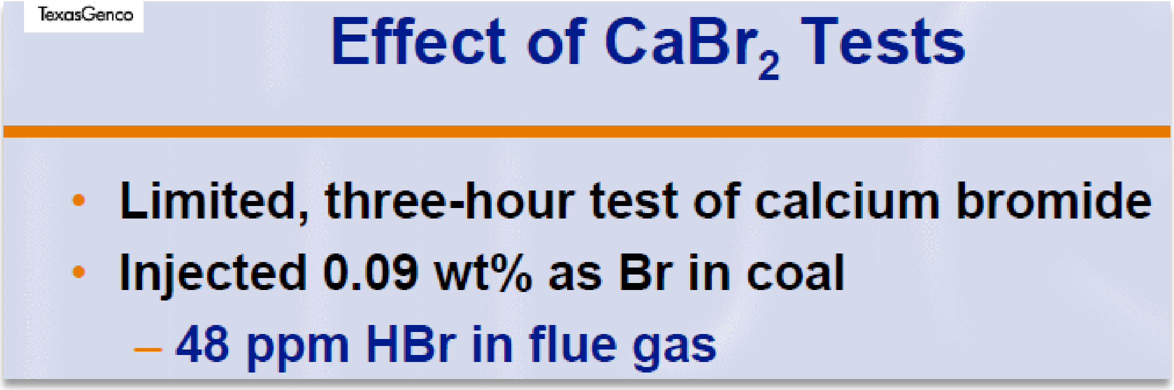
631. A POSITA would have known that the Br injected in Sjostrom would have been in the form of an aqueous solution containing a bromide salt, which is in liquid form as taught by Eckberg. A POSITA would have understood that at combustion temperatures found within the boiler, at least a portion of the aqueous calcium bromide injected at either Location 1 or Location 2 would have vaporized and reacted in the combustion chamber, leaving the boiler as HBr in the vapor phase.[1052] Eckberg confirms that when calcium bromide ($CaBr_2$) is combusted, the mercury-containing gas contains hydrogen bromide (HBr):[1053]

[1050] EX1011 (Eckberg) at 9.

[1051] EX1011 (Eckberg) at 9.

[1052] Patent Owner's expert agrees. EX1092 (O'Keefe Report) at 154.

[1053] EX1011 (Eckberg) at 14.



TexasGenco

Effect of $CaBr_2$ Tests

- Limited, three-hour test of calcium bromide
- Injected 0.09 wt% as Br in coal
  - 48 ppm HBr in flue gas

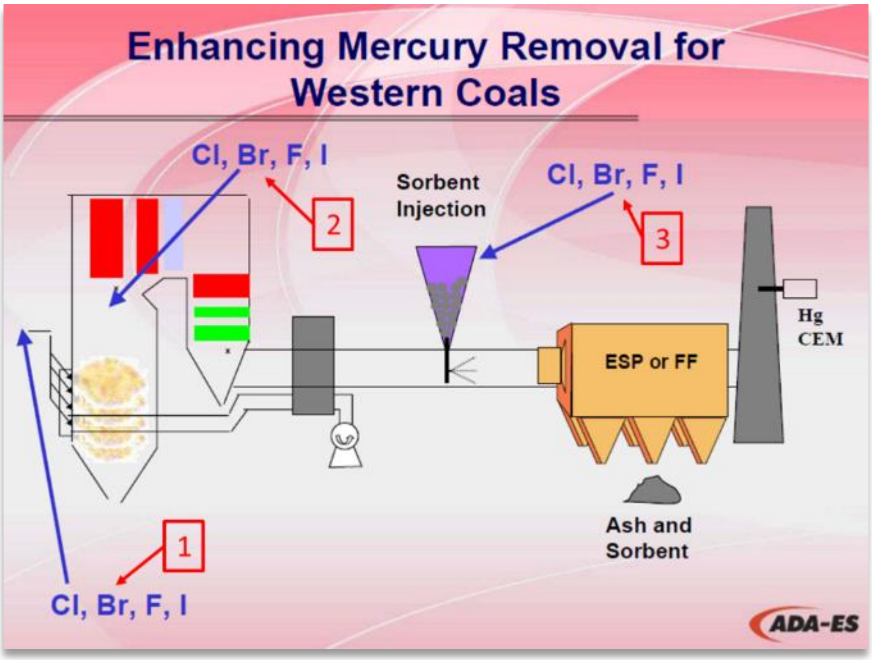
Once the HBr reaches the sorbent injection location, it makes contact with the injected sorbent in gaseous form.

7. <u>Claim 8: "The method of claim 1, further comprising injecting a secondary material into the mercury-containing gas downstream of the combustion chamber."</u>

632. This limitation is disclosed by Sjostrom. Sjostrom described testing mercury removal from flue gas of coal-fired power plants involving sorbent injection, halogen injection, and both sorbent and halogen injection.[1054] Specifically, the annotated figure below shows that Sjostrom teaches injection of bromine in at least three locations throughout the coal-combustion process.[1055]

[1054] EX1010 (Sjostrom) at 4.

[1055] EX1010 (Sjostrom) at 4 (annotations in red).



Enhancing Mercury Removal for Western Coals

Location 3 of Sjostrom teaches adding bromine or other halogens to the activated-carbon sorbent that is injected into the flue gas.[1056] The bromine (or other halogens) added at Location 3 is a secondary material that is injected into the mercury-containing flue gas. As confirmation of my analysis, Claim 9 of the ’114 Patent, which depends from this claim, requires “wherein the secondary material comprises a halogen, a compound derived from a halogen, a hydrohalide, a compound comprising a Group V or Group VI element and a molecular halogen, or a combination thereof.” Thus, the claimed “secondary material” found in this claim includes other halogens, such as Cl and I, which Sjostrom teaches may be injected at Location 3.

[1056] EX1010 (Sjostrom) at 4 (annotations in red).

633. This limitation is also obvious over Sjostrom in view of Eckberg. For example, Eckberg provides additional details regarding the specific chemical compound and concentration to use as the injected "Cl" or "Br" secondary material. Specifically, Eckberg teaches injection of "$CaCl_2$ (25 wt%)" and "$CaBr_2$ (52 wt%)."[1057] A POSITA would have been motivated to apply the teachings of Eckberg regarding chlorine injection to the system of Sjostrom, for the same reasons described in the "Reasons to Combine" section, regarding applying Eckberg's teachings regarding bromine composition injection. It would have been obvious to add the $CaBr_2$ or $CaCl_2$ of Eckberg, also at Location 3 of Sjostrom.

8. Claim 9: "The method of claim 8, wherein the secondary material comprises a halogen, a compound derived from a halogen, a hydrohalide, a compound comprising a Group V or Group VI element and a molecular halogen, or a combination thereof."

634. This limitation is disclosed by Sjostrom. As described for Claim 8, Sjostrom discloses injecting a secondary material into the mercury-containing gas downstream of the combustion chamber because it teaches that Cl or I may be injected at Location 3 of the system of Sjostrom.

[1057] EX1011 (Eckberg) at 9.

9. Claim 12: "The method of claim 1, wherein the activated carbon comprises powdered activated carbon, granular activated carbon, or a combination thereof."

635. This limitation is disclosed by Sjostrom. Sjostrom repeatedly discusses the use of activated carbon.[1058] Further, Sjostrom includes test results of "Untreated PAC Injection into ESP" for "PRB and Lignite Coals."[1059] A POSITA would have known that PAC stood for "powdered activated carbon." Sjostrom also discusses testing done with the injection of "DARCO FGD" sorbent.[1060] A POSITA would have known that DARCO FGD was a well-known type of powdered activated-carbon sorbent.[1061] Articles dating back to at least 1998 confirm that the chemical composition of "Norit Darco FGD" does not have halogens.[1062]

10. Claim 13: "The method of claim 1, wherein the sorbent material injected into the mercury-containing gas is substantially free of halogen and halide promotion."

636. This limitation is disclosed by Sjostrom. As described for Claim Element 1(c), Sjostrom discloses injecting sorbent into the mercury-containing gas.

[1058] EX1010 (Sjostrom) at 10, 20, 34.

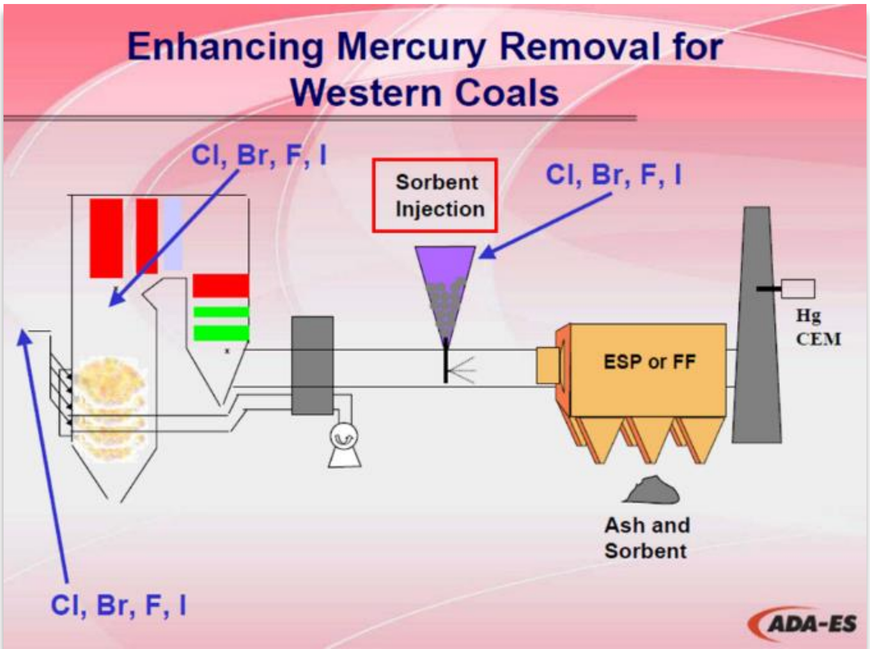
[1059] EX1010 (Sjostrom) at 20.

[1060] EX1010 (Sjostrom) at 15, 16,

[1061] Technology Background and State of the Art, §IX.C.3, § IX.G.2.

[1062] EX1048 (Carey) at 1169 (Table 1, discussing chemical analysis of Norit FGD).

As shown in the annotated figure below, Sjostrom described certain tests involving activated-carbon "sorbent injection" downstream of the boiler into the mercury-containing gas, at any of 3 locations.[1063]

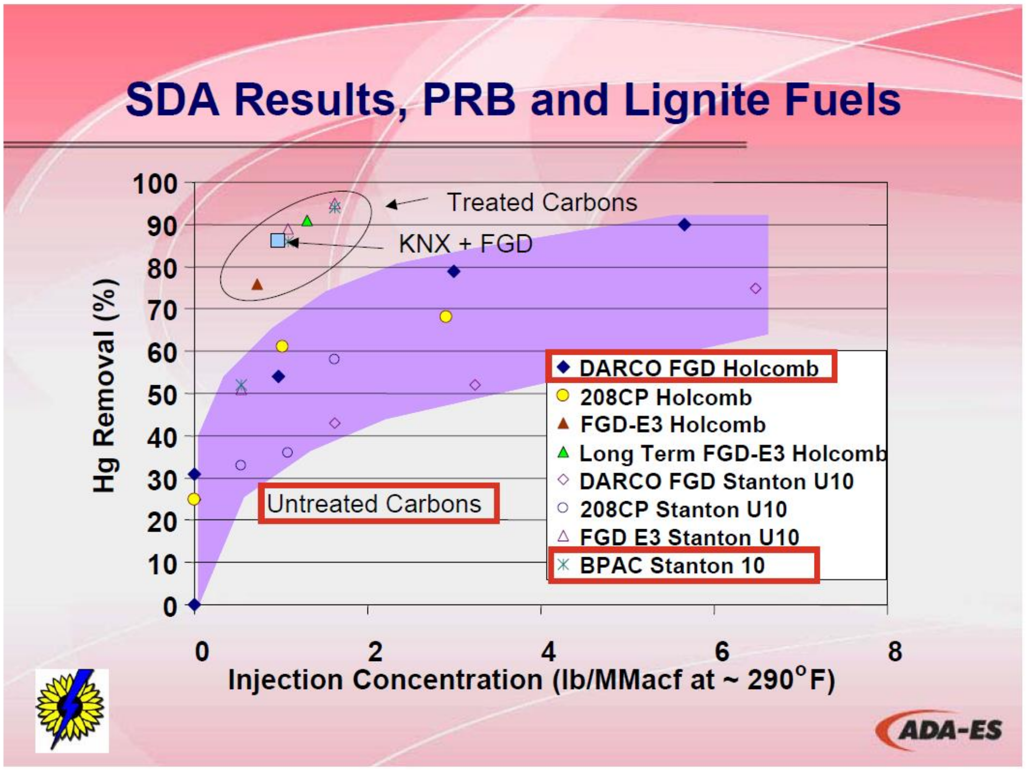


Enhancing Mercury Removal for Western Coals

Among the sorbent injected was "Untreated Carbons."[1064]

[1063] EX1010 (Sjostrom) at 4 (annotations in red).

[1064] EX1010 (Sjostrom) at 16 (annotations in red).



SDA Results, PRB and Lignite Fuels

A POSITA would have understood that "untreated carbons" are not pre-halogenated, and are substantially free or halogen or halide promotion. In addition, Sjostrom discloses testing conducted with "Darco FGD" (untreated PAC), which obtained over 70% mercury removal. A POSITA would have recognized that the Norit Darco FGD is substantially free of halogen and halide promotion.[1065] Articles dating back to at least 1998 confirm that the chemical composition of "Norit Darco FGD" does not have halogens.[1066] The untreated activated carbon (e.g., the Darco in solid blue

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[1065] Technology Background and State of the Art, §IX.C.3, §IX.G.2.

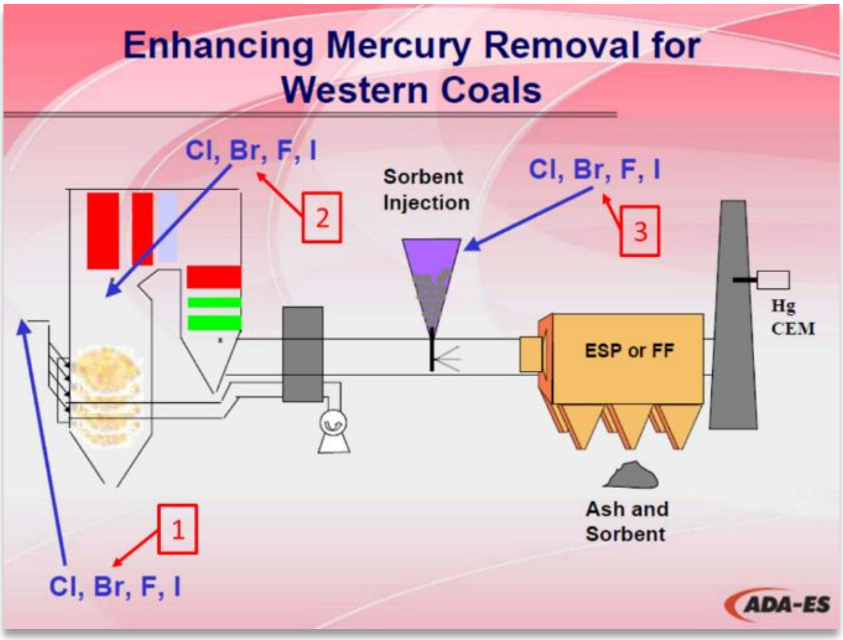
[1066] EX1048 (Carey) at 1169 (Table 1, discussing chemical analysis of Norit FGD).

diamonds) obtained more than 70% mercury removal. When adding KNX (an aqueous solution of bromide salt) (i.e., at Locations 1 or 2) to the Darco FGD, the mercury removal results are even higher, nearly 90% (as shown in the label "KNX + FGD"). Thus, it would have been at least obvious to try the untreated PAC (Darco FGD), as it would have been cheaper than the pre-brominated PAC (BPAC, shown in the asterisks). It was known that BPAC was a more expensive raw material, as compared to untreated PAC.

11. Claim 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."

637. This limitation is disclosed by Sjostrom. At Location 3, Sjostrom teaches contacting a base sorbent with another halogen prior to injection into the mercury-containing flue gas.[1067]

[1067] EX1010 (Sjostrom) at 4 (annotations in red).

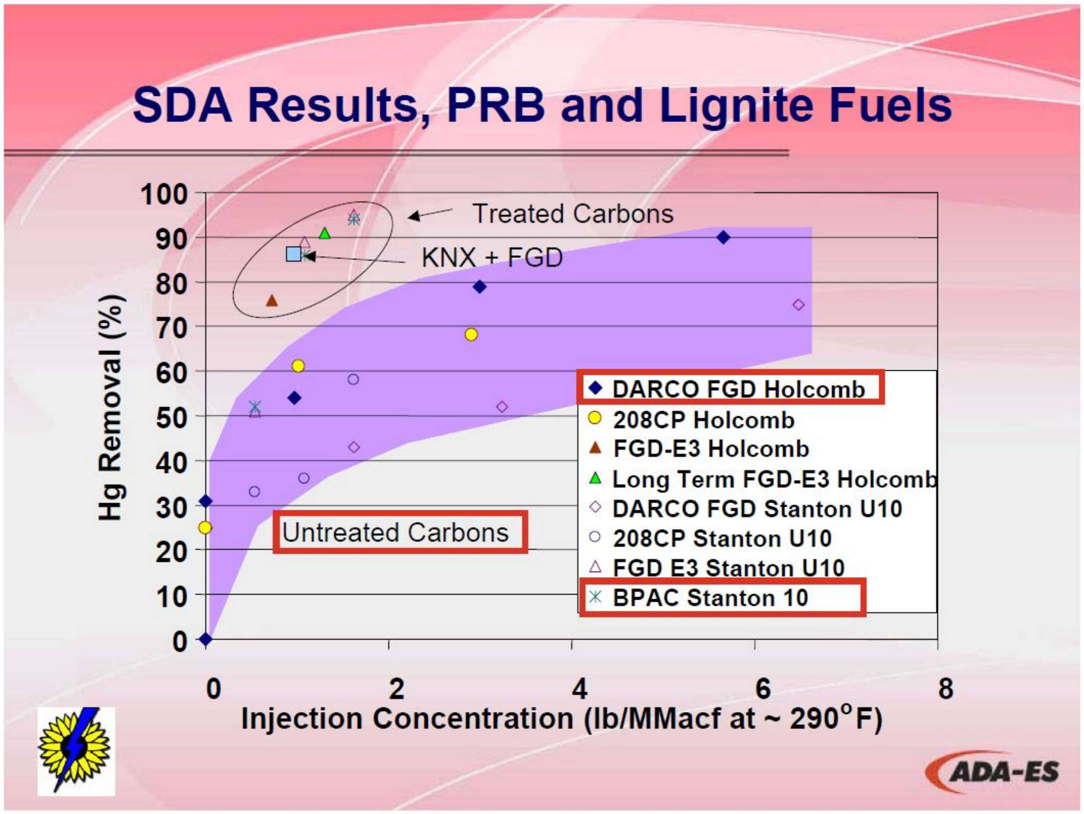


Enhancing Mercury Removal for Western Coals

Sjostrom also teaches pre-brominating (or pre-chlorinating) the activated carbon at Injection Point 3 (such as "BPAC," which stands for brominated-PAC).[1068] One of the tests in Sjostrom used "BPAC" at the Stanton unit. [1069]

[1068] EX1010 (Sjostrom) at 4 (annotations in red).

[1069] EX1010 (Sjostrom) at 16 (identifying "BPAC Stanton 10" in the legend).



SDA Results, PRB and Lignite Fuels

638. A POSITA would have been motivated to try such a configuration—adding bromine at Location 1 or 2, and also adding bromine to the sorbent before injecting at Location 3—particularly for coals with higher native mercury content (or lower native halogen content and/or lower unburned carbon in fly ash) in order to further reduce total mercury emissions. In situations where additional mercury capture was required, a POSITA would have been motivated to inject, or at least try injecting, "Br" at Location 1 or 2 while also adding a treated activated-carbon sorbent to the flue gas downstream of the boiler (e.g., at Location 3). A POSITA would have known that this approach would have increased overall mercury capture, albeit at an increased cost compared to using untreated activated carbon (plain Darco

FGD). A POSITA would have known that the sorbent and halogen would have made contact with one another and formed at least a quantity of promoted sorbent upon contact. A POSITA would also have known that halogens "promote" activated-carbon sorbents because they improve mercury removal by increasing the ability of the activated carbon to bind with the mercury.[1070]

12. Claim 15: "The method of claim 1, wherein the combustion chamber comprises a boiler."

639. This limitation is disclosed by Sjostrom. As discussed for Claim Element 1(a), Sjostrom discloses combusting coal in a combustion chamber (e.g., boiler) to form a mercury containing flue gas stream. This limitation is further rendered obvious by Eckberg, which expressly references a boiler. Indeed, the title of Eckberg is "Mercury Control Evaluation of Halogen Injection into a Texas Lignite-Fired Boiler."

