UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

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

Petitioners
v.

Birchtech Corp,

Patent Owner

Case Nos. IPR2025-00424 and IPR2025-00425
Patent No. 10,589,225

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. 10,589,225, which I may abbreviate as "the '225 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 '225 PATENT

8. The Challenged Claims of the '225 Patent, which are Claims 1-2, 5-15, 17-20, and 22-29 are set forth below. Some of the claim elements have been further sub-divided for ease of reference.

Claim Element	Claim Language from '225 Patent
1(Pre)	1. A method for treating a mercury-containing gas, the method comprising:
1(a)	combusting a mixture comprising coal, pyrolysis char, and an additive comprising HBr, a bromide compound, or a combination thereof, to form the mercury-containing, gas; and
1(b)	adding a particulate sorbent material comprising activated carbon into the mercury-containing gas.
2	2. The method of claim 1, wherein the pyrolysis char is a promoted pyrolysis char.
5	5. The method of claim 1, further comprising using a particle separation device to remove mercury from the flue gas and comprising collecting greater than 70 wt % of the mercury in the mercury-containing gas to produce a cleaned gas.

Claim Element	Claim Language from '225 Patent
6	6. The method of claim 5, further comprising: measuring the mercury content of the mercury-containing gas; and modifying, in response to the measured mercury content: an injection rate of injecting the sorbent into the mercury-containing gas, an amount of the additive in the mixture, or a combination thereof.
7	7. The method of claim 1, wherein the additive further comprises Br_2.
8	8. The method of claim 1, wherein the sorbent material is chosen from powdered activated carbon, granular activated carbon, carbon black, carbon fiber, aerogel carbon, pyrolysis char, and combinations thereof.
9	9. The method of claim 1, further comprising adding an alkaline component to the mercury-containing gas, the alkaline component chosen from alkali elements, alkaline earth elements, alkali salts, alkaline earth salts, and combinations thereof.
10	10. The method of claim 1, further comprising contacting the sorbent material with a mercury-stabilizing reagent chosen from S, Se, H_2S, SO_2, H_2Se, SeO_2, CS_2, P_2S_5, and combinations thereof.
11	11. The method of claim 1, further comprising contacting the sorbent material with a secondary component chosen from halogens, hydrogen halides, Group V halides, Group VI halides, and combinations thereof.
12	12. The method of claim 11, wherein the secondary component is chosen from halogens, halide salts, HI, HBr, HCl, and combinations thereof.
13	13. The method of claim 11, wherein the secondary component is chosen from I_2, HI, and combinations thereof.
14(pre)	14. A method for treating a mercury-containing gas, the method comprising:
14(a)	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; and

Claim Element	Claim Language from '225 Patent
14(b)	adding a particulate sorbent material comprising activated carbon into the mercury-containing gas.
15	15. The method of claim 14, wherein the pyrolysis char is a promoted pyrolysis char.
17(pre)	17. A method for treating a mercury-containing gas, the method comprising:
17(a)	combusting a mixture comprising coal, pyrolysis char, and an additive comprising HBr, a bromide compound, or a combination thereof, to form the mercury-containing gas; and
17(b)	adding a sorbent material comprising activated carbon into the mercury-containing gas.
18	18. The method of claim 1, further comprising modifying, in response to a measured mercury content, an injection rate of injecting the sorbent into the mercury-containing gas, an amount of the additive in the mixture, or a combination thereof.
19	19. The method of claim 1, wherein the coal comprises added sorbent enhancement additive that comprises the bromide compound.
20	20. The method of claim 1, wherein the coal is combusted in a combustion chamber at a coal-combustion facility, wherein the HBr, bromide compound, or combination thereof, is added to the coal before the coal enters the combustion chamber, wherein the addition of the HBr, bromide compound, or combination thereof, to the coal is performed at the coal-combustion facility.
22	22. The method of claim 1, wherein the sorbent is contacted with a halogen or halide promoter prior to the addition of the sorbent to the mercury-containing gas.
23	23. The method of claim 1, wherein the sorbent is free of contact with a halogen or halide promoter prior to the addition of the sorbent to the mercury-containing gas.

Claim Element	Claim Language from '225 Patent
24	24. The method of claim 6, wherein the measurement of the mercury content of the mercury-containing gas comprises continuous measurement.
25	25. The method of claim 1, wherein the coal comprises subbituminous coal.
26	26. The method of claim 1, wherein the coal comprises lignite coal.
27	27. The method of claim 1, wherein the mixture is combusted in a combustion chamber of a coal-combustion facility upstream of a scrubber, a particulate control system, or a combination thereof, wherein the particulate sorbent is added to the mercury-containing gas before the mercury-containing gas encounters the scrubber, the particulate control system, or the combination thereof.
28	28. The method of claim 26, wherein the particulate control system comprises an electrostatic precipitator, a baghouse, a fabric filter, or a combination thereof.
29	29. The method of claim 19, wherein the combustion chamber is a coal combustion furnace.

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 after May 2015. 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
1001	U.S. Patent No. 10,589,225 to Olson et al. (filed May 14, 2015) **("'225 Patent" or "Challenged Patent")**
1002	Declaration of Dr. Stephen Niksa in Support of Petition for *Inter Partes* Review of U.S. Patent No. 10,589,225 **("'225 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")**

Exhibit	Description of Exhibits
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 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")**

Exhibit	Description of Exhibits
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")**
1019	File History of U.S. Patent Application No. 15/974,343, which ultimately issued as U.S. Patent No. 10,668,430 **("'430 Patent File History")**.
1020	File History of U.S. Patent Prov. App. No. 60/605,640 **("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	RESERVED
1024	File History of U.S. Patent Application No. 15/997,091, which ultimately issued as U.S. Patent No. 10,596,517 **("'517 Patent File History")**.

Exhibit	Description of Exhibits
1025	File History of U.S. Patent Application No. 12/419,219, which ultimately issued as U.S. Patent No. 8,168,147 **("'147 Patent File History").**
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")**
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	U.S. Patent No. 8,512,655
1034	U.S. Patent No. 8,821,819

Exhibit	Description of Exhibits
1035	U.S. Patent No. 9,757,689
1036	CRC Handbook of Chemistry and Physics, 86th Ed.; Lide, D.R., ed. **("CRC Press: March 2005")**
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")**

Exhibit	Description of Exhibits
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, 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")**

Exhibit	Description of Exhibits
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/2015-09/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")**

Exhibit	Description of Exhibits
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/5810096dabfc9eba85256e440078905f.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	RESERVED
1064	Redline Comparison, showing changes from '558 Application (as published at 2015/0246315) to '970 Application (as published at 2018/0229182)
1065	U.S. Patent No. 8,168,147
1066	RESERVED
1067	RESERVED

Exhibit	Description of Exhibits
1068	File History of U.S. Patent Application No. 14/712,558, which ultimately issued as U.S. Patent No. 10,589,225 **("'225 Patent File History")**
1069	RESERVED
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 & 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 &

Exhibit	Description of Exhibits
	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/ACE2002/tech-program/MondayPM.asp#AE-1c (AWMA Technical Program Schedule for June 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)

Exhibit	Description of Exhibits
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)
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

Exhibit	Description of Exhibits
	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 (Oct. 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.
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

Exhibit	Description of Exhibits
1099	Affidavit of Tanya Zeif, Custodian of Records for Internet Archive (1/13/2025), sponsoring Exhibits 1009, 1061, 1087-1090
1100	NAS-NRC COMMITTEE ON CHEMISTRY OF COAL, CHEMISTRY OF COAL UTILIZATION: SECOND SUPPLEMENTARY VOLUME (Martin A. Elliott ed., 1981) (excerpted) **("Coal Chemistry")**
1101	*Midwest Energy Emissions Corp., et al. v. Arthur J. Gallagher & Co., et al.*, No. 1:19-cv-01334-CJB, Dkt. No. 444-1 (D. Del. Mar. 31, 2023) (excerpted) **("Markman Hr'g. Tr.")**
1102	Redline Comparison, showing changes from '595 Application (as published at 2009/0062119) to '558 Application (as published at 2015/0246315)
1103	U.S. Patent Pub. No. 2015/0246315 to Olson et al. (published Sep. 3, 2015) **("Published '558 Application")**

Other than citations to prosecution histories, EX1019-EX1022, EX1024-EX1026, EX1068, 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, 2, 5-15, 17-20, 22-29	Obvious over Vosteen589 (EX1005) in view of Starns (EX1008)
A2	1, 2, 5-15, 17-20, 22-29	Obvious over Vosteen589 (EX1005) in view of Mass-EPA (EX1009)
A3	1, 2, 5, 7, 8, 14, 15, 17, 19, 20, 25-29	Anticipated by Downs-Boiler (EX1006)
A4	1, 2, 5-8, 14-15, 17-20, 22-29	Obvious over Downs-Boiler (EX1006) in view of Starns (EX1008)
A5	1, 2, 5-9, 11-12, 14-15, 17-20, 22-29	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	1-2, 5-8, 10-12, 14-15, 17-20, 22-29	Sjostrom (EX1010) in view of Eckberg (EX1011)
B2	1-2, 5-15, 17-20, 22-29	Sjostrom (EX1010) in view of Olson-646 (EX1012)
B3	1-2, 5-15, 17-18, 22-24, 27-29	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 patentability 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 unpatentable. 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 unpatentable 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]

[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 2015.