13. Claim 16: "The method of claim 1, wherein the mercury-containing gas is a flue gas."

640. This limitation is disclosed by Sjostrom. Sjostrom discloses testing performed on the treatment of mercury-containing gas from a coal-fired power plant. A POSITA would have known that the mercury-containing exhaust gas from coal-

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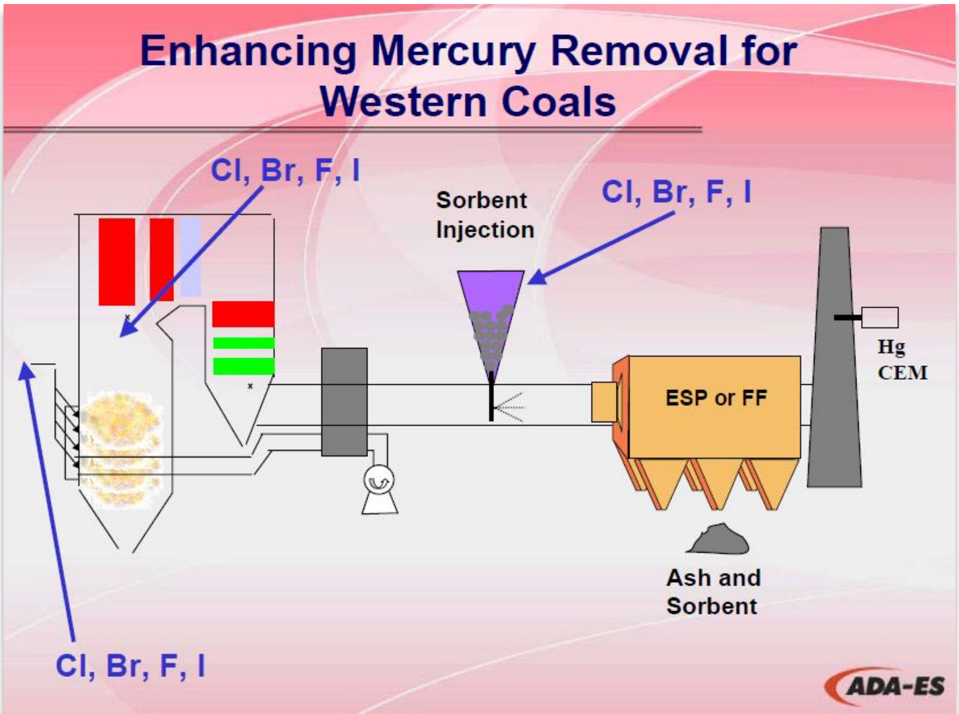
[1070] Technology Background and State of the Art, §IX.C.3, § IX.G.2.

fired power plants was commonly referred to as "flue gas." For example, Sjostrom discloses testing on coal-fired power plants according to the following schematic.[1071]



Enhancing Mercury Removal for Western Coals

Cl, Br, F, I

Sorbent Injection

Cl, Br, F, I

Hg CEM

ESP or FF

Ash and Sorbent

Cl, Br, F, I

ADA-ES

Further, Sjostrom expressly includes discussion of sampling and injection of "Flue Gas Flow."[1072] The discussion of "Flue Gas Flow" further supports that the mercury-containing gas is indeed a flue gas.

[1071] EX1010 (Sjostrom) at 4.

[1072] EX1010 (Sjostrom) at 19.

14. Claim 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."

641. This limitation would have been obvious in light of Sjostrom. Sjostrom discloses an "ESP or FF" to remove the sorbent from the mercury-containing gas.[1073]

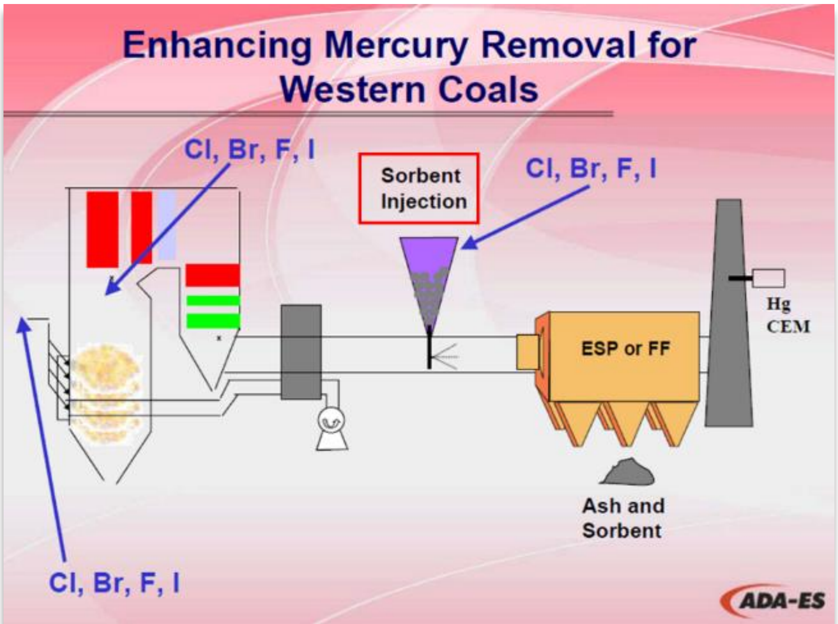
642. As I discuss in the Technology Background and State of the Art,[1074] it was known that electrostatic precipitators could be placed in one of two primary configurations: hot-side ESP and cold-side ESP. A cold-side ESP is located downstream from the air-preheater, and the hot-side ESP is located upstream of the air-preheater. With this finite number of solutions, it would have been obvious to at least try a hot-side ESP when implementing the halogenation and sorbent injection of Sjostrom. In a hot-side ESP, the sorbent would be injected upstream of the ESP, i.e., so that it can be removed. Because the hot-side ESP is located upstream of the air preheater, then any activated-carbon sorbent injected upstream of the ESP would have also been injected upstream of the air preheater.

[1073] EX1010 (Sjostrom) at 4 (annotations in red).

[1074] Technology Background and State of the Art, § IX.B.5.a.

15. Claim 18: "The method of claim 1, wherein the injection of the sorbent material into the mercury-containing gas occurs upstream of a particulate separator or a scrubber."

643. This limitation is disclosed by Sjostrom. As shown in the annotated figure below, Sjostrom described certain tests involving sorbent injection downstream of the boiler.[1075]



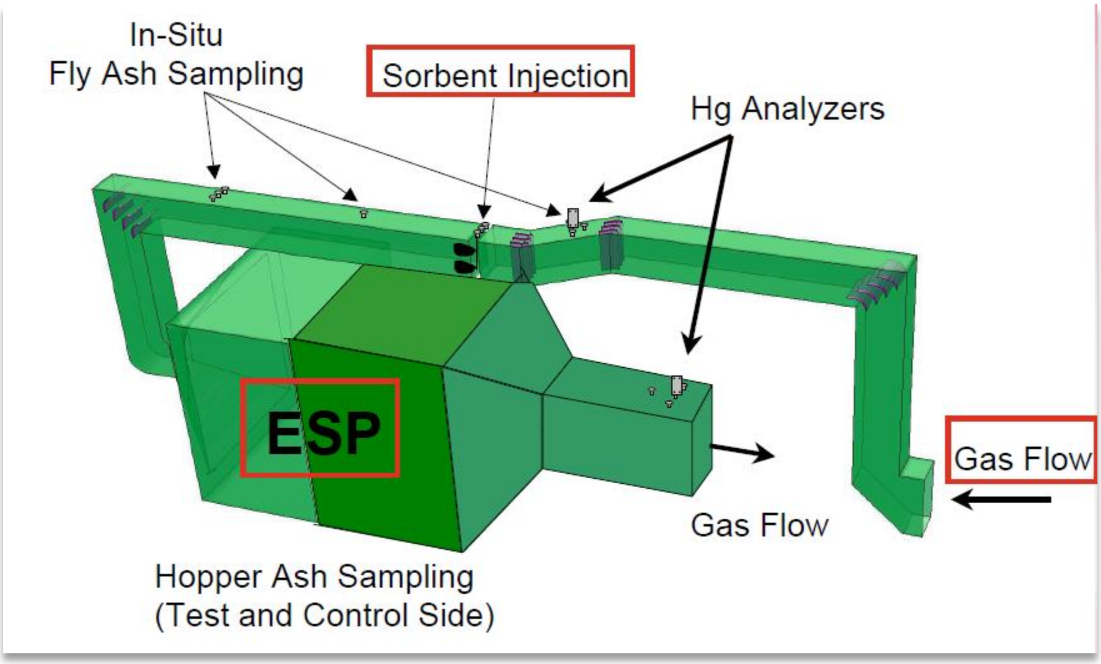
Enhancing Mercury Removal for Western Coals

The sorbent injection system of Sjostrom is shown upstream of an ESP or FF.[1076] The sorbent injection is also shown in another figure as being upstream of the ESP.[1077]

[1075] EX1010 (Sjostrom) at 4 (annotations in red).

[1076] EX1010 (Sjostrom) at 4.

[1077] EX1010 (Sjostrom) at 19.



A POSITA would have understood that ESPs and FFs were well-known particulate separators and would be used to collect the mercury-sorbent composition (and thus be downstream of where the mercury-sorbent composition is formed).[1078]

16. Claim 19: "The method of claim 1, wherein the coal comprises added halide sorbent enhancement additive."

644. This limitation is disclosed by Sjostrom. As described above for element 1(b), Sjostrom renders obvious wherein Br_2, HBr, Br^-, or a combination thereof, is added to the coal upstream of the combustion chamber in the form of a widely available bromine-containing material, such as an aqueous solution of a bromide salt (e.g., $CaBr_2$) that would have obviously dissociated to form Br^- ions.

[1078] Technology Background and State of the Art, IX.B.5.a

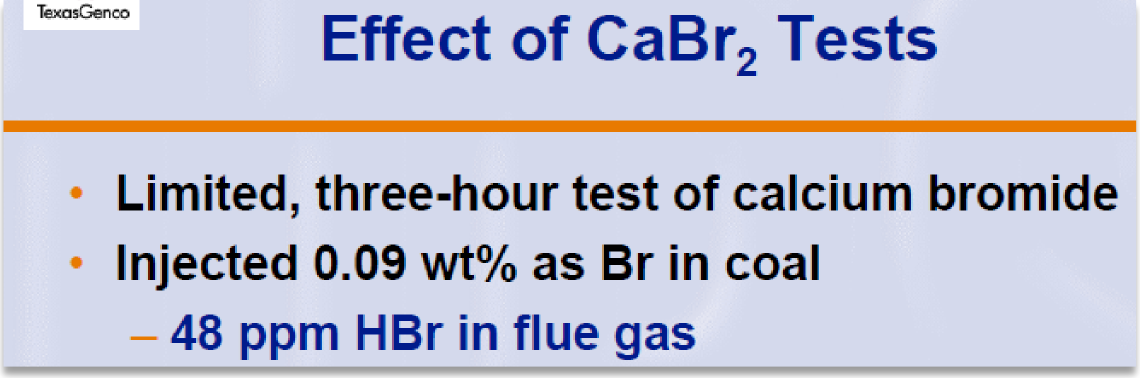
The ’114 Patent does not define “sorbent enhancement additive,” but as evidenced by claims 20 and 21 of the ’114 Patent, a sorbent enhancement additive at least includes Br^-, and a sorbent enhancement additive includes a bromide compound.

17. Claim 20: “The method of claim 1, wherein the combustion chamber comprises added Br_2, HBr, Br^-, or a combination thereof.”

645. This limitation is disclosed by Sjostrom. This limitation is also obvious over Sjostrom in view of Eckberg. As discussed above for element 1(b), Sjostrom discloses adding the Br-containing halogens directly to the combustion chamber and also to the coal (which is then fed to the combustion chamber).

646. A POSITA would have understood that at combustion temperatures found within the boiler, at least a portion of the Br injected at either Location 1 or Location 2 would have vaporized and reacted in the combustion chamber, leaving the boiler as HBr in the vapor phase. Eckberg confirms that when calcium bromide ($CaBr_2$) is combusted, the mercury-containing gas contains hydrogen bromide (HBr):[1079]

[1079] EX1011 (Eckberg) at 14.



TexasGenco

Effect of $CaBr_2$ Tests

- Limited, three-hour test of calcium bromide
- Injected 0.09 wt% as Br in coal
  - 48 ppm HBr in flue gas

18. Claims 21 and 22

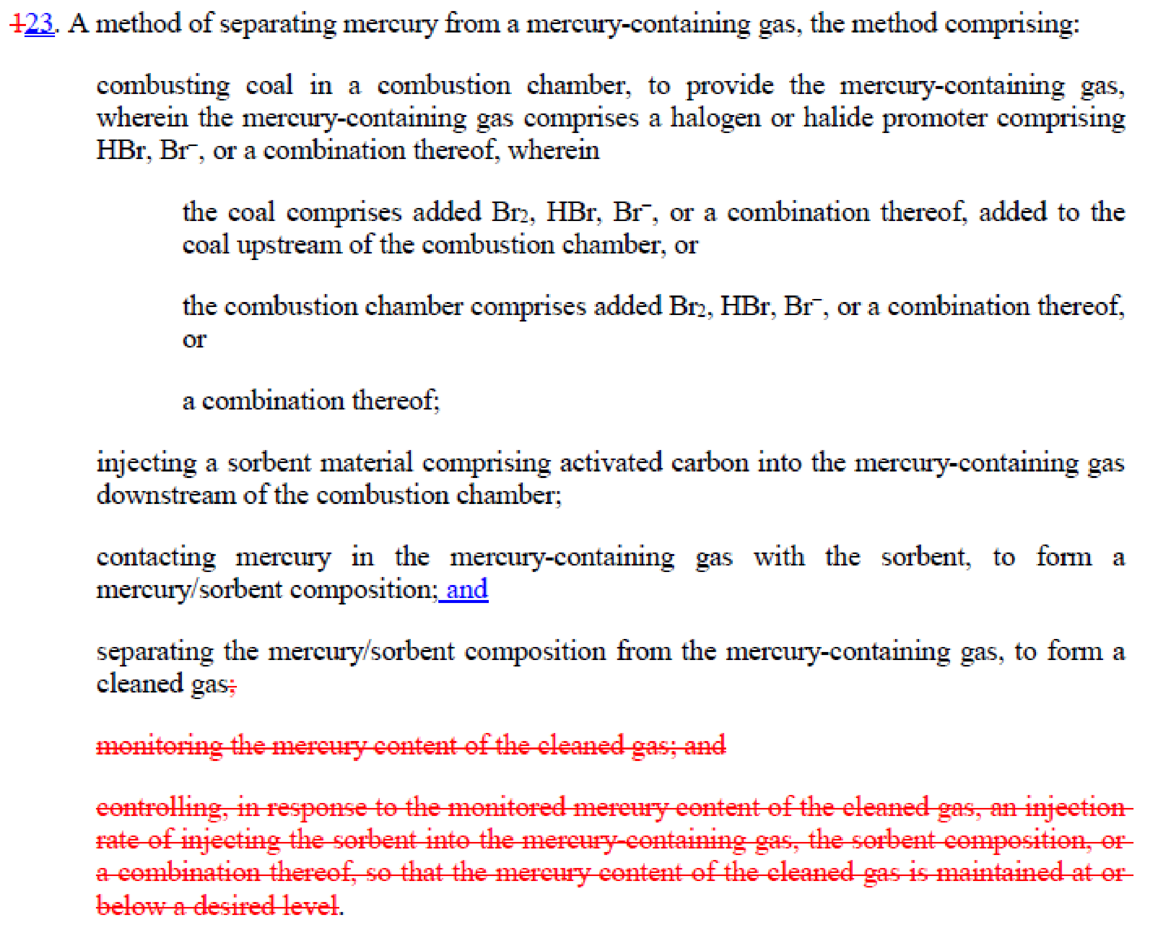
> **Claim 21: "The method of claim 1, wherein the coal comprises added sorbent enhancement additive that comprises Br^-."**
>
> **Claim 22: "The method of claim 21, wherein the sorbent enhancement additive comprises a bromide compound."**

647. These claims clarify that the "halogen or halide promoter" of Claim 1 is a "sorbent enhancement additive" that must be added to the coal. As described above for claim 19, Sjostrom renders obvious wherein the coal comprises added halide sorbent enhancement additive because it would have been obvious to add a widely available bromine-containing material, such as HBr or an aqueous solution of a bromide salt, such as $CaBr_2$ that would have obviously dissociated to form Br^- ions to the coal upstream of the boiler. Thus, Sjostrom renders obvious wherein the coal comprises added sorbent enhancement additive that comprises Br^- and wherein the sorbent enhancement additive comprises a bromide compound.

648. This limitation is further obvious over Sjostrom and Eckberg. Eckberg teaches the addition of "Br^-" ions in the form of aqueous calcium bromide ($CaBr_2$) solutions, as discussed above for element 1(b). Thus, Sjostrom in view of Eckberg renders obvious "wherein the coal comprises added sorbent enhancement additive that comprises Br^-" and "wherein the sorbent enhancement additive comprises a bromide compound."

D. INDEPENDENT CLAIM 23

649. As shown in the redline below, Claim 23 is nearly identical to claim 1, except that Claim 23 removes limitations.



~~1~~23. A method of separating mercury from a mercury-containing gas, the method comprising:

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

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;

injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber;

contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition; and

separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas~~;~~

~~monitoring the mercury content of the cleaned gas; and~~

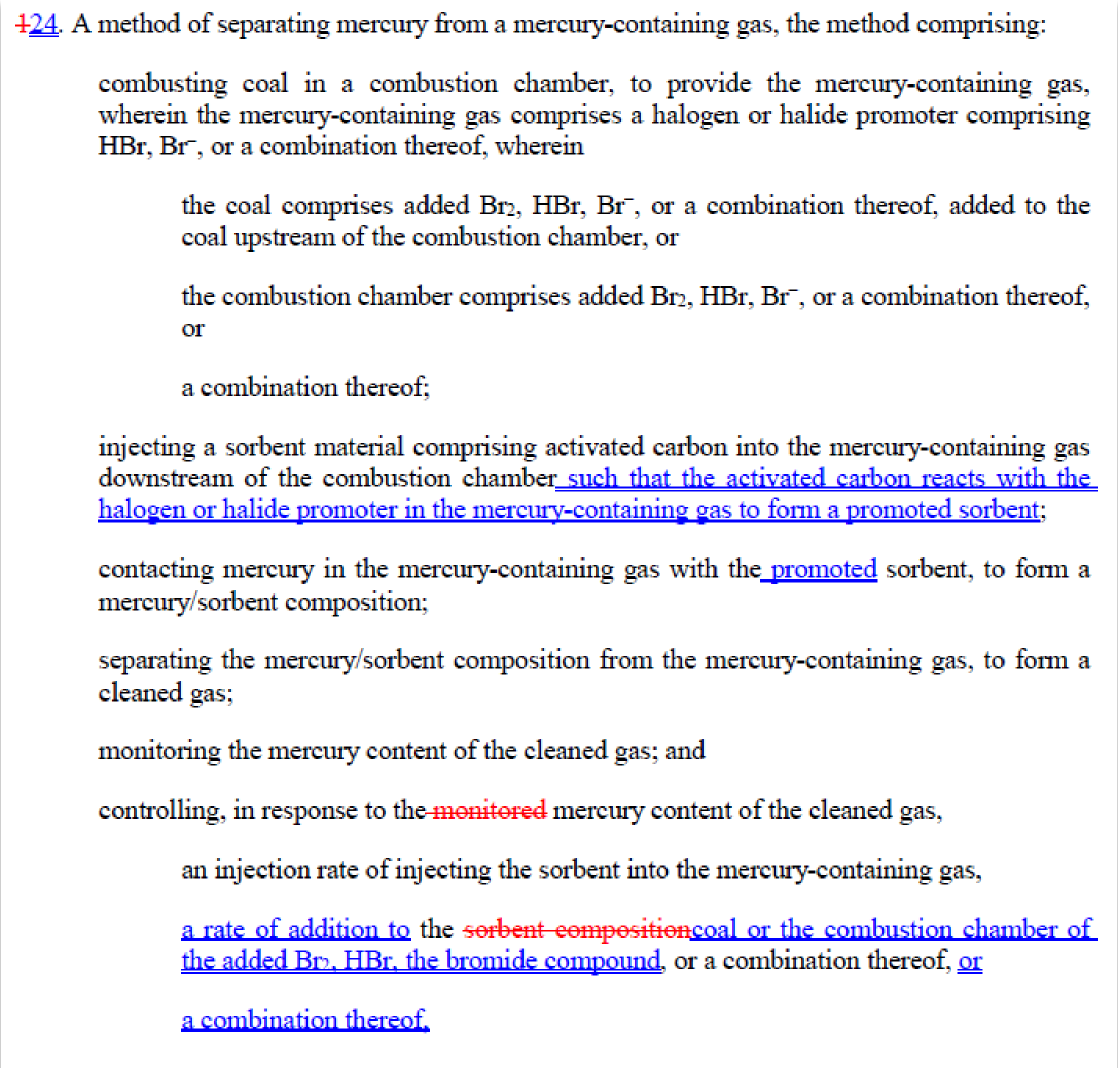
~~controlling, in response to the monitored mercury content of the cleaned gas, an injection rate of injecting the sorbent into the mercury-containing gas, the sorbent composition, or a combination thereof, so that the mercury content of the cleaned gas is maintained at or below a desired level~~.

Accordingly, my analysis provided for claim 1 applies to claim 23.[1080]

E. INDEPENDENT CLAIM 24

650. As shown in the redlines below, claim 24 is nearly identical to claim 1, with minor changes.

[1080] Patent Owner's expert agrees. EX1092 (O'Keefe Report) at 155 (applying same analysis for claim 23 as claim 1).



~~1~~24. A method of separating mercury from a mercury-containing gas, the method comprising:

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

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;

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;

contacting mercury in the mercury-containing gas with the promoted sorbent, to form a mercury/sorbent composition;

separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas;

monitoring the mercury content of the cleaned gas; and

controlling, in response to the ~~monitored~~ mercury content of the cleaned gas,

an injection rate of injecting the sorbent into the mercury-containing gas,

a rate of addition to the ~~sorbent composition~~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.

Accordingly, my analysis provided for claim 1 applies to claim 24.[1081]

[1081] Patent Owner's expert agrees. EX1092 (O'Keefe Report) at 155-157.

1. Claim 24: Preamble—"A method of separating mercury from a mercury-containing gas, the method comprising:"

651. The language of the preamble of claim 24 is identical to the preamble of claim 1. Accordingly, the explanation I provide above for the preamble of claim 1 applies equally to the preamble of claim 24.

2. Claim 24: Element 24(a)—"combusting coal in a combustion chamber, to provide the mercury-containing gas, wherein"

652. The language of Claim Element 24(a) is identical to the language of Claim Element 1(a). Accordingly, the explanation I provide above for Claim Element 1(a) applies equally to Claim Element 24(a).

3. Claim 24: Element 24(b)—"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 coal upstream of the combustion chamber, or the combustion chamber comprises added Br_2, HBr, Br^-, or a combination thereof, or a combination thereof;"

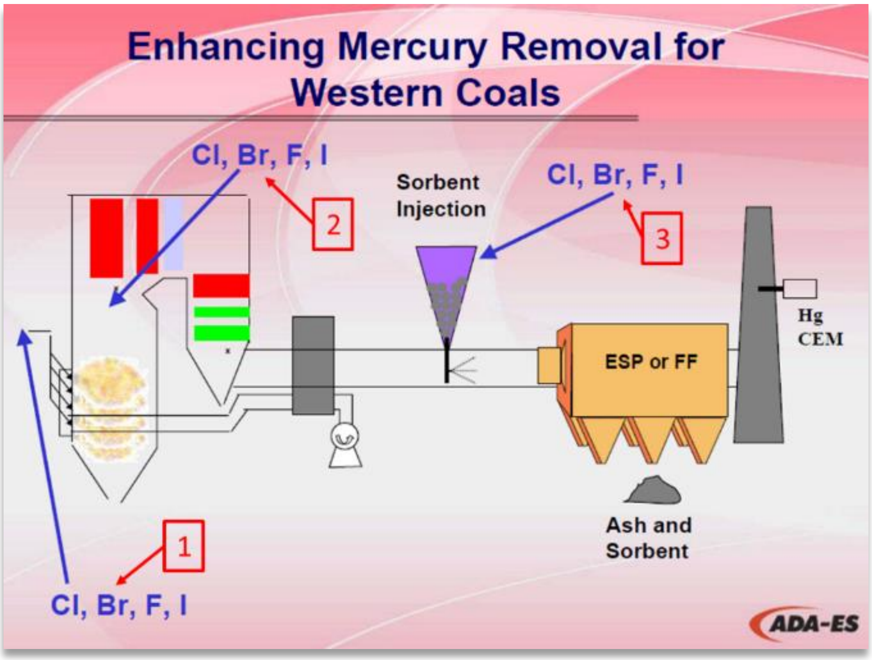
653. The language of Claim Element 24(b) is identical to the language of Claim Element 1(b). Accordingly, the explanation I provide above for Claim Element 1(b) applies equally to Claim Element 24(b).

4. Claim 24: Element 24(c)—"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; contacting mercury in the mercury-containing gas with the promoted sorbent, to form a mercury/sorbent composition;"

654. The language of Claim Element 24(c) is similar to the language of Claim Element 1(c), and I refer to my discussion of that Claim Element. Claim 24(c) adds the requirement that "the activated carbon reacts with the halogen or halide promoter in the mercury-containing gas to form a promoted sorbent; contacting mercury in the mercury-containing gas with the promoted sorbent, to form a mercury/sorbent composition." This addition is also disclosed because Sjostrom discloses contacting the sorbent material with the halogen in the mercury-containing flue gas. Sjostrom described testing mercury removal from flue gas of coal-fired power plants involving sorbent injection, halogen injection, and both sorbent and halogen injection.[1082] Specifically, the annotated figure below shows that Sjostrom teaches injection of bromine in at least three locations throughout the coal-combustion process.[1083]

[1082] EX1010 (Sjostrom) at 4.

[1083] EX1010 (Sjostrom) at 4 (annotations in red).



Location 1 of Sjostrom renders obvious injecting bromine upstream of the combustion chamber, such as by adding it to the coal entering the boiler.[1084] Location 2 of Sjostrom teaches injecting bromine into the boiler.[1085]

655. A POSITA would have understood that the bromine injected at Location 1 or Location 2 would have contacted the sorbent in the flue gas at or downstream of the sorbent injection point.[1086] A POSITA would also have known

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[1084] EX1010 (Sjostrom) at 4 (annotations in red).

[1085] EX1010 (Sjostrom) at 4 (annotations in red).

[1086] Patent Owner's expert agrees. EX1092 (O'Keefe Report) at 156 (labeled as limitation 24e).

that the sorbent and halogen would have reacted to form at least a quantity of promoted sorbent upon contact.[1087]

656. Specifically, by 2003, it was well-known that halides "improve[d] Hg capture both by conversion of the Hg^0 to the more easily removed Hg^{2+} forms and by enhancing the reactivity of Hg^0 with activated carbons."[1088] As described in my Technology Background section[1089], this occurred with two reaction mechanisms: by oxidizing the mercury (thus rendering it more susceptible to removal), and also by increasing the capacity of activated carbon to bind with the mercury. Thus, the halogen or halide promoter is reacting with both the activated carbon and with the mercury. A POSITA would have known that the introduction of halogens helped remove mercury by increasing the ability of the activated carbon to bind with the mercury. When bromine and carbon come into contact with each other (e.g., upon adsorption as in Sjostrom), a POSITA would have understood that the two react with one another and a promoted sorbent is formed.[1090]

[1087] Technology Background and State of the Art, §IX.C.3, § IX.G.2.

[1088] EX1062 (Crocker) at 2-3.

[1089] See Technology Background, SectionIX.C.32.

[1090] Technology Background and State of the Art, SectionsIX.C.3, IX.G.2.

5. Claim 24: Element 24(d)—"separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas;"

657. The language of Claim Element 24(d) is identical to the language of Claim Element 1(d). Accordingly, the explanation I provide above for Claim Element 1(d) applies equally to Claim Element 24(d).

6. Claim 24: Element 24(e)—"monitoring the mercury content of the cleaned gas; and"

658. The language of Claim Element 24(e) is identical to the language of Claim Element 1(e). Accordingly, the explanation I provide above for Claim Element 1(e) applies equally to Claim Element 24(e).

7. Claim 24: Element 24(f)(1)—"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 bromide compound, or a combination thereof, or a combination thereof,"

659. The language of Claim Element 24(f)(1) is similar to the language of Claim Element 1(f)(1), and I refer to my discussion of that Claim Element. Claim 24(f)(1) has the following changes, as compared to Claim Element 1(f)(1):

> controlling, in response to the monitored mercury content of the cleaned gas,
>
> an injection rate of injecting the sorbent into the mercury-containing gas,
>
> ~~the sorbent composition,~~

> 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,

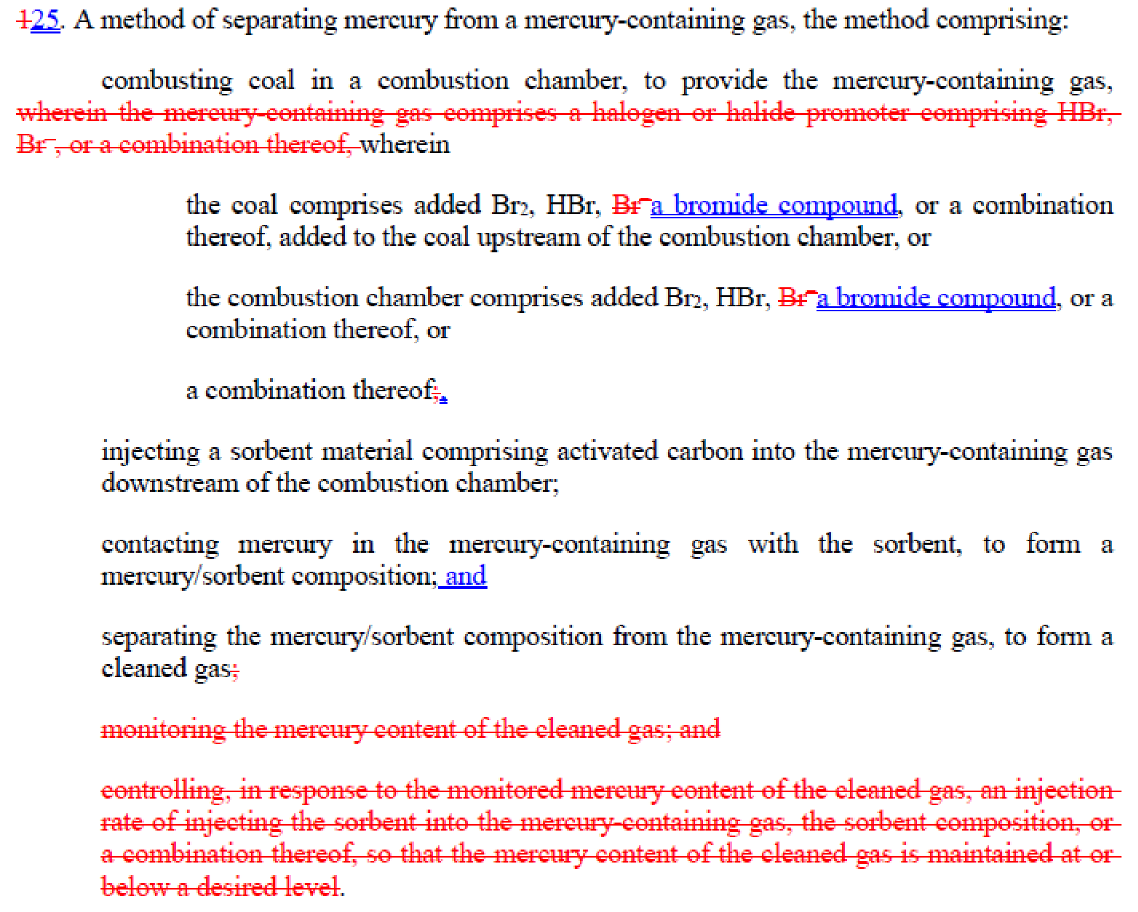
Claim Element 24(f)(1) is disclosed, for the reasons described above for element 1(f)(1), because Sjostrom discloses controlling the injection rate of the sorbent into the mercury containing gas in response to the monitored mercury content.

8. Claim 24: Element 24(f)(2)—"so that the mercury content of the cleaned gas is maintained at or below a desired level."

660. The language of Claim Element 24(f)(2) is identical to the language of Claim Element 1(f)(2). Accordingly, the explanation I provide above for Claim Element 1(f)(2) applies equally to Claim Element 24(f)(2).

F. INDEPENDENT CLAIM 25.

661. As shown in the redline below, claim 25 is nearly identical to claim 1, except that it removes limitations and replaces "Br-" with "a bromide compound."



~~1~~25. A method of separating mercury from a mercury-containing gas, the method comprising:

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

the coal comprises added Br_2, HBr, ~~Br^-~~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, ~~Br^-~~a bromide compound, or a combination thereof, or

a combination thereof~~;~~,

injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber;

contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition; and

separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas~~;~~

~~monitoring the mercury content of the cleaned gas; and~~

~~controlling, in response to the monitored mercury content of the cleaned gas, an 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~~.

Accordingly, my analysis provided for claim 1 applies to claim 25.

1. Claim 25: Preamble—"A method of separating mercury from a mercury-containing gas, the method comprising:"

662. The language of the preamble of claim 25 is identical to the preamble of claim 1. Accordingly, the explanation I provide above for the preamble of claim 1 applies equally to the preamble of claim 25.

2. Claim 25: Element 25(a)—"combusting coal in a combustion chamber, to provide the mercury-containing gas, wherein"

663. The language of Claim Element 25(a) is identical to the language of Claim Element 1(a). Accordingly, the explanation I provide above for Claim Element 1(a) applies equally to Claim Element 25(a).

3. Claim 25: Element 25(b)—"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 combination thereof,"

664. The language of Claim Element 25(b) is similar to the language of Claim Element 1(b), and I refer to my discussion of that Claim Element. Claim 25(b) has the following changes, as compared to Claim Element 1(b):

> 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^-,~~ 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, ~~Br^-,~~ a bromide compound, or a combination thereof,
>
> or a combination thereof;

Unlike claim 1, claim 25 does not recite that "the mercury containing gas comprises a halogen or halogen promoter . . . ." Further, claim 25 recites "a bromide compound" in place of "Br^-." A POSITA would have understood that Sjostrom's

"Br" teaches the use of bromide compounds as presently claimed.[1091] Thus, Sjostrom discloses this element for the same reasons it discloses Claim Element 1(b). The "bromide compound" is further obvious over Eckberg, which teaches the addition of an aqueous calcium bromide ($CaBr_2$) solution.

4. Claim 25: Element 25(c)—"injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber; contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition; and"

665. The language of Claim Element 25(c) is identical to the language of Claim Element 1(c). Accordingly, the explanation I provide above for Claim Element 1(c) applies equally to Claim Element 25(c).

5. Claim 25: Element 25(d)—"separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas."

666. The language of Claim Element 25(d) is identical to the language of Claim Element 1(d). Accordingly, the explanation I provide above for Claim Element 1(d) applies equally to Claim Element 25(d).

[1091] EX1010 (Sjostrom) at 4.

G. CLAIMS DEPENDING FROM CLAIM 25

1. Claim 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."

667. The language of claim 26 is similar to the language of claim 6, and I refer to my discussion of that claim. Claim 26 has the following changes, as compared to claim 6:

> wherein the coal comprises the added Br_2, HBr, ~~Br^-,~~ the bromide compound or a combination thereof, added to the coal upstream of the combustion chamber

A POSITA would have understood that Sjostrom's "Br" teaches the use of bromide compounds as presently claimed.[1092] Thus, Sjostrom renders obvious this element for the same reasons it discloses Claim 6. The "bromide compound" is further obvious over Eckberg, which teaches the addition of an aqueous calcium bromide ($CaBr_2$) solution, as described above for element 1(b).

2. Claim 27: "The method of claim 25, wherein the combustion chamber comprises the added Br_2, HBr, the bromide compound, or a combination thereof."

668. The language of claim 27 is similar to the language of claim 20, and I refer to my discussion of that claim. Claim 27 has the following changes, as compared to claim 20:

[1092] EX1010 (Sjostrom) at 4.

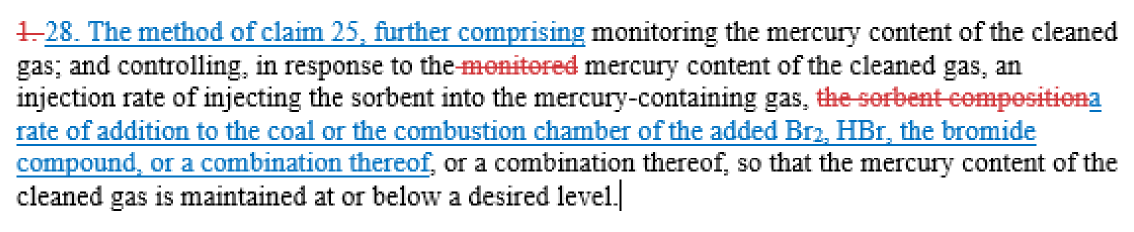
> wherein the combustion chamber comprises the added Br_2, HBr, ~~Br^-,~~ the bromide compound, or a combination thereof."

A POSITA would have understood that Sjostrom's "Br" teaches the use of bromide compounds as presently claimed.[1093] Thus, Sjostrom discloses this element for the same reasons it discloses Claim 20. The "bromide compound" is further obvious over Eckberg, which teaches the addition of an aqueous calcium bromide ($CaBr_2$) solution, as discussed above for Claim Element 1(b).

3. Claim 28: "The method of claim 25, further comprising monitoring the mercury content of the cleaned gas; and 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 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."

669. The language of claim 28 is similar to the language of Claim Elements 1(e), 1(f)(1), and 1(f)(2), and I refer to my discussion of those claim elements. A redline of these changes is shown below, comparing Claim 28 to Claim Elements 1(e), 1(f)(1), and 1(f)(2):

[1093] EX1010 (Sjostrom) at 4.



~~1.~~ 28. The method of claim 25, further comprising monitoring the mercury content of the cleaned gas; and controlling, in response to the ~~monitored~~ mercury content of the cleaned gas, an injection rate of injecting the sorbent into the mercury-containing gas, ~~the sorbent composition~~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.

Claim 28 is disclosed because Sjostrom discloses monitoring the mercury emissions levels and controlling the injection rate of the sorbent into the mercury containing gas to maintain the mercury emissions levels at or below a desired level, as discussed above for Claim Elements 1(e) and 1(f).[1094]

4. Claim 29: "The method of claim 25, wherein the mercury-containing gas comprises about 1 g to about 30 g of the element bromine per 100 g of the sorbent."

670. Claim 29 is merely an attempt to claim the optimum or workable range for a process of combining a particular conventional halogen (bromine) being used in a conventional way (halogens are inherent to coal, and both oxidize mercury and promote activated carbon) with a conventional sorbent (activated carbon). Nothing about the particular range of 1 g to about 30 g of the halide promoter per 100 g of the sorbent would lead to an unexpected result from what was already known to one of skill in the art. Through routine process optimization and routine experimentation, a person of ordinary skill in the art would have adjusted the rate of

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[1094] Patent Owner's expert agrees. EX1092 (O'Keefe Report) at 158.

addition of bromine-containing species and/or activated carbon injection rate to achieve about 1 g to about 30 g of halide promoter per 100g of carbon sorbent in the flue gas.[1095]

5. Claim 30: "The method of claim 25, wherein the mercury/sorbent composition comprises the element bromine, the sorbent material, and mercury."

671. This limitation is disclosed by Sjostrom. As discussed for claim 7, Sjostrom teaches that the bromide promoter is contacted with the sorbent in vapor form. At least a quantity of promoted sorbent comprising bromine and sorbent would have formed as a reaction between the sorbent and halogen upon contact. A POSITA would have known that the promoted carbon sorbent injected into the flue gas would contact and adsorb at least a quantity of the mercury in the flue gas. Upon adsorption, the mercury and activated carbon in the flue gas would contact (adhere to) one another to form a mercury/sorbent composition.[1096] A POSITA would have understood that this mercury/sorbent composition contains mercury, sorbent, and bromine.

[1095] Patent Owner's expert, Mr. O'Keefe, agrees. EX1092 (O'Keefe Report) at 153, 158.

[1096] Technology Background and State of the Art, Sections IX.C.3, IX.G.2.

XVII. GROUND B2: OBVIOUSNESS OVER SJOSTROM IN VIEW OF OLSON-646

672. It is my opinion that Sjostrom in view of Olson-646 render obvious each of claims 1-30 of the ’114 Patent.

A. REASONS TO COMBINE SJOSTROM WITH OLSON-646

673. A person of ordinary skill in the art would have been motivated to combine Sjostrom with Olson-646, and have a reasonable expectation of success in applying the teachings of Olson-646 to Sjostrom, because both references are directed to the same goal of removing mercury from coal-combustion flue gases. Both references teach the use of bromine-based halogens in conjunction with activated carbon to improve mercury removal from flue gas emission leaving coal-fired power plants. A POSITA would have looked to Olson-646 to provide certain implementation details regarding the system disclosed in Sjostrom, such as which specific bromine-containing (“Br”) species to use, the ratios of bromine promoter to activated-carbon sorbent, and further processes that take place downstream of the combustion chamber (such as location of sorbent injection). Sjostrom provides the location of where to inject halogens (e.g., to the coal, to the combustion chamber, or downstream) and describes the need for powdered activated carbon (PAC). In a complementary fashion, Olson-646 describes the location of where to inject PAC into the system and, once halogens are introduced into the system (as disclosed by

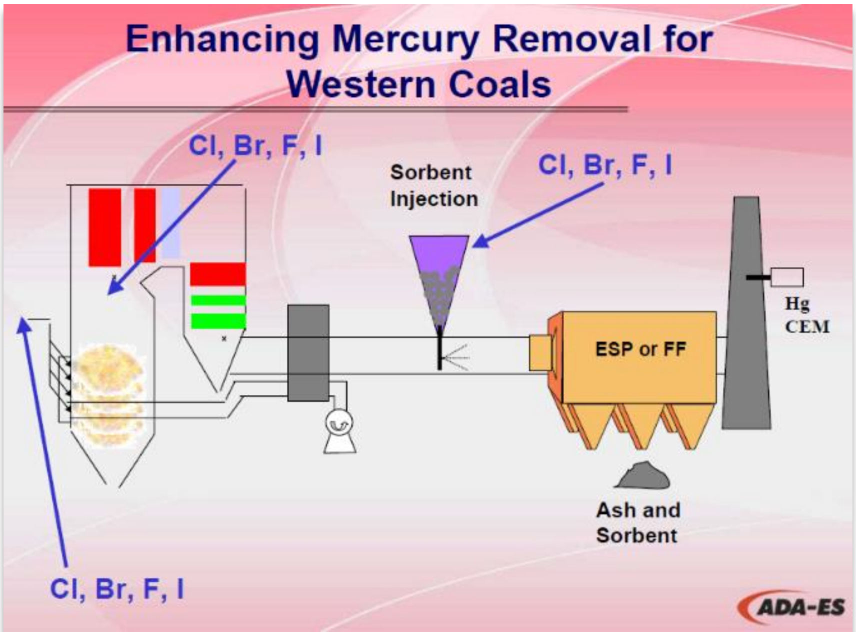
Sjostrom), how those halogens react with the PAC. Thus, a person of skill in the art would have been motivated to combine Sjostrom and Olson-646, and have a reasonable expectation of success in applying the teachings of Olson-646 to Sjostrom, because both references teach the use of halogens and activated-carbon sorbents to improve mercury removal from flue gas emission leaving coal-fired power plants. The title of Sjostrom is "Full Scale Evaluations of Mercury Control Technologies with PRB Coals."[1097] Similarly, the title of Olson is "Sorbents for the Oxidation and Removal of Mercury."[1098]

674. Sjostrom describes removing mercury from flue gas of coal-fired power plants using sorbent injection, halogen injection, and both sorbent and halogen injection as detailed below.[1099]

[1097] EX1010 (Sjostrom) at 1 (Title).