A. FUNDAMENTAL PRINCIPLES OF CHEMISTRY

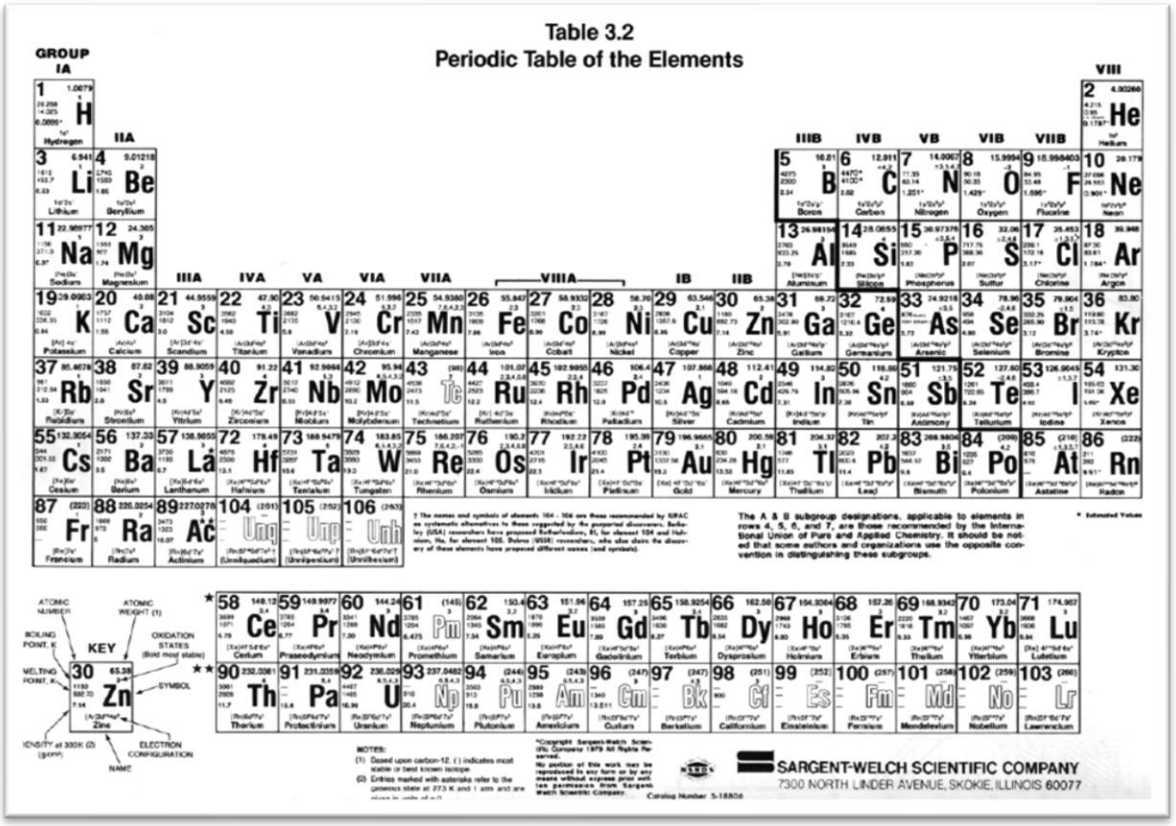
1. Periodic Table and Chemical Notation

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

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

[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,

[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)

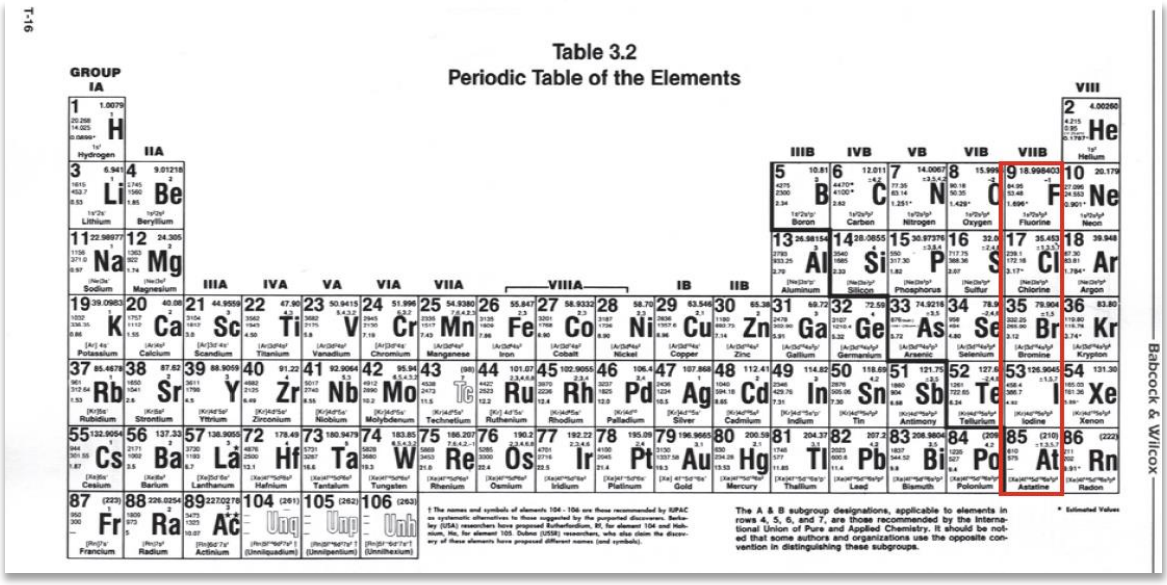
59. Elements in Group IV of the periodic table include carbon (C), silicon (Si), and germanium (Ge), among others.

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]



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

[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

[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

[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

[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

[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,

[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]

[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.

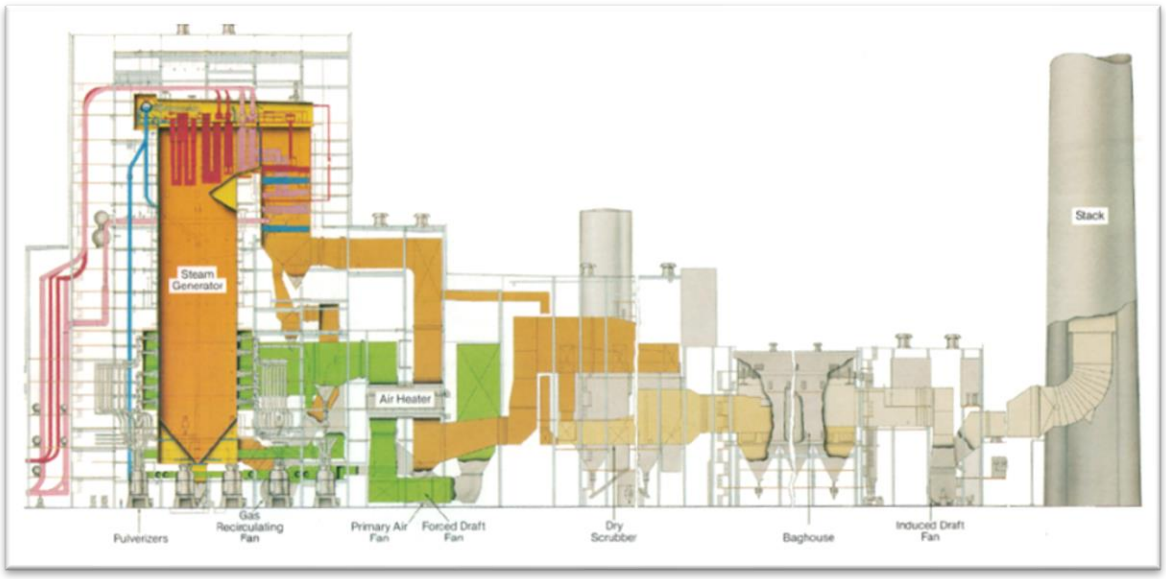
2. Combustion Chamber and Boiler

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]

[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

[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]

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

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

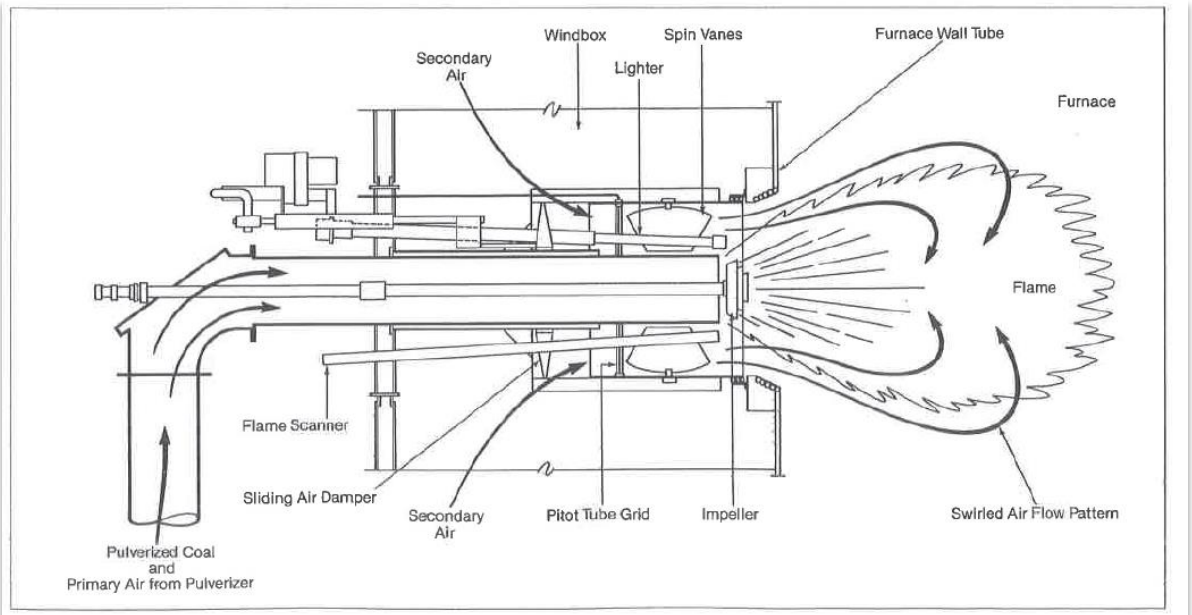


Fig. 5 S-type burner and components.

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

[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.

[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

[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

[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.

[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]

[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)

[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

[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]

[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

[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

[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

[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

[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]

[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

[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:

> 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. 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]

[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. Well-Known Structure of Activated Carbon

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

[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

[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:

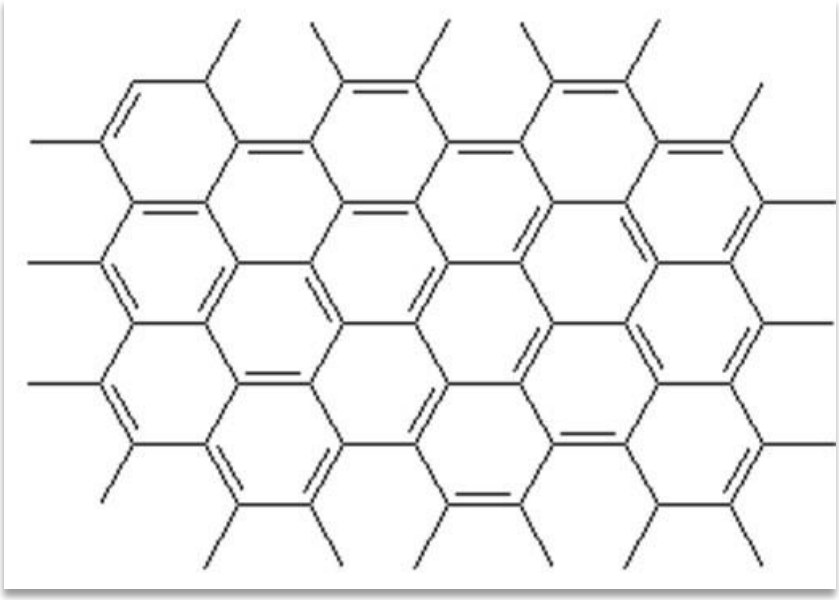
[108] EX1070 (Bansal) at viii.

[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

[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

[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

[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

[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

[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]

[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

[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) the amount of **sorbent** needed 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

[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

[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

[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

[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

[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]

[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

[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]

[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

[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—

[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

[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

[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

[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-

[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

[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

[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

[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

[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.

[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

[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]

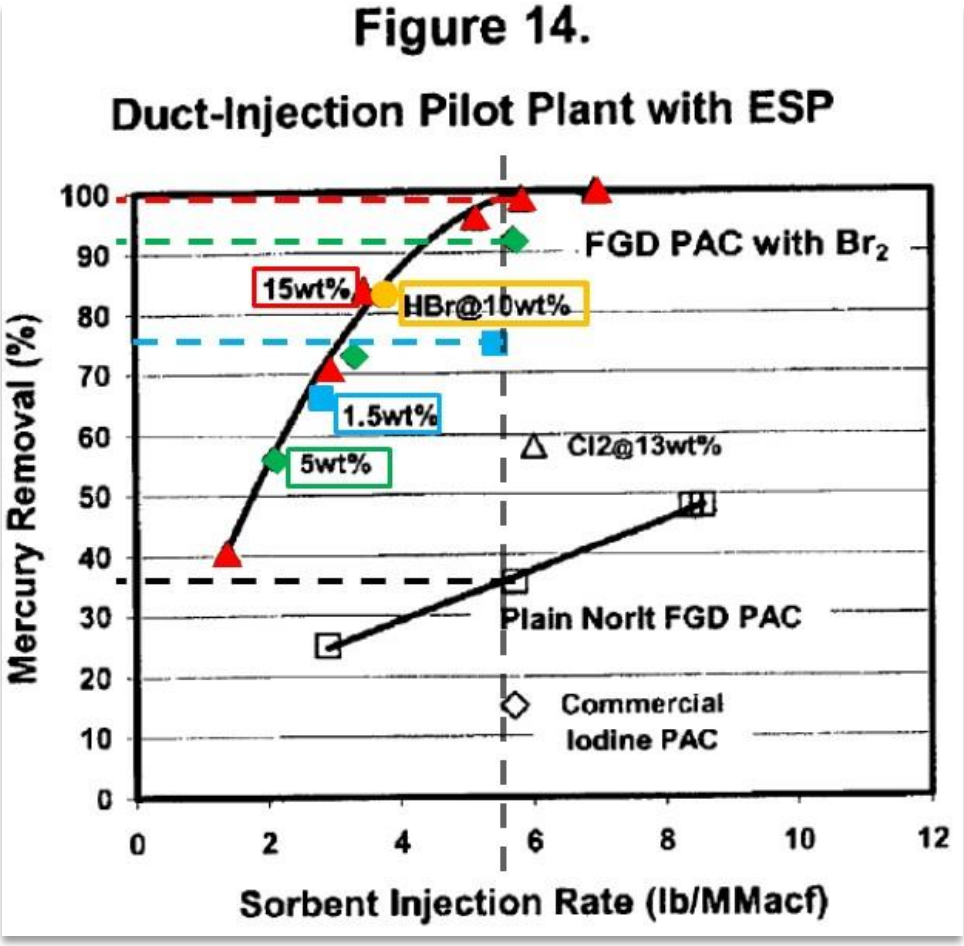
[217] EX1005 (Vosteen589) ¶[0046].