[1098] EX1012 (Olson-646) at 1 (Title).

[1099] EX1010 (Sjostrom) at 4.



Enhancing Mercury Removal for Western Coals

Cl, Br, F, I

Sorbent Injection

Cl, Br, F, I

Hg CEM

ESP or FF

Ash and Sorbent

Cl, Br, F, I

ADA-ES

Sjostrom demonstrates that activated-carbon sorbent injection was a well-known way of treating mercury emissions in flue gas.[1100] Sjostrom also teaches that halogens (e.g., "Cl, Br, F, I") may be injected at multiple locations.[1101] Sjostrom also shows activated-carbon sorbents that are treated with halogen additives are more effective at removing mercury from flue gas than untreated sorbent alone.[1102]

675. Sjostrom provides overall process descriptions and diagrams and highlights the improved results of halogens used in combination with activated-carbon sorbents. Olson-646 further describes the types of halogens that can be used

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[1100] EX1010 (Sjostrom) at 10-11.

[1101] EX1010 (Sjostrom) at 4.

[1102] EX1010 (Sjostrom) at 16.

to react with activated-carbon sorbent, and ratios that can be used. Like Sjostrom, Olson-646 describes using a conventional halogen (bromine) in a conventional way (as a promoter) to increase the effectiveness of a conventional sorbent (activated carbon) to capture mercury from coal flue gas.

676. A POSITA would have been motivated, with a reasonable expectation of success, to add HBr or Br_2 into the combustion chamber of Sjostrom (e.g., Location 2), because it would have been a simple substitution of one known element (e.g., the "Br" in Sjostrom at the location specified by Sjostrom) for another known element (e.g., Br_2 or HBr of Olson-646) to improve a known device (activated-carbon sorbent in Sjostrom and Olson-646) and obtain predictable results (e.g., more than 70% mercury removal in Sjostrom and Olson-646). Olson-646 teaches embodiments that upon contact with the sorbent, "the halogen/halide promoter is in gaseous or vapor form" that comprises "gaseous HBr or Br_2."[1103] A POSITA would also look to Olson-646 to select an appropriate "Br" (at Location 1 or Location 2 in Sjostrom) that yields gas-phase HBr or Br_2 when combusted (as disclosed by Olson-646). Such a selection would have been obvious as a matter of routine implementation.

[1103] EX1012 (Olson-646) ¶[0066].

677. A person of ordinary skill in the art would also look to Olson-646 for additional discussion of underlying chemistry already theorized to take place by the processes disclosed in Sjostrom. Figure 2 of Olson-646, reproduced below, shows "a theory developed from scientific evidence to explain the nature of the promoting compounds."[1104]

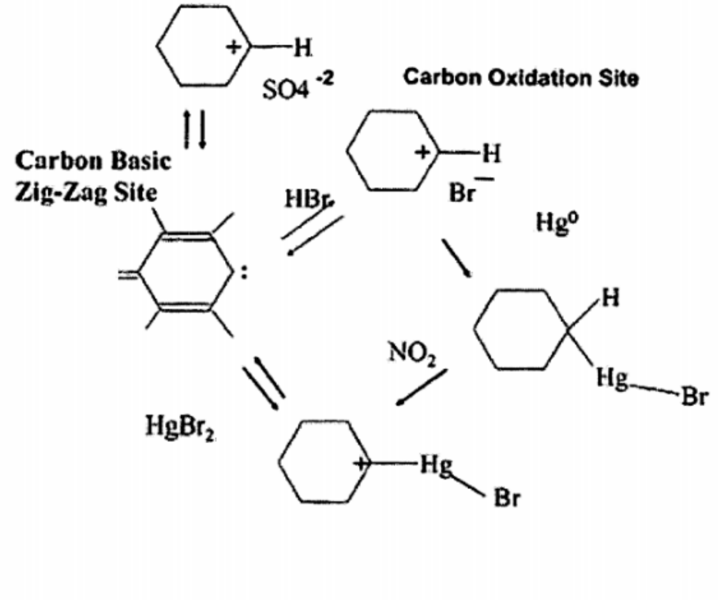


FIG. 2

Olson-646 explains that "hydrogen bromide reacts with the unsaturated structure of the activated carbon."[1105] Olson-646 teaches that the reaction may take place at "a carbene species on the edge of the graphene sheet structures of the carbon."[1106]

[1104] EX1012 (Olson-646) ¶[0054], Figure 2; *see also* ¶¶[0033], [0073].

[1105] EX1012 (Olson-646) ¶[0054].

[1106] EX1012 (Olson-646) ¶[0054].

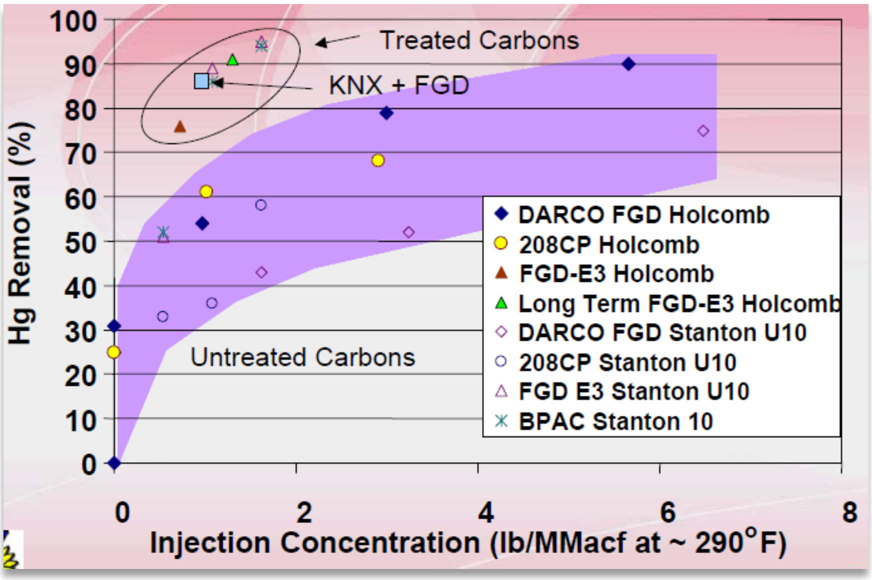
Further, Olson-646 explains that "[m]olecular bromine or a bromine compound reacts to form a similar structure, with a positive carbon that is active for oxidizing the mercury with subsequent capture by the sorbent."[1107] Figure 2 of Olson-646 shows that the complex includes the activated-carbon sorbent, the element bromine, and the element mercury. Thus, a POSITA would have been motivated to apply the teachings of Olson-646 to Sjostrom because it would have provided well-known details regarding the chemicals and associated reactions that would have been used in the system of Sjostrom for mercury control from coal flue gas.

678. A person of skill in the art would have been further motivated to combine the references to understand the chemical properties of activated carbon and halogen-promoted activated carbon, and would have had a reasonable expectation of success in doing so, because both references discuss the same halogen promoters (e.g., "Br" in Sjostrom and "HBr or Br_2" in Olson-646) and mercury sorbents (activated carbon). In fact, both references teach the same supplier (Norit) and specific brand name (Darco FGD®) of powdered activated carbon (PAC).[1108] Sjostrom describes mercury removal testing performed using "DARCO FGD"

[1107] EX1012 (Olson-646) ¶[0054].

[1108] EX1010 (Sjostrom) at 15, 16; EX1012 (Olson-646) ¶¶[0035], [0036], [0039], [0040], [0095], [0100], [0126] sorbent.[1109] Likewise, Olson-646 teaches the use of "powdered activated carbon" such as "NORIT Darco FGD."[1110]

679. A POSITA would have been additionally motivated to apply the teachings of Olson, and have had a reasonable expectation of success in doing so, because both references teach using the same chemicals to achieve the same results. For example, the below figure of Sjostrom shows removing 70 wt % or more of mercury from the mercury-containing coal flue gas using halogen treated activated carbons (KNX + FGD).[1111]



[1109] EX1010 (Sjostrom) at 15, 16.

[1110] EX1012 (Olson-646) ¶[0095].

[1111] EX1010 (Sjostrom) at 16.

Likewise, Olson-646 explains that "a method is provided for reducing mercury in flue gas comprising providing a sorbent, injecting the sorbent into a mercury-containing flue gas stream, collecting greater than 70 wt-% of the mercury in the flue gas on the sorbent to produce a cleaned flue gas, and substantially recovering the sorbent from the cleaned flue gas."[1112]

680. Looking to the implementation details provided in the Olson-646 reference to understand the chemicals and reactions taking place in Sjostrom, would have been nothing more than using known results of one process in a known way to improve a similar process. Further, the implementation details provided in Olson-646 are simply proposed workable ranges (such as concentration ratios), which were conventional and known in the art, and would have been selected, or at least tried, as part of routine process optimization by a POSITA applying the teachings of Sjostrom.

B. INDEPENDENT CLAIM 1

1. Claim 1: Preamble—"A method of separating mercury from a mercury-containing gas, the method comprising:"

681. As discussed regarding the preamble of claim 1, in Ground B1 above, the preamble is disclosed by Sjostrom. My analysis with regards to the disclosure of Sjostrom regarding this element for Ground B1 applies equally here.

[1112] EX1012 (Olson-646) ¶[0022].

2. Claim 1: Element (1)(a)—"combusting coal in a combustion chamber, to provide the mercury-containing gas, wherein"

682. As discussed in Ground B1 above, this limitation is disclosed by Sjostrom. My analysis with regards to the disclosure of Sjostrom regarding this element for Ground B1 applies equally here. In addition, Olson-646 states that the "combustion and gasification of fossil fuel such as coal generates flue gas that contains mercury . . . ."[1113]

3. Claim 1: Element (1)(b)—"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 coal upstream of the combustion chamber, or the combustion chamber comprises added Br_2, HBr, Br^-, or a combination thereof, or a combination thereof;"

683. As discussed in Ground B1 above, this limitation is disclosed and/or rendered obvious by Sjostrom. My analysis with regards to the disclosure of Sjostrom regarding this element for Ground B1 applies equally here.

684. In addition, this limitation is also obvious over Sjostrom in view of Olson-646. Olson-646 "provides a cost-effective way to capture pollutants by utilizing exceptionally reactive halogen/halide promoted carbon sorbents using a bromide (or other halogen/halide) treatment of the carbon, that capture mercury via

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[1113] EX1012 (Olson-646) ¶[0006].

mercury-sorbent surface reactions, at very short contact times of seconds or less."[1114] Olson-646 teaches embodiments "wherein the halogen/halide promoter is in gaseous or vapor form" that comprises "gaseous HBr or Br_2."[1115] A POSITA would have been motivated, with a reasonable expectation of success, to add HBr or Br_2 into the combustion chamber of Sjostrom (e.g., Location 2), because it would have been a simple substitution of one known element (e.g., the "Br" in Sjostrom at the location specified by Sjostrom) for another known element (e.g., Br_2 or HBr of Olson-646) to improve a known device (activated-carbon sorbent in Sjostrom and Olson-646) and obtain predictable results (e.g., more than 70% mercury removal in Sjostrom and Olson-646). In addition, a POSITA would have been motivated, and expected a reasonable chance of success, to use a "Br" in Sjostrom that upon combustion would yield HBr or Br_2 (which Olson-646 identifies as effective gas-phase promoters).

[1114] EX1012 (Olson-646) ¶[0043].

[1115] EX1012 (Olson-646) ¶[0066].

4. Claim 1: Element (1)(c)—"injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber; contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition;"

685. As discussed in Ground B1 above, this limitation is disclosed by Sjostrom. My analysis with regards to the disclosure of Sjostrom regarding this element for Ground B1 applies equally here.

686. The limitation of "contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition" is further obvious over Sjostrom in view of Olson-646. Olson-646 explains that a "promoted carbon sorbent and/or an optional alkali component is injected into contaminated flue gas stream 15."[1116] The "contaminated flue gas stream" refers to a stream of mercury-containing gas. Olson-646 explains that "[t]he halogen/halide . . . contacts and reacts with the base activated carbon prior to injection point 116."[1117]

687. Olson-646 describes that mercury and activated carbon in the flue gas would react to form a mercury/sorbent composition. Indeed, Olson-646 discloses a promoted activated-carbon sorbent "that capture[s] mercury via mercury-sorbent

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[1116] EX1012 (Olson-646) ¶[0061].

[1117] EX1012 (Olson-646) ¶[0062].

surface reactions,"[1118] Olson-646 further describes "AC mercury binding sites" (i.e., sites where mercury contacts the sorbent and forms a mercury/sorbent composition)[1119] and shows a mercury-sorbent composition in Figure 2 (annotated below).[1120]

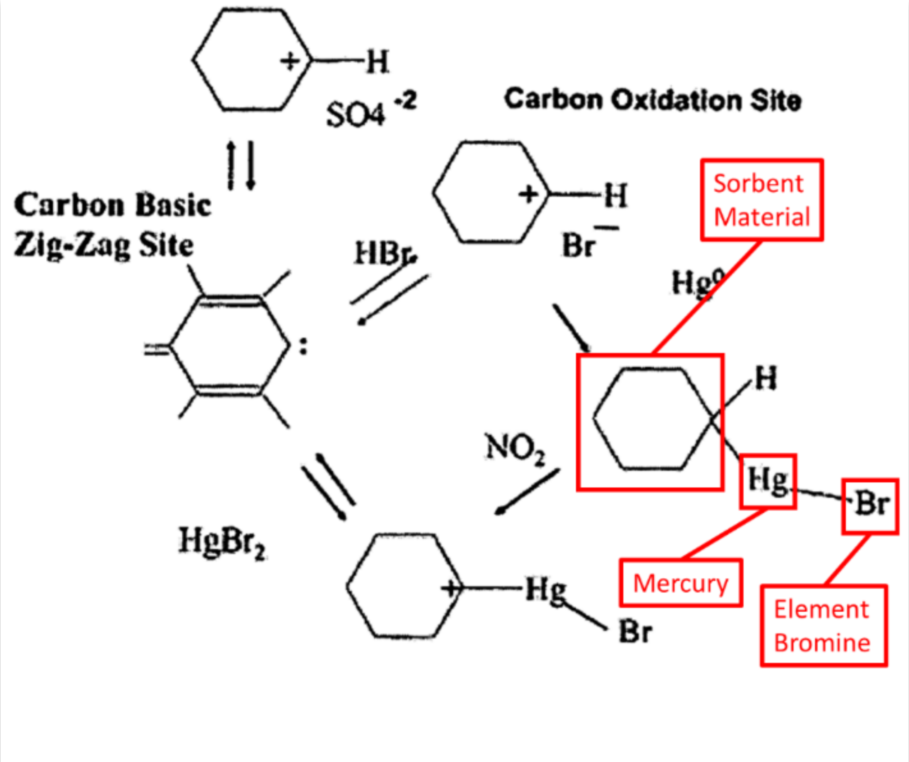

FIG. 2

Thus, Olson-646 discloses "contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition."

[1118] EX1012 (Olson-646) ¶[0043].

[1119] EX1012 (Olson-646) ¶[0128].

[1120] EX1012 (Olson-646) at Figure 2.

5. Claim 1: Element (1)(d)—"separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas;"

688. As discussed for Element 1(d) above, this limitation is disclosed by Sjostrom. It is also obvious in view of Olson-646, which discloses a particulate separator, such as an ESP or fabric filter.[1121] As described for Element 1(c), a POSITA would have known, or at least found it obvious, that the sorbent is a mercury/sorbent composition after it is introduced into the mercury-containing gas.

6. Claim 1: Element (1)(e)—"monitoring the mercury content of the cleaned gas; and"

689. As discussed for Element 1(e) in Ground B1 above, this limitation is disclosed by Sjostrom. It is also obvious in view of Olson-646. My analysis with regards to the disclosure of Sjostrom regarding these elements for Ground B1 applies equally here. In addition, Olson-646 states the claim language near-verbatim: "In a further embodiment, the method further comprises monitoring the mercury content of the clean flue gas."[1122] Olson-646 discloses a "Continuous Emission Monitor" (CEM) as the tool for monitoring mercury content of the cleaned gas.[1123]

[1121] EX1012 (Olson-646) ¶[0059].

[1122] EX1012 (Olson-646) ¶[0022].

[1123] EX1012 (Olson-646) ¶[0060].

7. <u>Claim 1: Element 1(f)—“</u>controlling, in response to the monitored mercury content of the cleaned gas, an 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.”

690. As discussed in Ground B1 above, these limitations are obvious over Sjostrom. My analysis with regards to these elements for Ground B1 applies equally here.

691. In addition, these limitations are also obvious over Sjostrom in view of Olson-646. After separation, Olson-646 explains that “[t]he reduced mercury ‘clean’ flue gas stream 142 is then monitored for mercury content by an optional CEM 205, which provides corresponding signals to an optional computer/controller 206 . . . to maintain the mercury concentration in exhaust stream 35 within desired limits, according to control algorithms well known in the art.”[1124] “CEM” stands for continuous emissions monitor. Even Olson-646 recognizes the corresponding control algorithms were “well known in the art” to keep the mercury content of the cleaned gas “within desired limits” (another term for “desired level”).[1125]

692. Olson-646 explains that “mercury CEM 205 and flow controllers 201, 202, 203, 208, and 209 are electrically connected via optional lines 207 (or

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[1124] EX1012 (Olson-646) ¶[0061].

[1125] EX1012 (Olson-646) ¶[0061].

wirelessly) to an optional digital computer (or controller) 206, which receives and processes signals and preferably controls the preparation and injection of promoted carbon sorbent into contaminated flue gas stream 15."[1126] Flow controller 201 controls the rate of injection of activated-carbon sorbent, flow controller 202 controls the rate of injection of halogen promoter, and flow controller 204 discloses the addition of both activated carbon and bromine-containing promoter into the mercury-containing flue gas 15.[1127]

[1126] EX1012 (Olson-646) ¶[0060], Figure 3.

[1127] EX1012 (Olson-646) ¶¶[0056, 60-61].

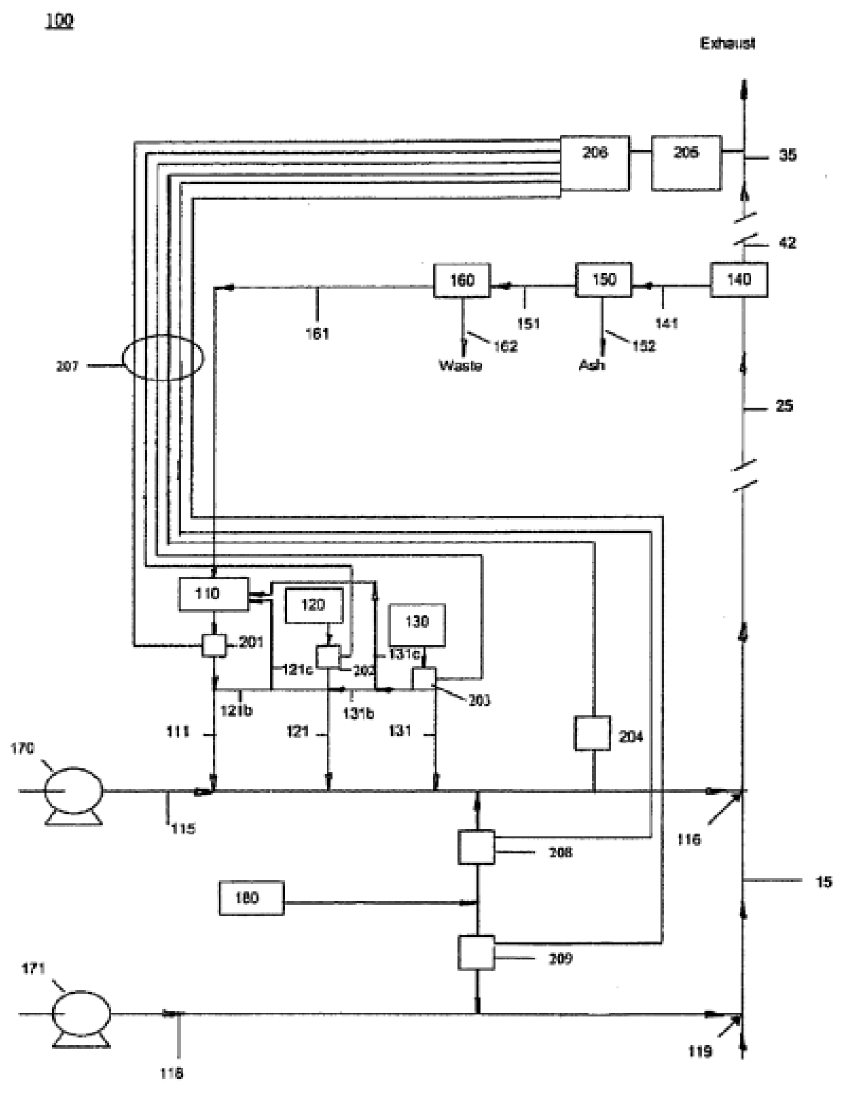

FIG. 3

And as discussed by Olson-646, above, each of these flow controllers and control algorithms were “known in the art,” and are used to control the mercury content of the cleaned gas based on feedback signals from mercury measurements.