[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).



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

[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]

H. PYROLYSIS CHAR

152. Pyrolysis char is a commercially important commodity sold as coke for steelmaking and as briquettes for household cooking throughout the developing countries. It is also a raw feedstock for activated carbons, including products such as Darco FGD from Norit Americas that are used for Hg emissions control. Pyrolysis char inevitably and necessarily forms whenever any coal is heated above about 400°C, which occurs in every technology for coal utilization, including coal-fired power plants.

153. Pyrolysis char is a product of a spontaneous chemical process called "devolatilization." The burning of coal (pyrolysis) partitions the coal into a complex mixture of gases called "volatiles" and a solid residue called "char." At the molecular level, any coal type is a three-dimensional network of interconnected organic molecules, including carbon, hydrogen, oxygen, and other elements. Unlike the repeating units in ordinary crosslinked polymers, there are many types of connected organic molecules within a coal's network. Upon heating the coal (e.g.,

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

in a combustion chamber), bonds between the organic molecules rupture and thereby depolymerize the network into an assortment of volatile products, but only partially. The depolymerization is always incomplete because another network develops from crosslinking reactions driven by certain oxygen groups within the coal while the original network depolymerizes. Pyrolysis char comprises the organics in the newly crosslinked network plus any fragments of the original coal network that are too large to vaporize, along with residual minerals. Since the crosslinking reactions are spontaneous, they are governed by a coal's original constitution and cannot be suppressed. Consequently, pyrolysis char inevitably forms with all coal types whenever they are heated in a combustion chamber.

154. The inevitability of char formation during pyrolysis was recognized long ago. For example, Howard explained it in terms of inefficient allocation of hydrogen (as compared to carbon) during pyrolysis:

> Unfortunately the structure of coal preferentially evolves hydrogen as chemical water (probably from the hydroxyl groups) and light, highly stable aliphatics (such as methane and ethane), depleting the remaining carbon of much needed hydrogen. Because of this inefficient use of intrinsic hydrogen, pyrolysis, even under the most favorable conditions, includes the formation of heavy tarry compounds and residual char.[227]

[227] EX1100 (Coal Chemsitry) p. 673.

Accordingly, a POSITA would have recognized that there would be some amount of pyrolysis char necessarily formed during coal combustion.

155. The inevitability of char within furnaces automatically produces combustible mixtures of decomposing coal, char, and other materials added to the combustion chamber (such as bromine promoters added to coal upstream of the combustion chamber and/or injected directly into a furnace). These mixtures entrain air that either passes through the coal burners or is directly injected into upper furnace elevations. Since coal flames are several hundred degrees hotter than the ignition temperatures for both coals and chars, a mixture of decomposing coal and char spontaneously burns as the mixtures are contacted by O_2 from the air streams while they move upward through the furnace, through the convective heat exchangers, and into the economizer. Pyrolysis chars are mostly carbon with minor amounts of oxygen, hydrogen, nitrogen, and sulfur. As such, the pyrolysis chars rapidly burn at furnace temperatures during the coal-combustion process, particularly since furnaces are operated with excess air above and beyond the level needed to burn away all fuel components to ensure that O_2 is available to burn char even as it reaches the furnace exit. Indeed, flue gas leaving a furnace exit always contains several percent O_2, even if nearly all char has been consumed.

X. OVERVIEW OF THE CHALLENGED PATENT FAMILY

A. SPECIFICATION OF THE '225 PATENT

156. The '225 Patent "relates to methods and materials for the removal of pollutants from flue gas[.]"[228] The '225 Patent discloses that "mercury is removed from gas streams generated during the burning or gasification of fossil fuels by highly reactive regenerable sorbents."[229]

157. The '225 Patent admits that known "mercury control methods" included "injection of fine sorbent particles into a flue gas duct" such as "activated carbon" to adsorb mercury.[230] The '225 Patent asserts that, at the time, the activated-carbon was not sufficiently reactive with mercury, and therefore "these sorbents must be used in large amounts, at high sorbent-to-mercury ratios, to effectively capture the mercury."[231] The '225 Patent states that the sorbents, including activated carbon, "tend to be relatively expensive and cannot be easily separated from the ash for regeneration and reuse."[232]

[228] EX1001 ('225 Patent) at 1:29-31.

[229] EX1001 ('225 Patent) at 1:31-33.

[230] EX1001 ('225 Patent) at 1:57-67.

[231] EX1001 ('225 Patent) at 2:11-17.

[232] EX1001 ('225 Patent) at 2:17-19.

158. To address the problem discussed above, the ’225 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 carbon, that capture mercury via mercury-sorbent surface reactions.”[233] The ’225 Patent further explains that “[t]he reactivity of the sorbent toward the pollutants is greatly enhanced, and the sorption capacity can be regenerated; i.e., the promoted sorbent may be regenerated, recycled and/or reused.”[234]

159. Figure 1 of the ’225 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 from flue gas and/or product gas form [*sic*, from] a gasification system streams.”[235]

[233] EX1001 (’225 Patent) at 6:25-29.

[234] EX1001 (’225 Patent) at 6:33-36.

[235] EX1001 (’225 Patent) at 6:47-51, Figure 1.

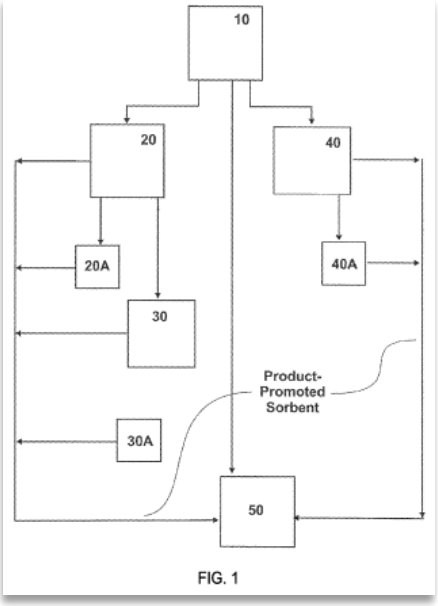


FIG. 1

The specification contemplates "[i]n a preferred embodiment illustrated by path 10-20, block 10 illustrates providing a base activated carbon, and adding a halogen or halide promoter that reacts with the carbon, illustrated at block 20, to produce a product promoted sorbent."[236] The specification also describes another embodiment 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, producing a product promoted carbon sorbent."[237] For all embodiments, the specification explains that

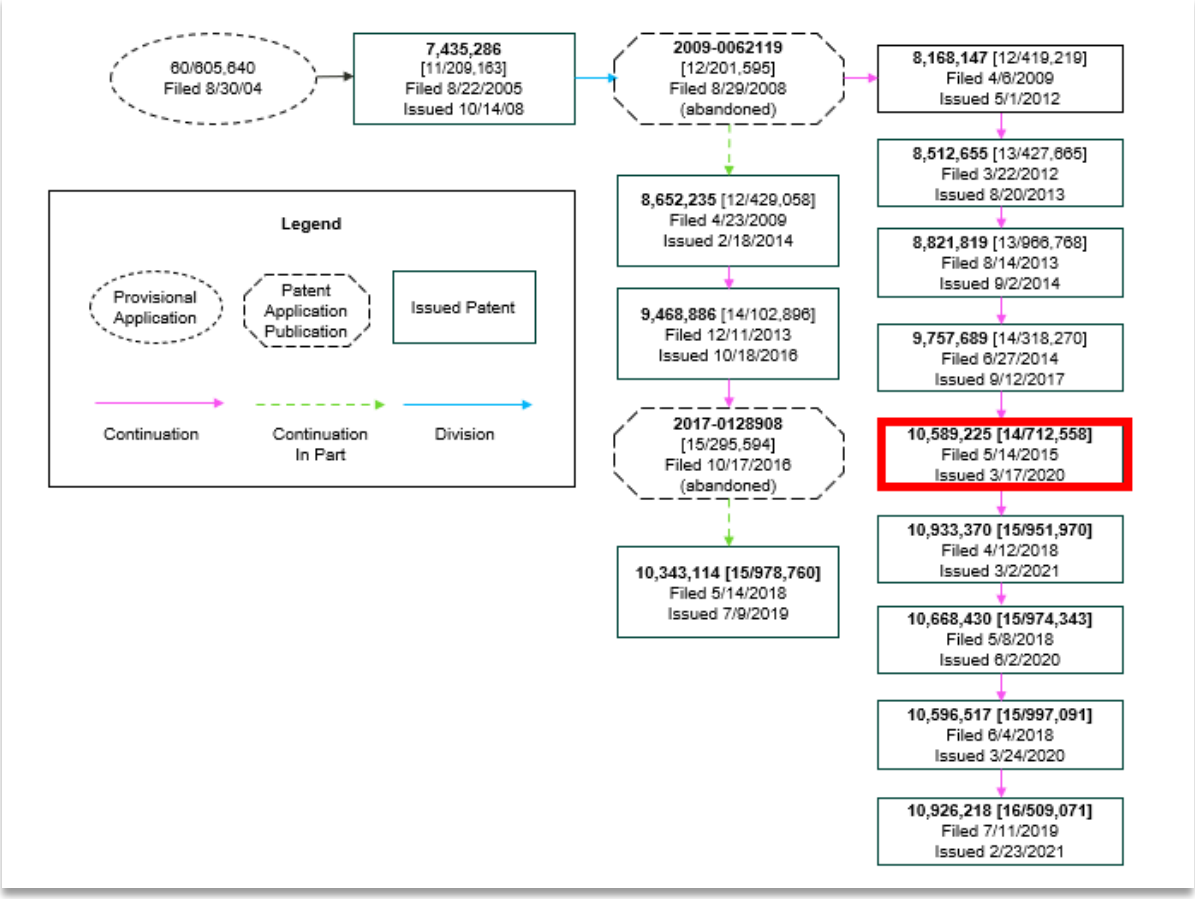
[236] EX1001 ('225 Patent) at 6:51-56.

[237] EX1001 ('225 Patent) at 7:10-14.

block 50 is "a flue gas stream [that] is treated with product promoted carbon sorbent prepared as described above."[238]

B. FAMILY TREE

160. I understand that the family tree below depicts the '225 Patent, and the patent applications to which it claims priority.[239]



[238] EX1001 ('225 Patent) at 7:20-23.

[239] EX1004 (Family Tree).

C. PROSECUTION HISTORY OF THE '225 PATENT

161. The '225 Patent was filed as U.S. Patent Application No. 14/712,558 (the "'558 Application") and claims priority as a continuation application of U.S. Patent Application No. 14/318,270 filed on June 27, 2014 (the "'270 Application") that has been issued as U.S. Patent No. 9,757,689. I have been informed that a "continuation" application is a type of patent application that is filed during the lifetime of an earlier nonprovisional application, repeating all the earlier nonprovisional application but aimed at pursuing a broader or different scope of patent protection. The '558 Application and the '270 Application are from a long line of other patent applications, which are reflected above in the family tree.[240] For convenience, I abbreviate the applications by the last three digits, so Application No. 14/712,558 is referred to as the '558 Application. The earliest non-provisional application in the chain is the '163 Application (filed Aug. 22, 2005), and Provisional Application No. 60/605,640 was filed August 30, 2004. I refer to this as the "Provisional."

1. Filing of U.S. Patent No. 10,589,225

162. The application that ultimately issued as the '225 Patent was filed on May 14, 2015, as U.S. Patent Application U.S. Patent Application No. 14/712,558

[240] EX1004 (Family Tree).

(the "'558 Application"). As originally filed, the '558 Application included 1 claim and 10 drawings (Figures 1-10).[241] As filed, claim 1 of the '558 Application is reproduced below:[242]

> CLAIMS
>
> WE CLAIM:
>
> 1. A promoted carbon sorbent comprising a base activated carbon that has reacted with a promoter selected from the group consisting of halides, halogens, and combinations thereof, such that the reaction product is effective for the removal of mercury from a gas stream.

2. Preliminary Amendment to the '558 Application

163. On May 15, 2015, 1 day after filing the '558 Application, a preliminary amendment was submitted, cancelling Claim 1 and adding new Claims 2-21. Independent Claims 2 and 21 are reproduced as filed below, while Claims 3-20 depended, directly or indirectly, from Claim 2. The applicant made no citations to the specification in support of the additional claims.[243]

[241] EX1068 ('225 Patent File History) atexhibit pages 41, 43-52.

[242] EX1068 ('225 Patent File History) atexhibit page 41.

[243] EX1068 ('225 Patent File History) atexhibit pages 1113-1117.

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

combusting coal, the coal comprising a promoter, to form the mercury-containing gas, wherein the promoter is chosen from halides, halogens, and combinations thereof;

adding a particulate sorbent material comprising activated carbon into the mercury-containing gas;

promoting at least a portion of the sorbent material by chemically reacting the sorbent material with the promoter in the mercury-containing gas, to form a particulate promoted sorbent material;

chemically reacting mercury in the mercury-containing gas with the promoted sorbent material, to form a mercury-sorbent particulate; and

separating the mercury-sorbent particulate from the mercury-containing gas.

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

adding a promoter to coal, wherein the promoter is chosen from Br_2, HBr, and combinations thereof;

combusting the coal to form the mercury-containing gas;

promoting at least a portion of the sorbent material by chemically reacting the sorbent material with the promoter in the mercury-containing gas, to form a particulate promoted sorbent material;

chemically reacting mercury in the mercury-containing gas with the promoted sorbent material, to form a mercury-sorbent particulate; and

separating the mercury-sorbent particulate from the mercury-containing gas.

164. Independent Claim 2 did not make explicit reference to Br_2, HBr, or Br, while independent Claim 21 recited "wherein the promoter is chosen from Br_2, HBr,

and combinations thereof."[244] This was the first recital of adding halogens upstream of the combustion chamber in the independent claims. The application would be published on September 3, 2015.[245] The published application has differing paragraph numbers from the specification provided with the initial filing of the '558 Application, and proceeding citations during prosecution to the specification were made according to the numbering in the published application.[246]

3. Subsequent Prosecution History

165. On July 6, 2017, the examiner rejected remaining claims 2-21.[247] The examiner first noted that the applicant's claim for priority to U.S. Patent App. No 14/318,270 (the "'270 Application") was not sufficient. The examiner stated that the disclosure of that application failed to provide adequate support.[248] The specification of the '558 Application was also objected to as failing to provide antecedent basis

[244] EX1068 ('225 Patent File History) atexhibit pages 1113, 1115-116.

[245] EX1068 ('225 Patent File History) at exhibit page 980.

[246] *Compare* EX1068 ('225 Patent File History) at exhibit pages 12-13 (¶¶ [0003]-[0004]) with EX1103 (Published '558 Application) at ¶¶ [0003]-[0006].

[247] EX1068 ('225 Patent File History) at exhibit page 923.

[248] EX1068 ('225 Patent File History) at exhibit page 924.

for the same subject matter not supported by the '270 Application. Furthermore, Claims 2-21 were rejected as failing to comply with the enablement requirement.[249]

166. The applicant responded on October 6, 2017, amending claims 2-5, 11, 12, 14, 19, and 21. The applicant also amended the specification, adding an additional paragraph, as shown below.[250]

IN THE SPECIFICATION

Please amend the specification as follows:

The following paragraph, to follow paragraph [0013], is added:

In an embodiment, coal and promoter can be present as a mixture. The promoter and the coal can be mixed before combustion of the coal at a location upstream of a boiler. The promoter can include a halide, a halogen, salts thereof, Br_2, HBr, and combinations thereof.

Amended Claims 2 and 21 are reproduced as filed below. The amendment to Claim 21 included replacing "wherein the promoter is chosen from Br_2, HBr, and combinations thereof" with "wherein the promoter is chosen from halides, halogens, salts thereof and combinations thereof."[251]

[249] EX1068 ('225 Patent File History) at exhibit pages 925-926.

[250] EX1068 ('225 Patent File History) at exhibit pages 513-517.

[251] EX1068 ('225 Patent File History) at exhibit page 516.