693. As discussed in Ground B1, including element 1(d), a POSITA viewing the charts of Sjostrom showing mercury removal (Y-axis) versus sorbent injection

rate (X-axis) would have been motivated to control the sorbent injection rate at a level that minimized costs while reaching mercury removal targets. A POSITA would have been motivated to look to Olson-646 for additional details as to the hardware and control algorithms to control sorbent-injection rates. A POSITA would have had a reasonable expectation of success in applying these operational details to Sjostrom because the system of Olson-646 and Sjostrom are substantially similar and are designed to achieve the same goal (e.g., removal of mercury from flue gas). Moreover, the hardware in Olson-646 involves mass-flow controllers and basic feedback logic, each of which were well-known to a person of ordinary skill in the art and routinely used in the power-generation industry. A POSITA would not have had to remove anything from the system of Sjostrom; they merely would have had to apply the teachings of Olson-646 to fill in the missing details, such as flow controllers and valves, to implement the desired control system.

C. CLAIMS DEPENDING FROM CLAIM 1

1. Claims 2 and 3

> **Claim 2: "The method of claim 1, comprising removing greater than 70 wt % of the mercury in the mercury-containing gas."**
>
> **Claim 3: "The method of claim 1, comprising removing greater than 70 wt % of the mercury in the mercury-containing gas on the sorbent."**

694. As discussed in Ground B1 above, Sjostrom discloses claim 2. My analysis with regards to the disclosure of Sjostrom regarding claim 2 for Ground B1 applies equally here.

695. In addition, claims 2 and 3 are also obvious over Sjostrom in view of Olson-646. For example, Olson-646 explains that "a method is provided for reducing mercury in flue gas comprising providing a sorbent, injecting the sorbent into a mercury-containing flue gas stream, collecting <u>greater than 70 wt-% of the mercury in the flue gas on the sorbent to</u> produce a cleaned flue gas, and substantially recovering the sorbent from the cleaned flue gas."[1128] Claim 30 of Olson-646 also discloses "collecting greater than 70 wt-% of the mercury in the flue gas on the

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[1128] EX1012 (Olson-646) ¶[0022].

sorbent to produce a cleaned flue gas, and substantially recovering the sorbent from the cleaned flue gas."[1129]

696. A person of skill in the art would have looked to the Olson-646 reference to further understand the mechanisms for the mercury-removal disclosed by Sjostrom. Specifically, a POSITA would have understood that the activated carbon of Sjostrom removed "greater than 70 wt % of the mercury in the mercury-containing gas on the sorbent," as discussed in Ground B1 above. It is obvious over Olson-646 that the mercury is removed "on the sorbent."

2. Claim 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."

697. This limitation is obvious over Sjostrom, as described above for Ground B1. This limitation would also be obvious over Sjostrom in view of Olson-646.

698. Olson-646 includes repeated discussion of this ratio of the halogen or halide promoter to the sorbent material in the mercury-containing gas. For example, Olson-646 discloses that in certain embodiments "the sorbent comprises from about

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[1129] EX1012 (Olson-646) at Claim 30.

1 to about 30 grams promoter per 100 grams of base activated carbon."[1130] A person of skill in the art would have looked to the Olson-646 reference to further understand the relationship between the halogen and activated carbon disclosed by Sjostrom. Specifically, a POSITA would have understood that the activated-carbon sorbent of Sjostrom would have "comprise[d] from about 1 to about 30 grams promoter per 100 grams of base activated carbon" after the activated-carbon sorbent made contact with the "Br" promoter.

3. Claim 5: "The method of claim 1, wherein the combustion chamber comprises the halogen or halide promoter."

699. As discussed in Ground B1 above, this limitation is disclosed by Sjostrom. My analysis with regards to the disclosure of Sjostrom regarding this element for Ground B1 applies equally here.

4. Claim 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."

700. As discussed in Ground B1 above, this limitation is rendered obvious by Sjostrom. My analysis with regards to the disclosure of Sjostrom regarding this element for Ground B1 applies equally here.

[1130] EX1012 (Olson-646) ¶[0014]; *see also* EX1012 (Olson-646) ¶[0018], Claims 3, 17.

701. In addition, this limitation is also obvious over Sjostrom in view of Olson-646 for the same reasons discussed above for Claim Element 1(b). Olson-646 teaches "wherein the halogen/halide promoter is in gaseous or vapor form" that comprises "gaseous HBr or Br_2."[1131] A POSITA desiring to determine the particular "Br" compounds at either location of Sjostrom, would have been motivated to try other forms of bromide (to create the gas-phase HBr in the combustion chamber), for reasons discussed in the Reasons to Combine section. Sjostrom discloses the location of adding Br-containing halogens (i.e., to the coal), and Olson-646 identifies which types of Br-containing halogens would be effective in the gas-phase when contacting activated carbon downstream of the combustion chamber.

5. **Claim 7: "The method of claim 1, wherein the promoter is contacted with the sorbent in vapor form, gaseous form, liquid form, or in an organic solvent."**

702. This limitation is obvious over Sjostrom in view of Olson-646. Sjostrom described testing mercury removal from flue gas of coal-fired power plants involving sorbent injection, halogen injection, and both sorbent and halogen

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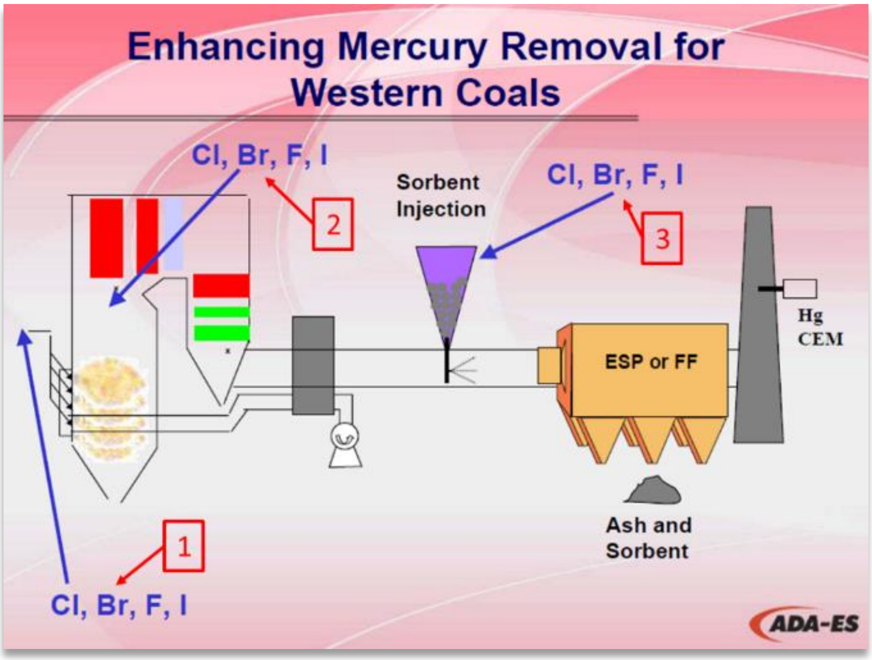
[1131] EX1012 (Olson-646) ¶[0066].

injection.[1132] Specifically, the annotated figure below shows that Sjostrom teaches injection of bromine in at least three locations throughout the process.[1133]



A POSITA would have understood that at combustion temperatures found within the boiler, at least a portion of the aqueous calcium bromide injected at either Location 1 or Location 2 would have vaporized and reacted in the combustion chamber, leaving the boiler as HBr in the vapor phase. Olson-646 teaches embodiments "wherein the halogen/halide promoter is in gaseous or vapor form" that comprises "gaseous HBr or Br_2."[1134] While Olson-646 does not disclose adding

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[1132] EX1010 (Sjostrom) at 4.

[1133] EX1010 (Sjostrom) at 4 (annotations in red).

[1134] EX1012 (Olson-646) ¶[0066].

HBr or Br_2 to the combustion chamber or coal, a POSITA would have looked to Olson to identify the effectiveness of HBr and Br_2 in promoting activated carbon.

6. Claim 8: "The method of claim 1, further comprising injecting a secondary material into the mercury-containing gas downstream of the combustion chamber."

703. As discussed in Ground B1 above, this limitation is disclosed by Sjostrom. My analysis with regards to the disclosure of Sjostrom regarding this element for Ground B1 applies equally here.

704. In addition, this limitation is also obvious over Sjostrom in view of Olson-646. Olson-646 repeatedly refers to a "secondary component," which a POSITA would have understood is another term for "secondary material."[1135] Olson- 646 provides more detail of injecting a secondary material into flue gas in Figure 3, reproduced below.[1136]

[1135] EX1012 (Olson-646) ¶¶[0011], [0014], [0015], [0017], Claims 4-8, 11, 24-27, 38-43.

[1136] EX1012 (Olson-646) ¶[0056], Figure 3.

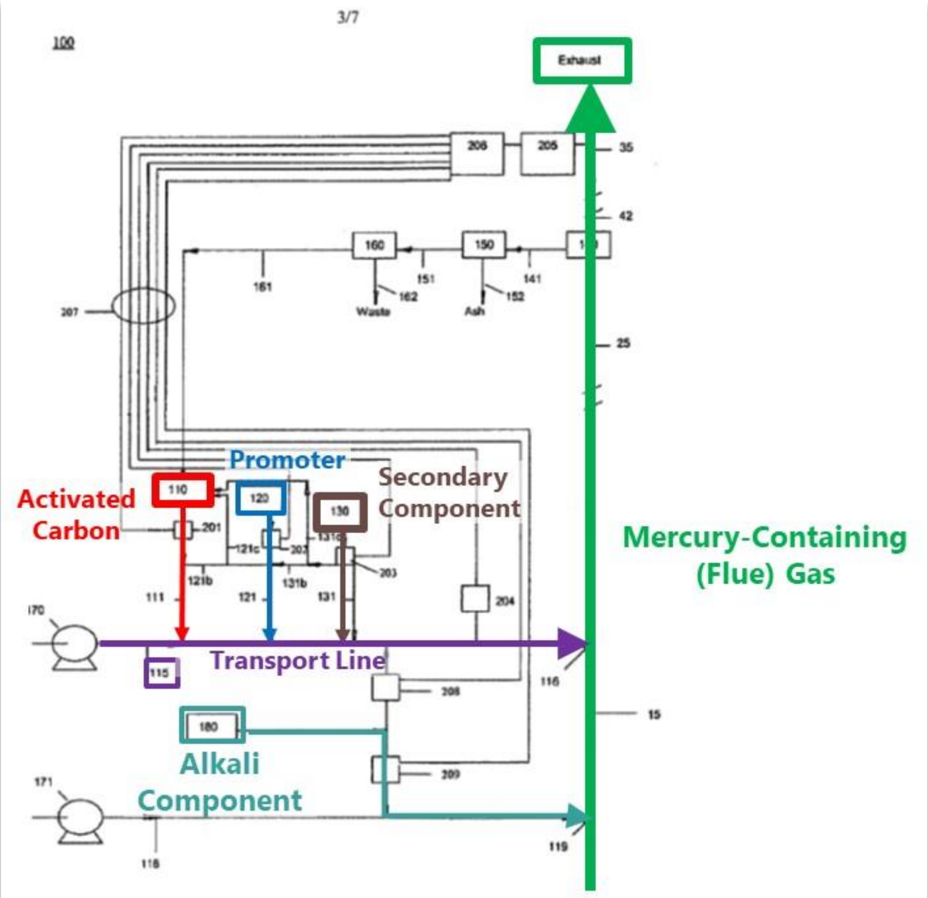

FIG. 3

Figure 3 of Olson-646 shows a schematic of "mercury control system 100 comprising preparation of promoted carbon sorbents," which includes "an optional secondary component reservoir 130, and an optional akali [*sic*] component reservoir 180."[1137] Specifically, Olson-646 teaches that "the optional secondary component may be contacted and react directly in transport line 115 via line 131, or optionally

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[1137] EX1012 (Olson-646) ¶[0056].

as described above with respect to the halogen/halide, via lines 131b and 131c."[1138] As shown in Figure 3, transport line 115 leads into flue gas stream 15. The secondary materials (such as alkali components) enhance the mercury-removal ability of the activated carbon as follows:

> Without wishing to be bound by any particular theory, the Synergy observed in the improved performance when co-injecting the two materials can be explained as follows. First, tests indicate that binding sites on AC can be consumed by Sulfur species and other contaminants. The alkali material interacts and reacts with these species thus minimizing their consumption of AC mercury binding sites. Second, other work has shown that standard AC will continue to oxidize mercury even though the binding sites are fully consumed. This oxidized mercury can then react with alkali material and subsequently be captured by the particulate control device. Thus, combining alkali with treated and/or non-treated AC synergistically takes advantage of these two mechanisms, resulting in improved mercury capture at reduced costs.[1139]

705. Olson-646 teaches that in certain embodiments, the "optional secondary component compris[es] a halogen or a hydrohalide."[1140] Olson-646 explains that these secondary components are added "such that the reactivity and mercury capacity of the sorbent are enhanced."[1141] A POSITA would have desired

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[1138] EX1012 (Olson-646) ¶[0063].

[1139] EX1012 (Olson-646) ¶[0128].

[1140] EX1012 (Olson-646) ¶[0014]; *see also* EX1012 (Olson-646) at Claim 4.

[1141] EX1012 (Olson-646) ¶[0014]; *see also* EX1012 (Olson-646) at Claim 4.

to lower the cost of mercury removal by increasing the reactivity and capacity of the activated-carbon sorbent of Sjostrom, thereby requiring less expensive activated-carbon sorbent to obtain the same mercury removal rates. Thus, a POSITA would have been motivated to use the optional secondary components of Olson-646 "to further increase reactivity and mercury capacity."[1142]

706. As previously discussed, Sjostrom teaches injection of bromine in one or more of at least three locations throughout the coal-combustion process.[1143] Location 3 of Sjostrom teaches adding bromine or other halogens to the activated-carbon sorbent that is injected into the flue gas, downstream of the combustion chamber.[1144] Thus, a POSITA would have had a reasonable expectation of success in adding the optional secondary component of Olson-646 to Location 3 of Sjostrom as they are described in both references as the location for simultaneous injection of sorbent and halogen.

[1142] EX1012 (Olson-646) ¶[0011].

[1143] EX1010 (Sjostrom) at 4.

[1144] EX1010 (Sjostrom) at 4.

7. Claim 9: "The method of claim 8, wherein the secondary material comprises a halogen, a compound derived from a halogen, a hydrohalide, a compound comprising a Group V or Group VI element and a molecular halogen, or a combination thereof."

707. As discussed in Ground B1 above, this limitation is disclosed by Sjostrom. My analysis with regards to the disclosure of Sjostrom regarding this element for Ground B1 applies equally here.

708. In addition, this limitation is also obvious over Sjostrom in view of Olson-646. Olson discloses embodiments wherein "the optional secondary component is selected from the group consisting of Group V halides, Group VI halides, HI, HBr, HCl, and combinations thereof."[1145] Olson-646 discloses other embodiments wherein "the optional secondary component is selected from the group consisting of iodine, hydrohalides, Group V halides, Group VI halides, and combinations thereof."[1146]

8. Claim 10: "The method of claim 1, wherein the sorbent material injected into the mercury-containing gas further comprises a non-carbon sorbent material."

709. This claim is obvious over Sjostrom in view of Olson-646. Olson-646 teaches "co-injecting an optional alkaline material, including without limitation

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[1145] EX1012 (Olson-646) ¶[0017]; *see also* EX1012 (Olson-646) at Claim 7.

[1146] EX1012 (Olson-646) ¶[0025]; *see also* EX1012 (Olson-646) at Claim 39.

alkaline and alkaline earth components."[1147] Claims 31 and 40 of Olson-646 further disclose "co-injecting an optional alkaline component into the mercury containing flue gas stream."[1148] Olson-646 teaches that the alkaline material is used "to improve the efficiency of mercury capture by capturing oxidized mercury and/or capturing gaseous components that might otherwise reduce sorbent capacity."[1149] The secondary materials (such as alkali components) enhance the mercury-removal ability of the activated carbon as follows:

> Without wishing to be bound by any particular theory, the Synergy observed in the improved performance when co-injecting the two materials can be explained as follows. First, tests indicate that binding sites on AC can be consumed by Sulfur species and other contaminants. The alkali material interacts and reacts with these species thus minimizing their consumption of AC mercury binding sites. Second, other work has shown that standard AC will continue to oxidize mercury even though the binding sites are fully consumed. This oxidized mercury can then react with alkali material and subsequently be captured by the particulate control device. Thus, combining alkali with treated and/or non-treated AC synergistically takes advantage of these two mechanisms, resulting in improved mercury capture at reduced costs.[1150]

[1147] EX1012 (Olson-646) ¶[0026].

[1148] EX1012 (Olson-646) at claims 31, 40.

[1149] EX1012 (Olson-646) ¶[0026].

[1150] EX1012 (Olson-646) ¶[0128].

The optional component acts as a sorbent in that it adsorbs other species that would compete with mercury for the activated-carbon binding sites. Thus, Olson-646 discloses "wherein the sorbent material injected into the mercury-containing gas further comprises a non-carbon sorbent material." A person of skill in the art would have been motivated to use co-injection of an alkaline sorbent as taught by Olson-646 in combination with activated carbon injection of Sjostrom as Olson-646 teaches that its use "improve[s] the efficiency of mercury capture."[1151]

9. Claim 11: "The method of claim 10, wherein the non-carbon sorbent material comprises at least one of a porous felsic material, a vesicular felsic material, a porous basaltic material, a vesicular basaltic material, a clay-based compound, an alkaline compound, a calcium hydroxide compound, a sodium acetate compound, and a bicarbonate compound."

710. This claim is obvious over Sjostrom in view of Olson-646. Olson-646 teaches "co-injecting an optional alkaline material, including without limitation alkaline and alkaline earth components."[1152] Olson-646 further discloses that "the optional alkaline material may preferably comprise calcium oxide, sodium carbonate, and the like, as are known in the art."[1153] Olson-646 also discloses that

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[1151] EX1012 (Olson-646) ¶[0026].

[1152] EX1012 (Olson-646) ¶[0026].

[1153] EX1012 (Olson-646) ¶[0026].

"co-injecting lime with activated carbon vastly improved mercury removal."[1154] The examples provided in Olson-646 of "calcium oxide" and "lime" are examples of alkaline compounds.

10. Claim 12: "The method of claim 1, wherein the activated carbon comprises powdered activated carbon, granular activated carbon, or a combination thereof."

711. As discussed in Ground B1 above, this limitation is disclosed by Sjostrom. My analysis with regards to the disclosure of Sjostrom regarding this element for Ground B1 applies equally here. Olson-646 also discloses this limitation near-verbatim.[1155]

11. Claim 13: "The method of claim 1, wherein the sorbent material injected into the mercury-containing gas is substantially free of halogen and halide promotion."

712. As discussed in Ground B1 above, this limitation is rendered obvious by Sjostrom. My analysis with regards to the disclosure of Sjostrom regarding this element for Ground B1 applies equally here.

[1154] EX1012 (Olson-646) ¶[0127].

[1155] EX1012 (Olson-646) at cl. 2.

12. Claim 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."

713. As discussed in Ground B1 above, this limitation is rendered obvious by Sjostrom. My analysis with regards to the disclosure of Sjostrom regarding this element for Ground B1 applies equally here.

714. In addition, this limitation is also obvious over Sjostrom in view of Olson-646. Sjostrom and Olson use the same brand name of commercial product—Norit Darco FGD sorbent.[1156] And similar to Injection Point 3 of Sjostrom, Olson-646 teaches first promoting a base activated carbon (item 10) with a bromine promoter (items 20, 40), and then injecting the "promoted carbon sorbent" into the mercury-containing flue gas (item 50).[1157]

[1156] EX1010 (Sjostrom) at 15, 16; EX1012 (Olson-646) ¶[0095].

[1157] EX1012 (Olson-646) at Figure 1, ¶¶[0045]-[0048].

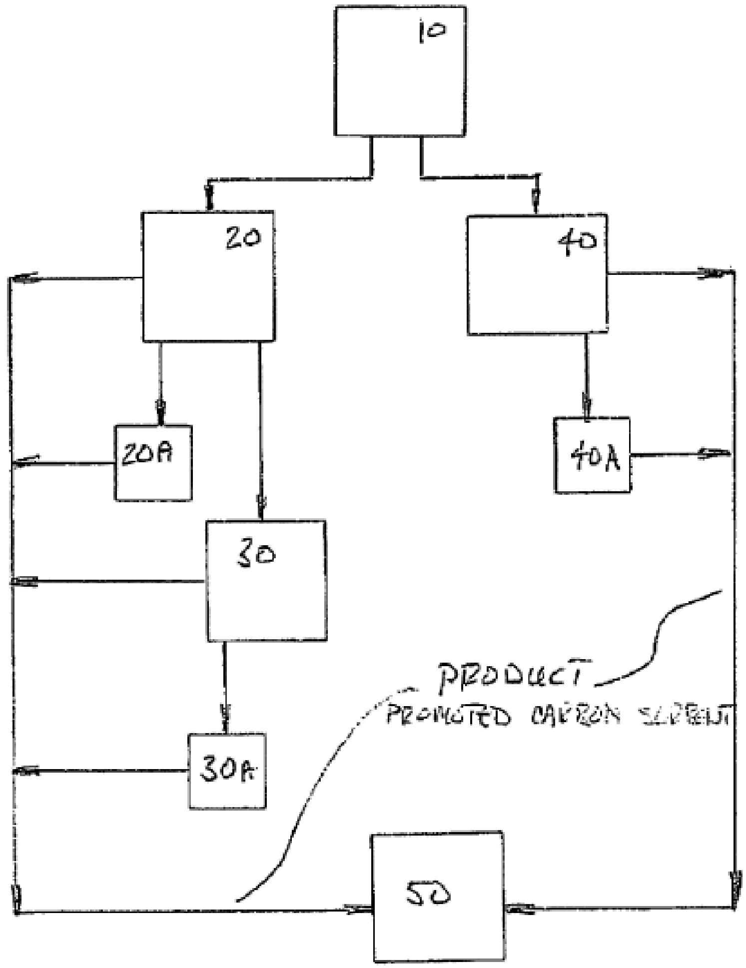


FIG. 1

715. A POSITA would have been motivated to try adding bromine at Injection Points 1 or 2, as taught by Sjostrom, and also adding bromine to the sorbent before injecting at Injection Point 3, as taught by both Sjostrom and Olson-646—particularly for coals with higher native mercury content (or lower native halogen content and/or lower unburned carbon in fly ash) in order to further reduce total mercury emissions. In situations where additional mercury capture was required, a POSITA would have been motivated to inject, or at least try injecting, "Br" at

Location 1 or 2 while adding a treated activated-carbon sorbent to the flue gas downstream of the boiler (e.g., at Location 3). A POSITA would have known that this approach would have increased overall mercury capture, albeit at an increased cost compared to using bromine only at Injection Points 1 and 2.