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

combusting a mixture of coal~~, the coal comprising~~ and a promoter, to form the mercury-containing gas, wherein the promoter is chosen from halides, halogens, salts thereof, and combinations thereof;

adding a particulate sorbent material comprising activated carbon into the mercury-containing gas;

promoting at least a portion of the sorbent material by chemically reacting the sorbent material with the promoter in the mercury-containing gas, to form a particulate promoted sorbent material;

chemically reacting mercury in the mercury-containing gas with the promoted sorbent material, to form a mercury-sorbent particulate; and

separating the mercury-sorbent particulate from the mercury-containing gas.

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

combusting coal~~adding~~ mixed with a promoter~~ to coal~~, wherein the promoter is chosen from ~~Br_2, HBr,~~ halides, halogens, salts thereof, and combinations thereof[[;]],~~combusting the coal~~ to form the mercury-containing gas;

injecting a particulate sorbent material comprising activated carbon into the mercury-containing gas;

promoting at least a portion of the sorbent material by chemically reacting the sorbent material with the promoter in the mercury-containing gas, to form a particulate promoted sorbent material;

chemically reacting mercury in the mercury-containing gas with the promoted sorbent material, to form a mercury-sorbent particulate; and

separating the mercury-sorbent particulate from the mercury-containing gas,

wherein the coal and promoter are mixed at a location upstream of a combustion furnace where combustion occurs.

167. The applicant cited Figure 2, and pages 2, 3, and 9 of the Provisional as support for the amendment to Claim 2 and the specification and stated that Claim 21 was amended similarly to Claim 2.[252] As further discussed below, Figure 2 and pages 2, 3, and 9 of the Provisional were not included in the specification of the '558 application, nor in preceding non-provisional applications.

168. On December 6, 2017, the examiner issued a final rejection of then-pending Claims 2-21.[253] The examiner again stated that the disclosure of the '270 Application (parent) failed to provide support as required for the benefit of an earlier filing date, taking issue with the same subject matter as did the previous rejection.[254]

169. The examiner also objected to the amendment to the specification as introducing new matter. The specification was further objected to as failing to provide proper antecedent basis.[255] Additionally, Claims 2-21 were rejected for failing both the written description and enablement requirements.[256]

[252] EX1068 ('225 Patent File History) at exhibit page 518.

[253] EX1068 ('225 Patent File History) at exhibit page 73.

[254] EX1068 ('225 Patent File History) at exhibit pages 74-76.

[255] EX1068 ('225 Patent File History) at exhibit pages 76-77.

[256] EX1068 ('225 Patent File History) at exhibit pages 77-79.

170. The Applicant's response, on January 23, 2018, cancelled the amendment to the specification, but did not amend the claims.[257] On February 12, 2018, the examiner issued an advisory action.[258] The advisory action included a statement that prior-filed applications, including the Provisional, failed to provide support for the claims of the '558 Application.[259] There was also an Applicant-Initiated Interview in March of 2018.[260]

171. In response to the advisory action, the applicant cancelled pending Claims 2-21 and added Claims 22-41 on April 2, 2018.[261] The applicant noted "that the pending claims are similar to the issued claims of U.S. patent no. 7, 435,286."[262] The sole independent claim, Claim 22, is reproduced below as filed.[263]

[257] EX1068 ('225 Patent File History) at exhibit pages 1809-1813.

[258] EX1068 ('225 Patent File History) at exhibit page 1795.

[259] EX1068 ('225 Patent File History) at exhibit pages 1796-1798.

[260] EX1068 ('225 Patent File History) at exhibit pages 1792.

[261] EX1068 ('225 Patent File History) at exhibit pages 1688-1690.

[262] EX1068 ('225 Patent File History) at exhibit page 1691.

[263] EX1068 ('225 Patent File History) at exhibit page 1688.

22. (New) A method for reducing mercury in a mercury-containing gas to a desired level, the method comprising:

injecting a sorbent into the mercury-containing gas;

collecting greater than 70 wt% of the mercury in the mercury-containing gas to produce a cleaned gas, wherein the sorbent is a promoted activated carbon that is promoted with at least one promoter that is a halogen, a halide, or a combination thereof, wherein the mercury-containing gas is a coal-combustion 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 the desired level.

172. The applicant did not make citations to support the newly added claims, but did note that the cancellation of claims included "all claims explicitly reciting application of the promoter or promoter precursor to the coal prior to combustion."[264] Claims 35 and 36 are additionally reproduced below:[265]

35. (New) The method of claim 22, wherein the promoter is Br_2, HBr, Br^-, sodium bromide, calcium bromide, or a combination thereof.

36. (New) The method of claim 22, wherein the promoter is HBr or Br^-.

[264] EX1068 ('225 Patent File History) at exhibit page 1691.

[265] EX1068 ('225 Patent File History) at exhibit page 1689.

173. On May 15, 2018, the applicant further augmented the claims. Claim 22 was amended, while 26, 35, and 37 were cancelled.[266] Additionally, new claims 42-44 were added.[267] The applicant described the changes as amending Claim 22 "to move some features to new dependent claims 42-44, and to incorporate features from canceled dependent claims 26 and 35."[268] Amended Claim 22 is reproduced as filed below.

22. (Currently Amended) A method for reducing mercury in a mercury-containing gas ~~to a desired level~~, the method comprising:

injecting a sorbent into the mercury-containing gas;

collecting ~~greater than 70 wt% of the~~ mercury in the mercury-containing gas on the sorbent to produce a cleaned gas, wherein the sorbent is a promoted activated carbon that is promoted in-flight with at least one promoter that is ~~a halogen, a halide,~~ Br_2, HBr, Br^-, or a combination thereof, wherein the mercury-containing gas is a coal-combustion 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 the desired level~~.

[266] EX1068 ('225 Patent File History) at exhibit pages 1671-1674.

[267] EX1068 ('225 Patent File History) at exhibit page 1674.

[268] EX1068 ('225 Patent File History) at exhibit page 1675.

This amendment brought the promoter being "Br_2, HBr, Br^-, or a combination thereof" back into the sole independent claim.[269] The applicant did not cite the specification as support for these changes.

174. On May 23, 2018, the examiner issued a notice of non-compliant amendment.[270] The examiner stated that Claims 22-41 were "directed to an invention that is independent or distinct form the invention originally claimed."[271] On June 13, 2018, the applicant further adjusted the claims. Claims 22-44 were cancelled, and claims 45-65 were added.[272] The applicant described the differences between Claims 45-65 and claims 2-21:[273]

[269] EX1068 ('225 Patent File History) at exhibit page 1671.

[270] EX1068 ('225 Patent File History) at exhibit page 1660.

[271] EX1068 ('225 Patent File History) at exhibit page 1657.

[272] EX1068 ('225 Patent File History) at exhibit pages 1638-1643.

[273] EX1068 ('225 Patent File History) at exhibit page 1644.

Claims 45 to 65 are similar to claims 2-21, with a difference that instead of reciting combustion of coal mixed with a promoter, the claims recite combustion of coal in a combustor that includes pyrolysis char and a promoter (claims 45 and 65), injecting the pyrolysis char and promoter within the combustor (claim 61), or injecting an in-flight promoted pyrolysis into the combustor (claim 63). Independent claims 45, 61, and 63 also recite that the promoter comprises "…Br_2, HBr, Br^-, or a combination thereof…", a slightly a narrower range of promoters than prior claim 2's "…halides, halogens, salts thereof, and combinations thereof…." Examples of support for the new claims are given in the following table, with citations referring to the present published US application. No new matter is added via the new claims herein.

175. Claims 45, 61, 63, and 65 were independent, and each describe the promoter comprising "Br_2, HBr, Br^-, or a combination thereof."[274] The support identified by applicants for Claims 45, 61, and 63 is shown below, while Claim 65 cited the same support as Claim 45:[275]

Claim #, feature	Example of support
45, combusting a mixture comprising coal, pyrolysis char, and a promoter, to form the mercury-containing gas	[0006] combusting coal to form the mercury-containing gas [0119] the halogen/halide promoted sorbent can be added where desired, "e.g., before, after, or within the boiler." [0049] the activated carbon can be pyrolysis char [0073] and [0093] a promoted sorbent can include the promoter
45, wherein the promoter comprises Br_2, HBr, Br^-, or a combination thereof	[0066] Br_2 [0066] and [0067] HBr [0073] halide ions such as Br^-

[274] EX1068 ('225 Patent File History) at exhibit pages 1638, 1641-1643.

[275] EX1068 ('225 Patent File History) at exhibit pages 1644-1645, 1648-1650.

45, adding a particulate sorbent material comprising activated carbon into the mercury-containing gas	[0056], [0057], and FIG. 3, activated carbon reservoir 110 connects via transport lines 111 and 115 to injection point 116. [0058] "For clarity, single injection points 116 or 119 are shown in FIG. 3, although one skilled in the art will understand that multiple injection points are within the scope of the present invention."
45, promoting at least a portion of the sorbent material by chemically reacting the sorbent material in-flight, to form a particulate promoted sorbent material	[0062] promotion can be "in-flight" [0077] and [0078] "in-flight" promotion can be contact between the vapors of the promoter with the carbon particles at the coal-combustion site, which can be distributed in a transport stream or other gas stream. [0058] "For clarity, single injection points 116 or 119 are shown in FIG. 3, although one skilled in the art will understand that multiple injection points are within the scope of the present invention."
45, chemically reacting mercury in the mercury-containing gas with the promoted sorbent material, to form a mercury-sorbent particulate	[0072] promoted sorbent has high reactivity with mercury.
45, separating the mercury-sorbent particulate from the mercury-containing gas	[0059] the system can include a particulate separator.

61, like claim 45, but reciting "combusting coal in a combustor comprising pyrolysis char and a promoter"	[0119] the halogen/halide promoted sorbent can be added where desired, "e.g., before, after, or within the boiler." [0049] the activated carbon can be pyrolysis char [0073] and [0093] a promoted sorbent can include the promoter

63, like claim 45, but reciting "combusting coal in a combustor and adding within the combustor an in-flight promoted pyrolysis char promoted by a promoter"	[0119] the halogen/halide promoted sorbent can be added where desired, "e.g., before, after, or within the boiler." [0049] the activated carbon can be pyrolysis char [0073] and [0093] a promoted sorbent can include the promoter [0062] promotion can be "in-flight" [0077] and [0078] "in-flight" promotion can be contact between the vapors of the promoter with the carbon particles at the coal-

176. On June 22, 2018, the applicant made further changes to the claims via supplemental amendment. Claims 45-65 were cancelled and Claims 66-82 were added.[276] The applicant described the new claims as "similar to claims 45-65, with a difference that the independent claims do not require that the particulate sorbent injected into the flue gas be promoted in-flight, do not require chemical reaction of the sorbent and the mercury, and do not require removal of the mercury from the flue gas."[277] Claims 66, 79, 81, and 82 were independent, and structured similarly to previous claims 45, 61, 53, and 65 respectively.[278] Example independent Claim 66 is reproduced below as filed.

[276] EX1068 ('225 Patent File History) at exhibit pages 1617-1620.

[277] EX1068 ('225 Patent File History) at exhibit page 1621.

[278] EX1068 ('225 Patent File History) at exhibit pages 1617-1620.

66. (New) A method for treating a mercury-containing gas, the method comprising:

combusting a mixture comprising coal, pyrolysis char, and a promoter, to form the mercury-containing gas, wherein the promoter comprises Br_2, HBr, Br^-, or a combination thereof; and

adding a particulate sorbent material comprising activated carbon into the mercury-containing gas.

The applicant provided no additional support for the additional claims. At this point, the independent claims each in part recited "wherein the promoter comprises Br_2, HBr, Br^-, or a combination thereof." Dependent Claim 72 further recited "wherein the promoter further comprises Br_2."

177. On July 2, 2018, the examiner issued a non-final rejection. Claims 66-78 and 82 were rejected as failing to comply with the enablement requirement. Each claim was also rejected over prior art and as double-patenting.[279] The July 2, 2018, filings also included a summary of June 19-21, 2018, interviews:[280]

Claim Interpretation and/or scope:
Interviews conducted on multiple occasions from 06/19/2018-06/21/2018. The examiner pointed to 112(a) and (b) issues stemming from the newly filed claims 45-65. The applicant pointed to the specification stating before during or after for support for the sorbent being within the combustion process. The examiner agreed that there was support for that limitation. The examiner pointed out that there was no support for the inflight reaction within the mercury containing gas of the promoter and that of the sorbent material. It was agreed that changing the preamble of the claim to be "treating" and removing the the limitations regarding reacting the promotion of the sorbent material would help in overcoming the 112 issues.

[279] EX1068 ('225 Patent File History) at exhibit pages 1586-1596.

[280] EX1068 ('225 Patent File History) at exhibit page 1598.

178. The applicant responded on August 14, 2018, not amending, cancelling, or adding any claims.[281] The applicant summarized previous interviews.[282, 283]

Interview Summary

Applicant wishes to thank Examiner Orlando for the courtesy of a telephone interview on March 6, 2018. During the interview, various issues of support and priority of the claims were discussed. The Examiner agreed that a CIP including the disclosure of the priority provisional application would resolve the § 112 issues in the Final Office Action mailed 12/6/2018. Subsequently, Applicant has amended the present claims via the supplemental amendment of 7/22/2018 to avoid the § 112 rejections asserted by the Final Office Action, and has filed several Track 1 CIP applications incorporating the disclosure of the provisional application.

179. The examiner issued an additional non-final rejection on October 19, 2018.[284] Claims 68 and 69 were rejected as indefinite.[285] All claims were also rejected over prior art, and as double patenting.[286]

[281] EX1068 (’225 Patent File History) at exhibit page 1574.

[282] EX1068 (’225 Patent File History) at exhibit page 1616.

[283] Additionally, while the Interview Summary describes a “March 6, 2018” interview and a “12/6/2018” Final Office Action, the correct dates appear to be March 1, 2018 and December 6, 2017, respectively. EX1068 (’225 Patent File History) at exhibit pages 73, 1792.

[284] EX1068 (’225 Patent File History) at exhibit page 1493.

[285] EX1068 (’225 Patent File History) at exhibit page 1494.

[286] EX1068 (’225 Patent File History) at exhibit pages 1494-1514.

180. The applicant continued to amend the claims. Claims 66, 68-69, 72, 79, 81, and 82 were amended on December 3, 2018.[287] Amended claims 66 and 72 are reproduced below:[288]

> 66. (Currently Amended) A method for treating a mercury-containing gas, the method comprising:
>
> combusting a mixture comprising coal, pyrolysis char, and a promoter, to form the mercury-containing gas, wherein the promoter comprises [[Br_2,]]HBr, Br^-, or a combination thereof; and
>
> adding a particulate sorbent material comprising activated carbon into the mercury-containing gas.

> 72. (Currently Amended) The method of claim 66, wherein the promoter [[is]]further comprises ~~Br_2, HBr, Br^-, or a combination thereof~~.

Independent claims 79, 81, and 82 were amended similarly to claim 66. The applicant did not cite to the specification for support of the amendments.[289]

181. On January 11, 2019, the examiner issued a final rejection. All claims were rejected over prior art in addition to as double patenting.[290] The applicant again submitted an amendment on July 10, 2019. Claims 66-69, 71-72, and 79-82 were

[287] EX1068 (’225 Patent File History) at exhibit pages 1455-1457.

[288] EX1068 (’225 Patent File History) at exhibit pages 1455-1456.

[289] EX1068 (’225 Patent File History) at exhibit page 1458.

[290] EX1068 (’225 Patent File History) at exhibit pages 1408-1428.

amended, while new claims 83-94 were added.[291] Amended Claim 66 is reproduced below:[292]

> 66. (Currently Amended) A method for treating a mercury-containing gas, the method comprising:
>
> combusting a mixture comprising coal, pyrolysis char, and an additive comprising HBr, a bromide compound, or a combination thereof ~~promoter~~, to form the mercury-containing gas~~, wherein the promoter comprises HBr, Br⁻, or a combination thereof~~; and
>
> adding a particulate sorbent material comprising activated carbon into the mercury-containing gas.

As support for the amendment to Claim 66, and "corresponding[]" amendments to Claims 79, 81, and 82, the applicant cited paragraphs [0054] and [0071].[293] At this point, each independent claim recited "an additive comprising HBr, a bromide compound, or a combination thereof."

182. The applicant pointed towards the following portions of the specification for support of newly-added Claims 83-94:[294]

[291] EX1068 ('225 Patent File History) at exhibit pages 1348-1352.