13. Claim 15: "The method of claim 1, wherein the combustion chamber comprises a boiler."

716. As discussed in Ground B1 above, this limitation is disclosed by Sjostrom. My analysis with regards to the disclosure of Sjostrom regarding this element for Ground B1 applies equally here.

14. Claim 16: "The method of claim 1, wherein the mercury-containing gas is a flue gas."

717. As discussed in Ground B1 above, this limitation is disclosed by Sjostrom. My analysis with regards to the disclosure of Sjostrom regarding this element for Ground B1 applies equally here.

15. Claim 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."

718. As discussed in Ground B1 above, this limitation is obvious over Sjostrom. My analysis with regards to the disclosure of Sjostrom regarding this element for Ground B1 applies equally here.

16. Claim 18: "The method of claim 1, wherein the injection of the sorbent material into the mercury-containing gas occurs upstream of a particulate separator or a scrubber."

719. As discussed in Ground B1 above, this limitation is disclosed by Sjostrom. My analysis with regards to the disclosure of Sjostrom regarding this element for Ground B1 applies equally here. In addition, this limitation is also obvious over Sjostrom in view of Olson-646. Olson646 says, "When particle injection is employed, the mercury captured on the Sorbent particles is removed from the gas stream in a bag house or electrostatic precipitator (ESP) and collected along with ash particulate."[1158] A POSITA would recognize this description as an instruction to position ACI upstream of a particulate separator.

17. Claims 19 and 20

Claim 19: "The method of claim 1, wherein the coal comprises added halide sorbent enhancement additive."

Claim 20: "The method of claim 1, wherein the combustion chamber comprises added Br_2, HBr, Br^-, or a combination thereof."

720. As discussed in Ground B1 above, these limitations are rendered obvious by Sjostrom. My analysis with regards to these claims for Ground B1 applies equally here.

[1158] EX1012 (Olson-646) ¶[0007].

721. In addition, these limitations are also obvious over Sjostrom in view of Olson-646. As described above, a POSITA would have been motivated, and expected a reasonable chance of success, to apply the teachings of Olson-646 (e.g., the injection of HBr or Br_2) to the system of Sjostrom, as discussed in the Reasons to Combine section. Olson-646 explains that the "invention provides for cost-effective removal of pollutants including mercury, using sorbent enhancement additives."[1159] Thus, a POSITA would have understood that Olson-646 referred to the HBr or Br_2 as sorbent enhancement additives. A POSITA would have been motivated, and expected a reasonable chance of success, to use a "Br" in Sjostrom that upon combustion would yield HBr or Br_2 (which Olson-646 identifies as effective gas-phase promoters).

18. Claim 21: "The method of claim 1, wherein the coal comprises added sorbent enhancement additive that comprises Br^-."

722. As discussed in Ground B1 above, this limitation is obvious in view of Sjostrom. My analysis with regards to the disclosure of Sjostrom regarding this element for Ground B1 applies equally here.

[1159] EX1012 (Olson-646) ¶[0009].

19. Claim 22: "The method of claim 21, wherein the sorbent enhancement additive comprises a bromide compound."

723. As discussed in Ground B1 above, this limitation is obvious in view of Sjostrom. My analysis with regards to the disclosure of Sjostrom regarding this element for Ground B1 applies equally here.

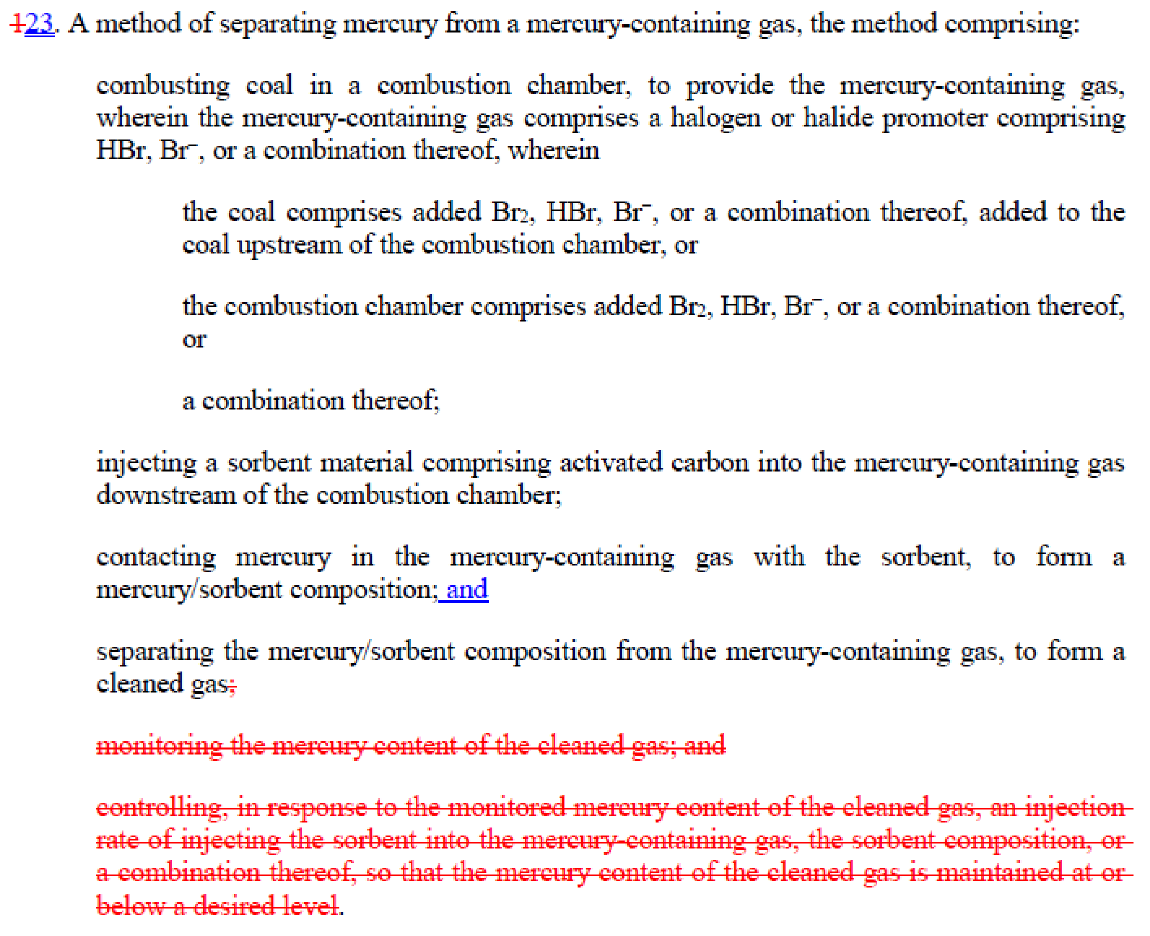
724. This limitation is further obvious over Olson-646, which "provides a cost-effective way to capture pollutants by utilizing exceptionally reactive halogen/halide promoted carbon sorbents using a bromide (or other halogen/halide) treatment of the carbon, that capture mercury via mercury-sorbent surface reactions, at very short contact times of seconds or less."[1160] Olson-646 teaches embodiments "wherein the halogen/halide promoter is in gaseous or vapor form" that comprises "gaseous HBr or Br_2."[1161] A POSITA would have understood that HBr is one type of bromide compound. As described above in Reasons to Combine, a POSITA would have been motivated, and expected a reasonable chance of success, to apply the teachings of Olson-646 (e.g., the injection of HBr) to the system of Sjostrom. While Olson-646 does not expressly disclose adding HBr or Br_2 to the coal, it does identify the effectiveness of gas-phase HBr promoting activated carbon in the mercury-containing gas.

[1160] EX1012 (Olson-646) ¶[0043].

[1161] EX1012 (Olson-646) ¶[0066].

D. INDEPENDENT CLAIM 23

725. As shown in the redline below, Claim 23 is nearly identical to claim 1, except that Claim 23 removes limitations.



~~1~~23. A method of separating mercury from a mercury-containing gas, the method comprising:

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

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;

injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber;

contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition; and

separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas~~;~~

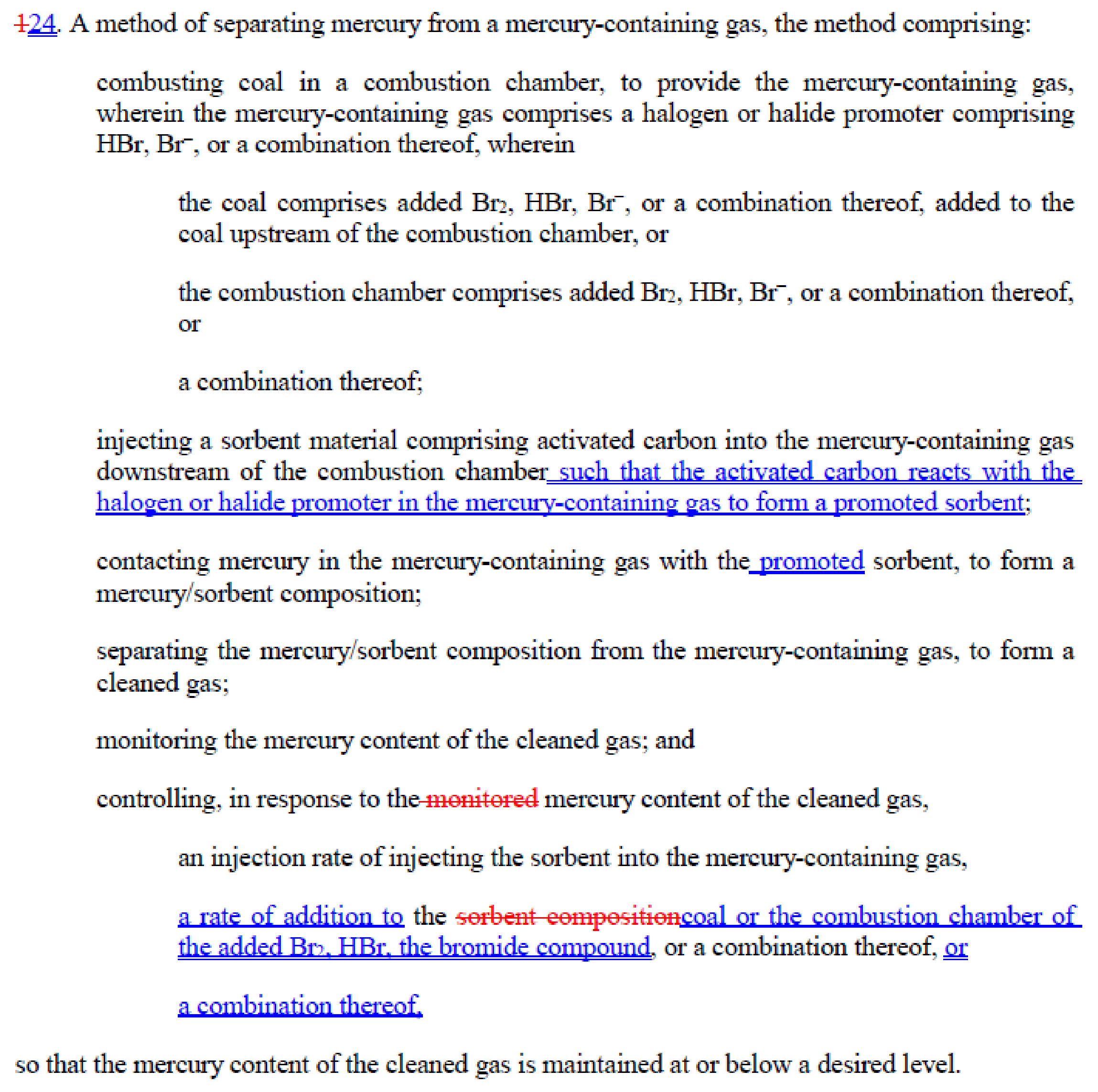
~~monitoring the mercury content of the cleaned gas; and~~

~~controlling, in response to the monitored mercury content of the cleaned gas, an 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~~.

Accordingly, my analysis provided for claim 1 applies to claim 23.

E. INDEPENDENT CLAIM 24

726. As shown in the redlines below, claim 24 is nearly identical to claim 1, with minor changes.



~~1~~24. A method of separating mercury from a mercury-containing gas, the method comprising:

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

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;

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;

contacting mercury in the mercury-containing gas with the promoted sorbent, to form a mercury/sorbent composition;

separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas;

monitoring the mercury content of the cleaned gas; and

controlling, in response to the ~~monitored~~ mercury content of the cleaned gas,

an injection rate of injecting the sorbent into the mercury-containing gas,

a rate of addition to the ~~sorbent composition~~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.

Accordingly, my analysis provided for claim 1 applies to claim 24.

1. Claim 24: Preamble—"A method of separating mercury from a mercury-containing gas, the method comprising:"

727. The language of the preamble of claim 24 is identical to the preamble of claim 1. Accordingly, the explanation I provide above for the preamble of claim 1 applies equally to the preamble of claim 24.

2. Claim 24: Element 24(a)—"combusting coal in a combustion chamber, to provide the mercury-containing gas,"

728. The language of Claim Element 24(a) is identical to the language of Claim Element 1(a). Accordingly, the explanation I provide above for Claim Element 1(a) applies equally to Claim Element 24(a).

3. Claim 24: Element 24(b)—"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 coal upstream of the combustion chamber, or the combustion chamber comprises added Br_2, HBr, Br^-, or a combination thereof, or a combination thereof;"

729. The language of Claim Element 24(b) is identical to the language of Claim Element 1(b). Accordingly, the explanation I provide above for Claim Element 1(b) applies equally to Claim Element 24(b).

4. Claim 24: Element 24(c)—"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; contacting mercury in the mercury-containing gas with the promoted sorbent, to form a mercury/sorbent composition;"

730. The language of Claim Element 24(c) is similar to the language of Claim Element 1(c), and I refer to my discussion of that Claim Element. Claim 24(c) adds the requirement that "the activated carbon reacts with the halogen or halide

promoter in the mercury-containing gas to form a promoted sorbent." As discussed in Ground B1 above, this additional limitation is disclosed by Sjostrom. My analysis with regards to the disclosure of Sjostrom regarding this element for Ground B1 applies equally here.

731. This additional limitation is also disclosed by Olson-646. When bromine and carbon come into contact with each other, as in Sjostrom and Olson-646, a POSITA would have understood that this is a disclosure that they react to form a promoted sorbent.[1162] For example, Olson-646 explains that Figure 2 of Olson-646, reproduced below, shows "a theory developed from scientific evidence to explain the nature of the promoting compounds."[1163]

[1162] Technology Background and State of the Art, §IX.C.3, § IX.G.2.

[1163] EX1012 (Olson-646) ¶[0054].

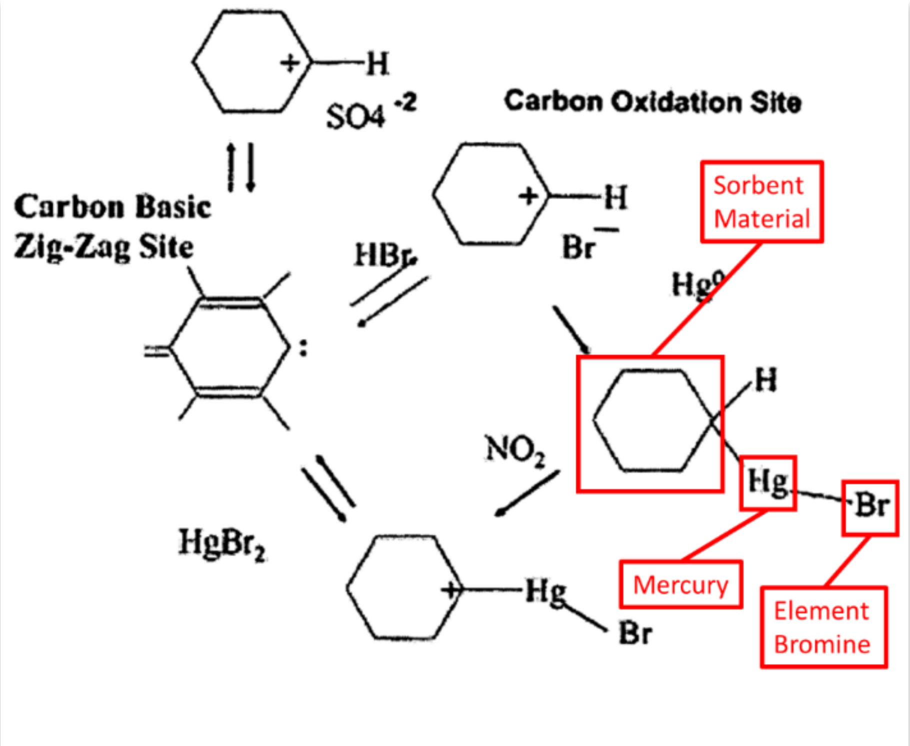


FIG. 2

Olson-646 explains that "hydrogen bromide <u>reacts wit</u>h the unsaturated structure of the activated carbon."[1164] Olson-646 teaches that the reaction may take place at "a carbene species on the edge of the graphene sheet structures of the carbon."[1165] Further, Olson-646 explains that "[m]olecular bromine or a bromine compound reacts to form a similar structure, with a positive carbon that is active for oxidizing the mercury with subsequent capture by the sorbent."[1166] Figure 2 of Olson-646

[1164] EX1012 (Olson-646) ¶[0054].

[1165] EX1012 (Olson-646) ¶[0054].

[1166] EX1012 (Olson-646) ¶[0054].

shows that once the bromine/activated carbon complex contacts mercury, it chemically reacts with (e.g., adsorbs) the mercury.

732. A person of skill in the art would have looked to the Olson-646 reference to further understand the relationship between the halogen and activated carbon disclosed by Sjostrom. Specifically, a POSITA would have understood that the activated-carbon sorbent of Sjostrom would have made contact and reacted with the "Br" promoter. Olson-646 further renders obvious that halogen and sorbent would make contact and react with one another (and with mercury), such that "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."

5. Claim 24: Element 24(d)—"separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas;"

733. The language of Claim Element 24(d) is identical to the language of Claim Element 1(d). Accordingly, the explanation I provide above for Claim Element 1(d) applies equally to Claim Element 24(d).

6. Claim 24: Element 24(e)—"monitoring the mercury content of the cleaned gas; and"

734. The language of Claim Element 24(e) is identical to the language of Claim Element 1(e). Accordingly, the explanation I provide above for Claim Element 1(e) applies equally to Claim Element 24(e).

7. Claim 24: Element 24(f)(1)—"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 Br2, HBr, the bromide compound, or a combination thereof, or a combination thereof,"

735. The language of Claim Element 24(f)(1) is similar to the language of Claim Element 1(f)(1), and I refer to my discussion of that claim element. Claim 24(f)(1) has the following changes, as compared to Claim Element 1(f)(1):

> controlling, in response to the monitored mercury content of the cleaned gas,
>
> an injection rate of injecting the sorbent into the mercury-containing gas,
>
> ~~the sorbent composition,~~
>
> 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,

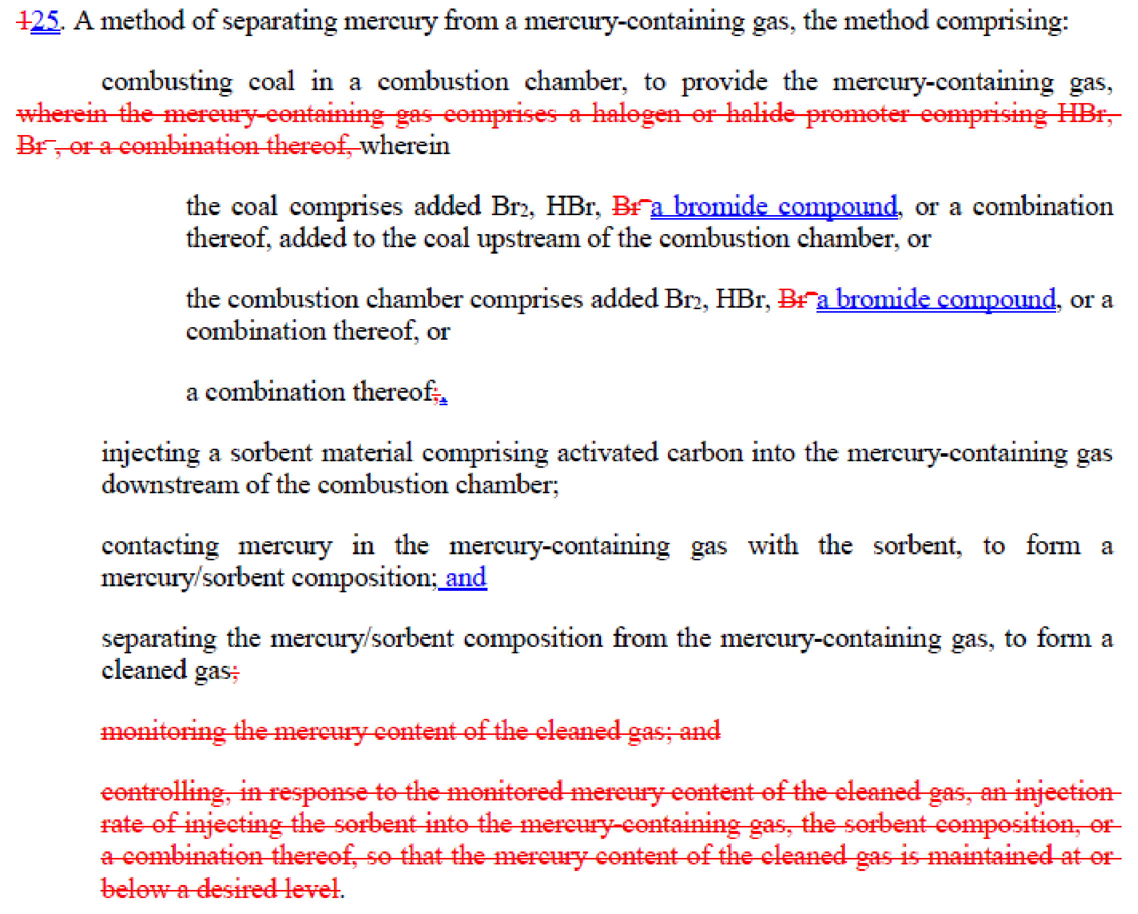
Claim Element 24(f)(1) is disclosed because both Sjostrom and Olson-646 disclose controlling the injection rate of the sorbent into the mercury containing gas in response to the monitored mercury content, as I describe for Claim Element 1(f)(1).

8. Claim 24: Element 24(f)(2)—"so that the mercury content of the cleaned gas is maintained at or below a desired level."

736. The language of Claim Element 24(f)(2) is identical to the language of Claim Element 1(f)(2). Accordingly, the explanation I provide above for Claim Element 1(f)(2) applies equally to Claim Element 24(f)(2).

F. INDEPENDENT CLAIM 25

737. As shown in the redline below, claim 25 is nearly identical to claim 1, except that it removes limitations and replaces "Br-" with "a bromide compound."



~~1~~25. A method of separating mercury from a mercury-containing gas, the method comprising:

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

the coal comprises added Br_2, HBr, ~~Br$^-$~~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, ~~Br$^-$~~a bromide compound, or a combination thereof, or

a combination thereof~~;~~,

injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber;

contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition; and

separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas~~;~~

~~monitoring the mercury content of the cleaned gas; and~~

~~controlling, in response to the monitored mercury content of the cleaned gas, an 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~~.

Accordingly, my analysis provided for claim 1 applies to claim 25.

1. Claim 25: Preamble—"A method of separating mercury from a mercury-containing gas, the method comprising:"

738. The language of the preamble of claim 25 is identical to the preamble of claim 1. Accordingly, the explanation I provide above for the preamble of claim 1 applies equally to the preamble of claim 25.

2. Claim 25: Element 25(a)—"combusting coal in a combustion chamber, to provide the mercury-containing gas, wherein"

739. The language of Claim Element 25(a) is identical to the language of Claim Element 1(a). Accordingly, the explanation I provide above for Claim Element 1(a) applies equally to Claim Element 25(a).

3. Claim 25: Element 25(b)—"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 combination thereof,"

740. The language of Claim Element 25(b) is similar to the language of Claim Element 1(b), and I refer to my discussion of that Claim Element. Claim 25(b) has the following changes, as compared to Claim Element 1(b):

> 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^-,~~ 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, ~~Br^-, ~~a bromide compound, or a combination thereof,
>
> or a combination thereof;

Unlike claim 1, claim 25 does not recite that "the mercury containing gas comprises a halogen or halogen promoter …" Further, claim 25 recites "a bromide compound" in place of "Br^-." A POSITA would have understood that Sjostrom's "Br" teaches the use of bromide compounds as presently claimed.[1167] Furthermore, as described above in the Reasons to Combine section, a POSITA would have been motivated, and expected a reasonable chance of success, to select an appropriate "Br" of Sjostrom to yield gas-phase HBr or Br_2.

4. Claim 25: Element 25(c)—"injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber; contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition; and"

741. The language of Claim Element 25(c) is identical to the language of Claim Element 1(c). Accordingly, the explanation I provide above for Claim Element 1(c) applies equally to Claim Element 25(c).

[1167] EX1010 (Sjostrom) at 4.

5. Claim 25: Element 25(d)—"separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas."

742. The language of Claim Element 25(d) is identical to the language of Claim Element 1(d). Accordingly, the explanation I provide above for Claim Element 1(d) applies equally to Claim Element 25(d).

G. CLAIMS DEPENDING FROM CLAIM 25

1. Claim 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."

743. The language of claim 26 is similar to the language of claim 6, and I refer to my discussion of that claim. Claim 26 has the following changes, as compared to claim 6:

> wherein the coal comprises the added Br_2, HBr, ~~Br^-,~~ the bromide compound or a combination thereof, added to the coal upstream of the combustion chamber

A POSITA would have understood that Sjostrom's "Br" teaches the use of bromide compounds as presently claimed.[1168] Thus, Sjostrom discloses this element for the same reasons it discloses Claim 6.

744. Furthermore, as described above in the Reasons to Combine section, a POSITA would have been motivated, and expected a reasonable chance of success,

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[1168] EX1010 (Sjostrom) at 4.

to apply the teachings of Olson-646 (e.g., the injection of HBr or Br_2) to the system of Sjostrom. While Olson-646 does not disclose adding HBr or Br_2 to the combustion chamber or coal, it does describe the effectiveness of HBr and Br_2 in promoting activated carbon.

2. Claim 27: "The method of claim 25, wherein the combustion chamber comprises the added Br_2, HBr, the bromide compound, or a combination thereof."

745. The language of claim 27 is similar to the language of claim 20, and I refer to my discussion of that claim. Claim 27 has the following changes, as compared to claim 20:

> wherein the combustion chamber comprises the added Br_2, HBr, ~~Br^-, ~~the bromide compound, or a combination thereof."

A POSITA would have understood that Sjostrom's "Br" teaches the use of bromide compounds as presently claimed.[1169] Thus, Sjostrom discloses this element for the same reasons it discloses Claim 20.

746. Furthermore, as described above in the Reasons to Combine section, a POSITA would have been motivated, and expected a reasonable chance of success, to apply the teachings of Olson-646 (e.g., the injection of HBr or Br_2) to the system of Sjostrom. While Olson-646 does not disclose adding HBr or Br_2 to the

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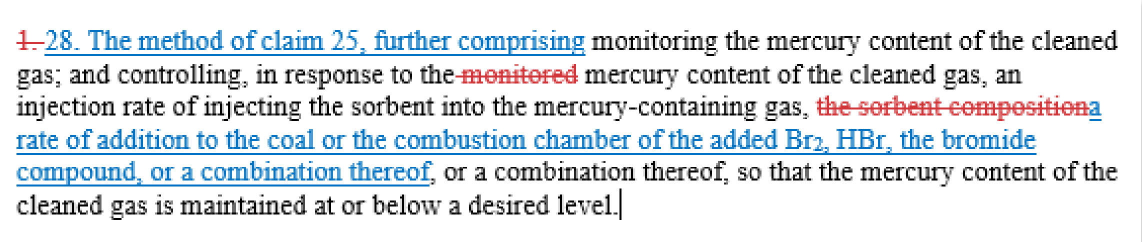
[1169] EX1010 (Sjostrom) at 4.

combustion chamber or coal, it does describe the effectiveness of HBr and Br_2 in promoting activated carbon.

3. Claim 28: "The method of claim 25, further comprising monitoring the mercury content of the cleaned gas; and 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 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."

747. The language of claim 28 is similar to the language of Claim Elements 1(e), 1(f)(1), and 1(f)(2), and I refer to my discussion of those Claim Elements. A redline of these changes is shown below, comparing claim 28 to Claim Elements 1(e), 1(f)(1), and 1(f)(2):



~~1.~~ 28. The method of claim 25, further comprising monitoring the mercury content of the cleaned gas; and controlling, in response to the ~~monitored~~ mercury content of the cleaned gas, an injection rate of injecting the sorbent into the mercury-containing gas, ~~the sorbent composition~~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.

Claim 28 is disclosed because Sjostrom discloses monitoring the mercury emissions levels and controlling the injection rate of the sorbent into the mercury containing gas to maintain the mercury emissions levels at or below a desired level, as discussed above for Elements 1(e) and 1(f).

4. <u>Claim 29: "The method of claim 25, wherein the mercury-containing gas comprises about 1 g to about 30 g of the element bromine per 100 g of the sorbent."</u>

748. This limitation is obvious over Sjostrom in view of Olson-646. Olson-646 includes repeated discussion of this ratio of the halogen or halide promoter to the sorbent material. For example, Olson-646 discusses embodiments wherein "the promoter is added at from about 1 to about 30 grams per 100 grams of activated carbon."[1170] This limitation also appears repeatedly in the claims of Olson-646.[1171] Olson-646 also discloses an embodiment wherein "the injected sorbent is prepared in-flight by reacting an activated carbon and a promoter within a pneumatic transport line from which the reaction product is injected to the mercury-containing flue gas stream."[1172] In that embodiment, Olson-646 explains that "the promoter is added at from about 1 to about 30 grams per 100 grams of activated carbon."[1173]

749. Claim 29 is merely an attempt to claim the optimum or workable range for a process of combining a particular conventional halogen (bromine) being used in a conventional way (halogens are inherent to coal, and both oxidize mercury and

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[1170] EX1012 (Olson-646) ¶[0023].

[1171] EX1012 (Olson-646) at Claims 37, 47.

[1172] EX1012 (Olson-646) ¶[0027].

[1173] EX1012 (Olson-646) ¶[0027].

promote activated carbon) with a conventional sorbent (activated carbon). Nothing about the particular range of 1 g to about 30 g of the halide promoter per 100 g of the sorbent would lead to an unexpected result from what was already known to one of skill in the art.

750. Through routine process optimization and routine experimentation, a person of ordinary skill in the art would have adjusted the rate of addition of bromine-containing species and/or activated carbon injection rate to achieve about 1 g to about 30 g of halide promoter per 100g of carbon sorbent in the flue gas.[1174]

5. Claim 30: "The method of claim 25, wherein the mercury/sorbent composition comprises the element bromine, the sorbent material, and mercury."

751. As discussed in Ground B1 above, this limitation is disclosed by Sjostrom. My analysis with regards to the disclosure of Sjostrom regarding this element for Ground B1 applies equally here.

752. In addition, this limitation is also obvious over Sjostrom in view of Olson-646. For example, Figure 2 of Olson-646, reproduced below, shows "a theory developed from scientific evidence to explain the nature of the promoting compounds."[1175]

[1174] Patent Owner's expert, Mr. O'Keefe, agrees. EX1092 (O'Keefe Report) at 153, 158.

[1175] EX1012 (Olson-646) ¶[0054], Figure 2.

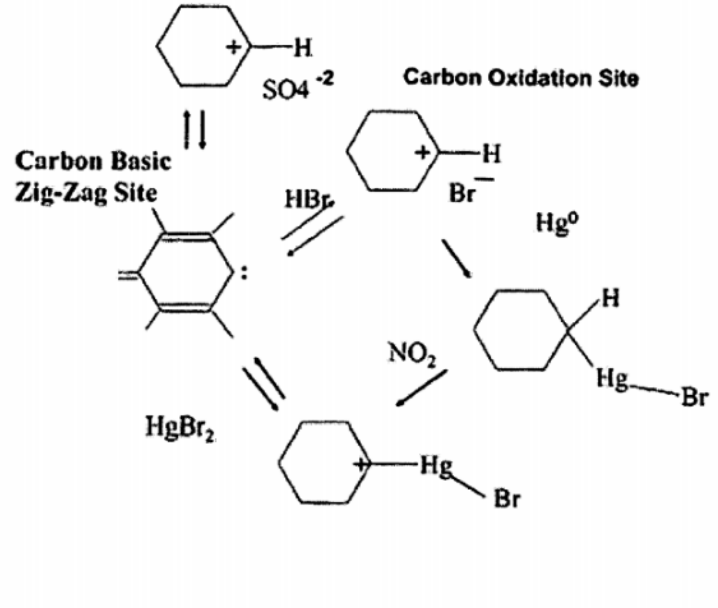

FIG. 2

As described for Element 1(b), at combustion temperatures found within the boiler, at least a portion of the Br injected at either Location 1 or Location 2 of Sjostrom would have vaporized and reacted to form HBr in the combustion chamber, leaving the boiler as HBr (hydrogen bromide) in the vapor phase. Olson-646 explains that "hydrogen bromide reacts with the unsaturated structure of the activated carbon."[1176] Olson-646 teaches that the reaction may take place at "a carbene species on the edge of the graphene sheet structures of the carbon."[1177] Further, Olson-646 explains that "[m]olecular bromine or a bromine compound reacts to form a similar structure, with a positive carbon that is active for oxidizing the mercury with subsequent capture by

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[1176] EX1012 (Olson-646) ¶[0054].

[1177] EX1012 (Olson-646) ¶[0054].

the sorbent."[1178] Figure 2 of Olson-646, annotated below, shows that the complex includes the activated-carbon sorbent, the element bromine, and the element mercury.

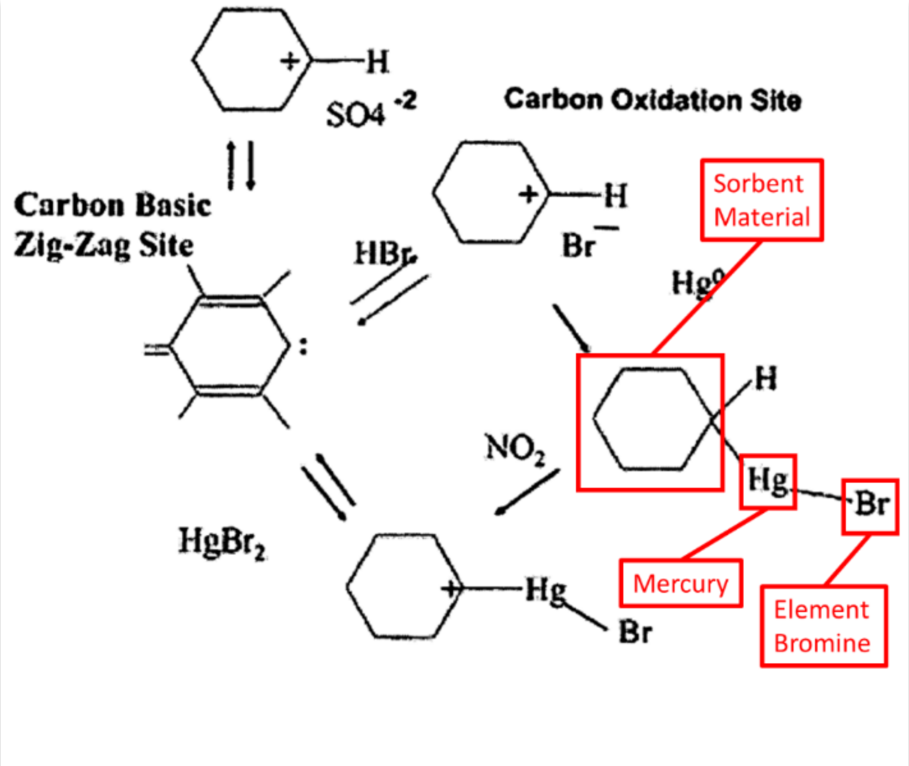

FIG. 2

753. A person of skill in the art would have looked to the Olson-646 reference to further understand the reaction and relationship already occurring between the halogen, activated carbon, and mercury disclosed by Sjostrom. Specifically, a POSITA would have understood that Sjostrom discloses a flue gas

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[1178] EX1012 (Olson-646) ¶[0054].

that would contain "Br", mercury, and activated carbon.[1179] To the extent that Sjostrom does not explicitly explain what occurs when these three components meet in the flue gas, Olson-646 provides this explanation.

XVIII. GROUND B3: ANTICIPATION BY OLSON-235

754. Because the priority date of the '114 Patent is no earlier than May 2018, Olson-235 qualifies as a prior art anticipatory reference. Olson-235 anticipates the claims below.

A. INDEPENDENT CLAIM 1

1. Element 1(Pre): "A method of separating mercury from a mercury-containing gas"

755. Olson-235 discloses the claim language verbatim.[1180]

2. Element 1(a): "combusting coal in a combustion chamber, to provide the mercury-containing gas,"

756. Olson-235 discloses "a combustion chamber that produces a mercury-containing gas."[1181] The "combustion chamber 301" combusts coal to provide the mercury-containing gas.[1182]

[1179] EX1010 (Sjostrom) at 4.

[1180] EX1018 (Olson-235) at 21:59-60

[1181] EX1018 (Olson-235) at 22:39-42.

[1182] EX1018 (Olson-235) at 17:60-18:25 & Figs. 5A-5B.

3. Element 1(b): "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 coal upstream of the combustion chamber, or the combustion chamber comprises added Br_2, HBr, Br-, or a combination thereof, or a combination thereof;"

757. Olson-235 fails to disclose that the coal comprises any bromine-containing chemicals "added to coal upstream of the combustion chamber." However, Olson-235 presents one of the claimed alternatives, that the "halogen or halide promoter is introduced … into a combustion chamber that produces a mercury-containing gas."[1183] Olson-235 refers to the "halide/halogen gas, for example, gaseous HBr or Br_2."[1184]

4. Element 1(c): "injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber; contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition"

758. Olson-235 discloses the claim language near-verbatim:

> "providing a base sorbent, either by injection or in situ creation, into a mercury-containing flue gas stream"[1185]

[1183] EX1018 (Olson-235) at 22:39-42.

[1184] EX1018 (Olson-235) at 15:34-35.

[1185] EX1018 (Olson-235) at 5:31-33.

> "carbon base sorbent may include powdered activated carbon"[1186]
>
> "When a promoted or a non-promoted base sorbent reacts with elemental or oxidized mercury, a mercury/sorbent chemical composition is formed."[1187]

5. **Element 1(d): "separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas;"**

759. Olson-235 further discloses "separating particulates from the mercury containing gas to form a cleaned gas, the particulates including ash and the mercury/sorbent chemical composition."[1188]

6. **Element 1(e): "monitoring the mercury content of the cleaned gas"**

760. Olson-235 discloses the claim language verbatim.[1189] Olson-235 also discloses "continuous measurement of mercury emissions."[1190]

[1186] EX1018 (Olson-235) at 10:53-55.

[1187] EX1018 (Olson 235) at 3:41-43.

[1188] EX1018 (Olson-235) at 22:23-25.

[1189] EX1018 (Olson-235) at 6:55-56, 7:8-9.

[1190] EX1018 (Olson-235) at 20:1-5.

7. Element 1(f): "controlling, in response to the monitored mercury content of the cleaned gas, an 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."

761. Olson-235 discloses "continuous measurement of mercury emissions as feedback to assist in control of the sorbent injection rate."[1191] Olson-235 also discloses that "the rate at which the carbon base sorbent is introduced or the rate at which the promoter is introduced or a combination thereof is adjusted according to the monitored mercury content of the cleaned gas so that the mercury content of the cleaned gas is maintained at substantially the desired level with minimal operating cost."[1192] The "rate at which the carbon base sorbent is introduced" refers to an injection rate of injecting the sorbent into the mercury-containing gas.

[1191] EX1018 (Olson-235) at 20:1-5.

[1192] EX1018 (Olson-235) at 6:64-67, 7:17-20.

B. CLAIMS DEPENDING FROM CLAIM 1

1. Claims 2-3: "removing greater than 70 wt % of the mercury in the mercury-containing gas [cl. 3—on the sorbent]"

762. Olson-235 discloses the claim language near-verbatim: "collecting greater than 70 wt % of the mercury in the flue gas on the promoted sorbent to produce a cleaned flue gas."[1193]

2. Claim 4: "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."

763. Olson-235 discloses the claim language near-verbatim: "the promoted sorbent comprises from about 1 to about 30 grams of promoter per 100 grams of base sorbent."[1194]

3. Claim 5: "the combustion chamber comprises the halogen or halide promoter."

764. This limitation is disclosed for the reasons stated above for Claim Element 1(b).

[1193] EX1018 (Olson-235) at 5:33-35.

[1194] EX1018 (Olson-235) at 5:52-54.

4. <u>Claim 7: "the promoter is contacted with the sorbent in vapor form, gaseous form, liquid form, or in an organic solvent."</u>

765. Olson-235 states that "the promoter is substantially in vapor form when combined with the base sorbent."[1195]

5. <u>Claims 8 and 9</u>

> **Claim 8: "injecting a secondary material into the mercury-containing gas downstream of the combustion chamber."**
>
> **Claim 9: "wherein the secondary material comprises a halogen, a compound derived from a halogen, a hydrohalide, a compound comprising a Group V or Group VI element and a molecular halogen, or a combination thereof"**

766. Regarding Claim 8, Olson-235 discloses that "an alkaline component is coinjected into the gas stream," which refers to the mercury-containing gas downstream of the combustion chamber.[1196] This is as "secondary component reservoir 130, and an alkali component reservoir 180," which are added "via injection point 119, into [mercury-containing] flue gas stream 15" downstream of the combustion chamber.[1197]

[1195] EX1018 (Olson-235) at 4:42-43.

[1196] EX1018 (Olson-235) at 6:43-45; also at 6:5-14.

[1197] EX1018 (Olson-235) at 13:10-42, Fig. 3.

767. Regarding Claim 8 and Claim 9, Olson-235 discloses that "halogen or halide promoter is injected into a combustion chamber" and then states that "said halogen or halide promoter is <u>additionally injected</u> downstream of the combustion chamber."[1198] This "additional" injection represents a secondary material.

6. <u>Claim 10: "The method of claim 1, wherein the sorbent material injected into the mercury-containing gas further comprises a non-carbon sorbent material."</u>

768. Olson-235 discloses "coinjecting an optional alkaline material, including without limitation alkaline and alkaline earth components, to improve the efficiency of mercury capture by capturing oxidized mercury and/or capturing gaseous components that might otherwise reduce promoted sorbent capacity. In another embodiment, the optional alkaline material may preferably comprise calcium oxide, sodium carbonate, and the like, as are known in the art."[1199] In other words, the alkaline material functions as a sorbent itself.

[1198] EX1018 (Olson-235) at 22:39-45.

[1199] EX1018 (Olson-235) at 6:5-14

7. Claim 11: "The method of claim 10, wherein the non-carbon sorbent material comprises at least one of a porous felsic material, a vesicular felsic material, a porous basaltic material, a vesicular basaltic material, a clay-based compound, an alkaline compound, a calcium hydroxide compound, a sodium acetate compound, and a bicarbonate compound."

769. Olson-235 discloses this limitation for the reasons cited for Claim 10 above. For example, Olson-235 discloses "alkaline and alkaline earth components" such as "calcium oxide, sodium carbonate, and the like." These are examples of an alkaline compound.[1200] Olson-235 also discloses this claim near verbatim:

> In an embodiment, the base sorbent for the promoted sorbent is selected from the group consisting of carbon, activated carbon, porous felsic materials, vesicular felsic materials, porous basaltic materials, vesicular basaltic materials, clay-based compounds, alkaline compounds, calcium hydroxide compounds, Sodium acetate compounds, bicarbonate compounds, and combinations thereof. [1201]

8. Claim 12: "the activated carbon comprises powdered activated carbon, granular activated carbon, or a combination thereof."

770. Olson-235 includes language almost identical to the claim language.[1202]

[1200] EX1018 (Olson-235) at 6:5-14

[1201] EX1018 (Olson-235) at 7:51-57.

[1202] EX1018 (Olson-235) at 10:53-55.

9. Claim 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."

771. Olson-235 discloses:

> form a promoted halogenated carbon sorbent and … chemically reacting elemental mercury in the mercury containing gas with the promoted halogenated carbon sorbent."[1203]
>
> [P]romoted sorbent … is injected into contaminated flue gas stream 15. After contacting the injected material with the contaminated flue gas stream 15, the injected material reduces the mercury concentration.[1204]

10. Claim 15: "the combustion chamber comprises a boiler."

772. "[C]hamber 301 is a boiler."[1205]

11. Claim 16: "the mercury-containing gas is a flue gas."

773. "A halogen/halide-promoted sorbent is described that is highly effective for the removal of mercury from flue gas streams."[1206]

[1203] EX1018 (Olson-235) at 22:15-20.

[1204] EX1018 (Olson-235) at 14:30-34.

[1205] EX1018 (Olson-235) at 17:67 and 18:1.

[1206] EX1018 (Olson-235) at 3:25-27

12. Claims 17-18: "the injection of the sorbent material into the mercury-containing gas occurs upstream of [cl. 17—an air pre-heater] [cl. 18—particulate separator or a scrubber]"

774. "A base sorbent (carbon, non-carbon, or their combination) is introduced at location 402 upstream of air heater 302."[1207] The phrase "air heater" is another way of saying "air pre-heater." "Downstream from injection point 116 and 119 [for the sorbent] is provided particulate separator 140."[1208]

13. Claim 20: "the combustion chamber comprises added Br_2, HBr, Br-, or a combination thereof."

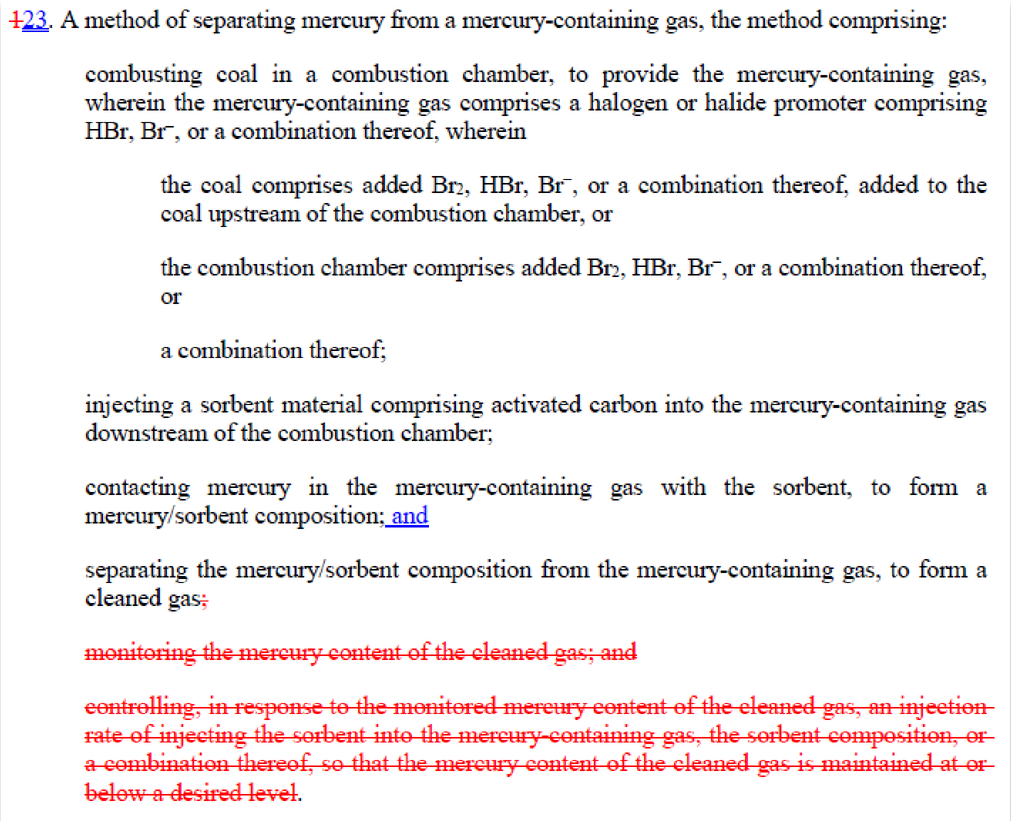
775. This claim is disclosed for the reasons discussed above for Element 1(b). The combustion chamber comprises HBr.

C. INDEPENDENT CLAIM 23

776. Claim 23 is nearly identical to Claim 1 with some limitations removed, as shown in the redline below:

[1207] EX1018 (Olson-235) at 18:33-35

[1208] EX1018 (Olson-235) at 14:4-5



~~1~~23. A method of separating mercury from a mercury-containing gas, the method comprising:

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

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;

injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber;

contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition; and

separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas~~;~~

~~monitoring the mercury content of the cleaned gas; and~~

~~controlling, in response to the monitored mercury content of the cleaned gas, an 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~~.

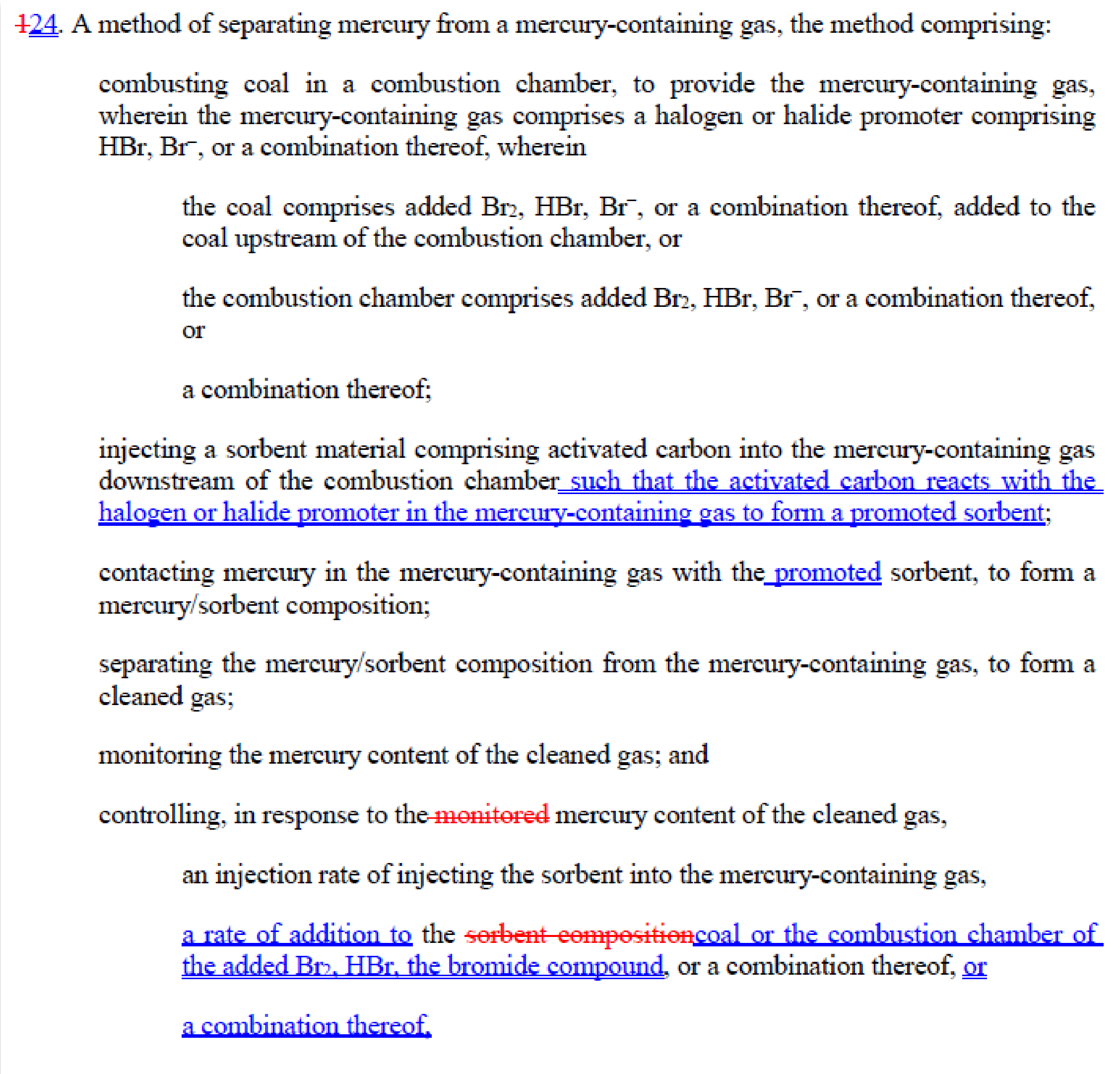
Thus, claim 23 is anticipated for the reasons described for claim 1.[1209]

D. INDEPENDENT CLAIM 24

777. The limitations of Claim 24 are nearly identical to the limitations of Claim 1.[1210] The differences between both the claims are highlighted and addressed below:

[1209] Patent Owner's expert agrees. EX1092 (O'Keefe Report) at 155 (applying same analysis for claim 23 as claim 1).

[1210] Patent Owner's expert agrees. EX1092 (O'Keefe Report) at 155-157.



~~1~~24. A method of separating mercury from a mercury-containing gas, the method comprising:

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

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;

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;

contacting mercury in the mercury-containing gas with the promoted sorbent, to form a mercury/sorbent composition;

separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas;

monitoring the mercury content of the cleaned gas; and

controlling, in response to the ~~monitored~~ mercury content of the cleaned gas,

an injection rate of injecting the sorbent into the mercury-containing gas,

a rate of addition to the ~~sorbent composition~~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.

1. Element 24(c): "…the activated carbon reacts with the halogen or halide promoter in the mercury-containing gas to form a promoted sorbent"

778. Olson-235 discloses "chemically reacting the carbon sorbent material … with the halogen or a halide promoter to form a promoted halogenated carbon sorbent."[1211]

2. Element 24(f): "controlling, in response to the mercury content of the cleaned gas…"

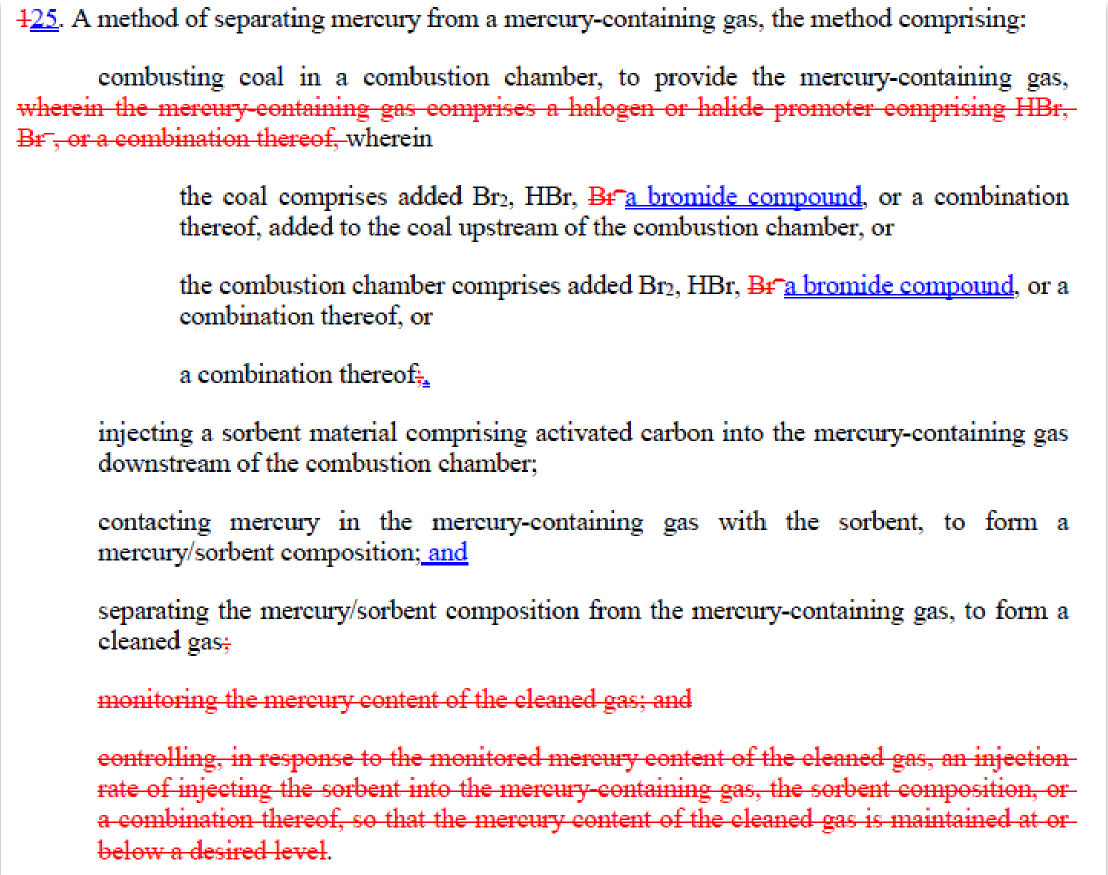
779. This limitation is disclosed, as I discuss above for Claim Element 1(f). Olson-235 discloses: "the rate at which the carbon base sorbent is introduced or the rate at which the promoter is introduced or combination thereof is adjusted according to the monitored mercury content of the cleaned gas so that the mercury content of the cleaned gas is maintained at substantially the desired level with minimal operating cost"[1212]

E. INDEPENDENT CLAIM 25

780. Claim 25 is nearly identical Claim 1 with some limitations removed:

[1211] EX1018 (Olson-235) at 21:65-66, 22:15-16.

[1212] EX1018 (Olson-235) at 6:62-67.



~~1~~25. A method of separating mercury from a mercury-containing gas, the method comprising:

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

the coal comprises added Br_2, HBr, ~~Br^-~~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, ~~Br^-~~a bromide compound, or a combination thereof, or

a combination thereof~~;~~,

injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber;

contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition; and

separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas~~;~~

~~monitoring the mercury content of the cleaned gas; and~~

~~controlling, in response to the monitored mercury content of the cleaned gas, an 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~~.

Thus, Claim 25 is anticipated over the reference, Olson-235. As described for Element 1(b), Olson-235 discloses adding Br_2 or HBr to the combustion chamber.

F. CLAIMS DEPENDING FROM CLAIM 25

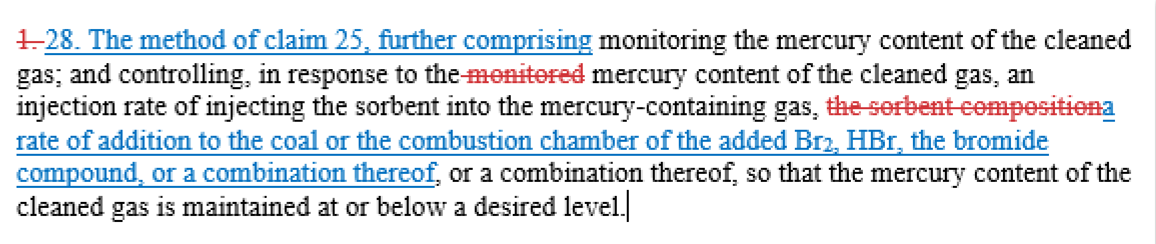
1. Claim 27: "the combustion chamber comprises the added Br_2, HBr, the bromide compound, or a combination thereof."

781. As described in Element 1(b) above, Olson-235 further discloses adding Br_2 or HBr to the combustion chamber.[1213]

[1213] EX1018 (Olson-235) at 22:39-42.

2. Claim 28: "monitoring the mercury content of the cleaned gas; and 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 Br2, 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."

782. Claim 28 is anticipated for similar reasons as Claim 1. A redline comparing the elements of Claim 28 to Elements 1(e)-1(f) as presented below:



~~1.~~ 28. The method of claim 25, further comprising monitoring the mercury content of the cleaned gas; and controlling, in response to the ~~monitored~~ mercury content of the cleaned gas, an injection rate of injecting the sorbent into the mercury-containing gas, ~~the sorbent composition~~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.

As referenced in the discussion above in Elements 1(e)-1(f), Olson-235 further discloses controlling a sorbent injection rate in response to the monitored mercury content.

3. Claim 29: "the mercury-containing gas comprises about 1 g to about 30 g of the element bromine per 100 g of the sorbent."

783. Olson-235 discloses, "the promoter is reacted in the gas phase or as a vapor…the promoter is added at from about 1 to about 30 grams per 100 grams of

the base sorbent."[1214] As per the discussion of Element 1(b) presented above, the promoter includes HBr or Br_2.

4. Claim 30: "the mercury/sorbent composition comprises the element bromine, the sorbent material, and mercury."

784. As referenced in the figure below, the "model is presented for the reactivity of the bromine-treated carbon with mercury shown in FIG. 2."[1215]

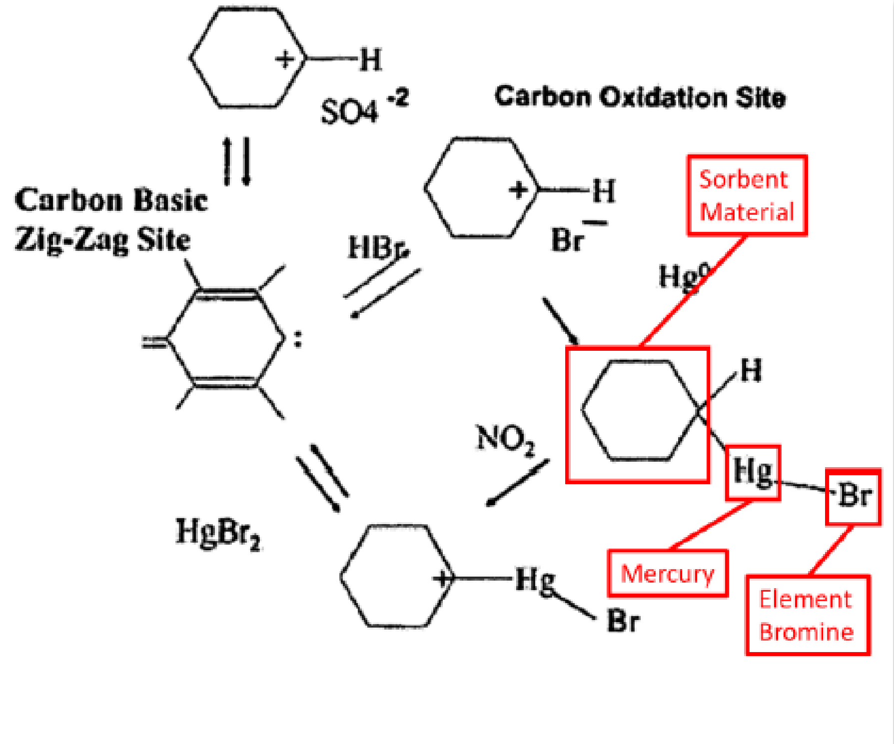


FIG. 2

[1214] EX1018 (Olson-235) at 5:51-54.

[1215] EX1018 (Olson-235) at 16:60-62.

EX1018, Fig. 2 (annotations in red). In the above model, there is a composition formed of sorbent (labeled "sorbent material"), mercury ("Hg"), and the element bromine ("Br").

XIX. CONCLUSION

785. I, Stephen Niksa, do hereby declare and state, 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 fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code. I declare under penalty of perjury that the foregoing is true and correct.

Executed this 17 of January, 2025 in California.

Dr. Stephen Niksa