[292] EX1068 ('225 Patent File History) at exhibit page 1348.

[293] EX1068 ('225 Patent File History) at exhibit page 1297.

[294] EX1068 ('225 Patent File History) at exhibit page 1298.

New claim	Support
83	[0091]
84	[0009], [0054], [0081], and [0086]
85	[0070] and Example 10 at [0119]
86	Example 10 at [0119]
87	[0078]
88	[0120]
89	[0091]
90	[0106]
91	[0120]
92	[0119], [0108]
93	[0108]
94	[0110]

Each of these claims depended from Claim 66.

183. Another non-final rejection followed on September 12, 2019. The claims all received double patenting rejections over multiple patents and co-pending applications.[295] The applicant filed a terminal disclaimer, alongside amendments to Claims 79 and 82, on September 17, 2019.[296] The examiner issued a notice of allowance on December 13, 2019.[297]

[295] EX1068 (’225 Patent File History) at exhibit pages 1254-1266.

[296] EX1068 (’225 Patent File History) at exhibit pages 1242-1250.

[297] EX1068 (’225 Patent File History) at exhibit pages 1175-1181.

D. PRIORITY DATE OF THE CHALLENGED CLAIMS OF THE '225 PATENT

184. I have been asked to review the '225 Patent, and its earlier filed parent applications,[298] 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 '225 Patent are disclosed (either expressly or inherently) in the '558 application or those earlier filed parent applications. Second, I have been asked to analyze whether each of the claim limitations of the '225 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.

185. First, I conclude that there are claim limitations in each of the issued claims of the '225 Patent claims that are not disclosed (either expressly or inherently) in earlier-filed applications, or even within the '225 Patent's own specification. These include limitations missing from each challenged independent claim (claims 1, 14, and 17), such as the limitations below:

- "combusting a mixture comprising coal, pyrolysis char, and an additive comprising HBr, a bromide compound, or a combination thereof…" (Claims 1 and 17);

[298] EX1004 (Family Tree).

- "combusting coal in a combustor comprising pyrolysis char and an additive comprising HBr, a bromide compound, or a combination thereof…" (Claim 14);

186. At least dependent Claims 6-7, 18-20 and 23-24 also include limitations lacking support:

- "modifying … an amount of the additive" in the combustion chamber (Claims 6, 18, 24);
- "wherein the additive [in the combustion chamber] further comprises Br_2" (Claim 7);
- "wherein the coal comprises added sorbent enhancement additive that comprises the bromide compound" (Claim 19);
- "wherein the coal is combusted in a combustion chamber at a coal-combustion facility, wherein the HBr, bromide compound, or combination thereof, is added to the coal before the coal enters the combustion chamber" (Claim 20); and
- "wherein the sorbent is free of contact with a halogen or halide promoter prior to the addition of the sorbent to the mercury containing gas." (Claim 23).

187. In the subsections below, I first explain why these limitations were not present in the specification of the '558 Application. I also explain why these limitations were not present in parent applications.

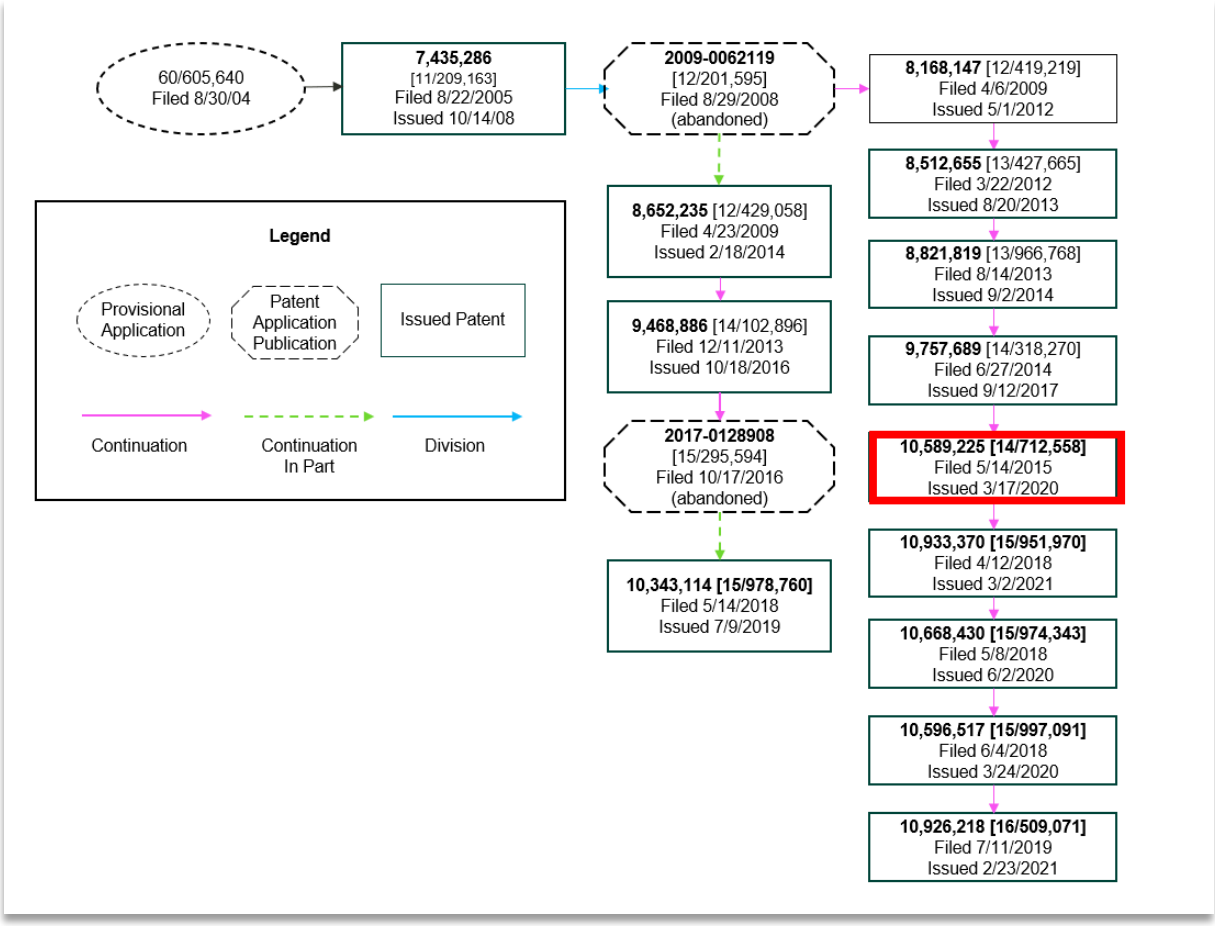
188. Second, I conclude that there are claim limitations in each of the issued claims of the '225 Patent that are not disclosed (either expressly or inherently) in the Provisional.

189. Third, I have concluded that there is at least one intervening patent—U.S. Patent No. 8,168,147—that has issued patent claims lacking support in its specification, and in which the only possible support comes from the Provisional.

190. At least because the claims of the ’225 Patent are not disclosed in the specification of the ’558 Application or its parent applications, the claims of the ’225 Patent are not entitled to a priority date before May 15, 2015, the date of the preliminary amendment that introduced then-pending independent Claims 2 and 21. Claim 2 in-part recited “combusting coal, the coal comprising a promoter, to form the mercury-containing gas, wherein the promoter is chosen from halides, halogens, and combinations thereof,” while Claim 21 recited “adding a promoter to coal, wherein the promoter is chosen from Br_2, HBr, and combinations thereof.” Before the addition of these claims on May 15, 2015, the ’558 Application and its parent applications did not describe adding halogens to the coal, the combustion chamber, or anywhere else for combustion.

1. The Claims of The '225 Patent Are Not Supported by Its Specification or the Preceding Non-Provisional Applications

191. I understand that the '558 Application (U.S. Patent Application No. 14/712,558) ultimately issued into U.S. Patent No. 10,589,225 ('225 Patent).[299] This patent is shown below:[300]



[299] EX1001 (U.S. Patent No. 10,589,225).

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

I have been asked to review the issued claims of the ’225 Patent and then assess whether claims of the ’225 Patent find support in the specification or parent applications of the ’225 Patent.

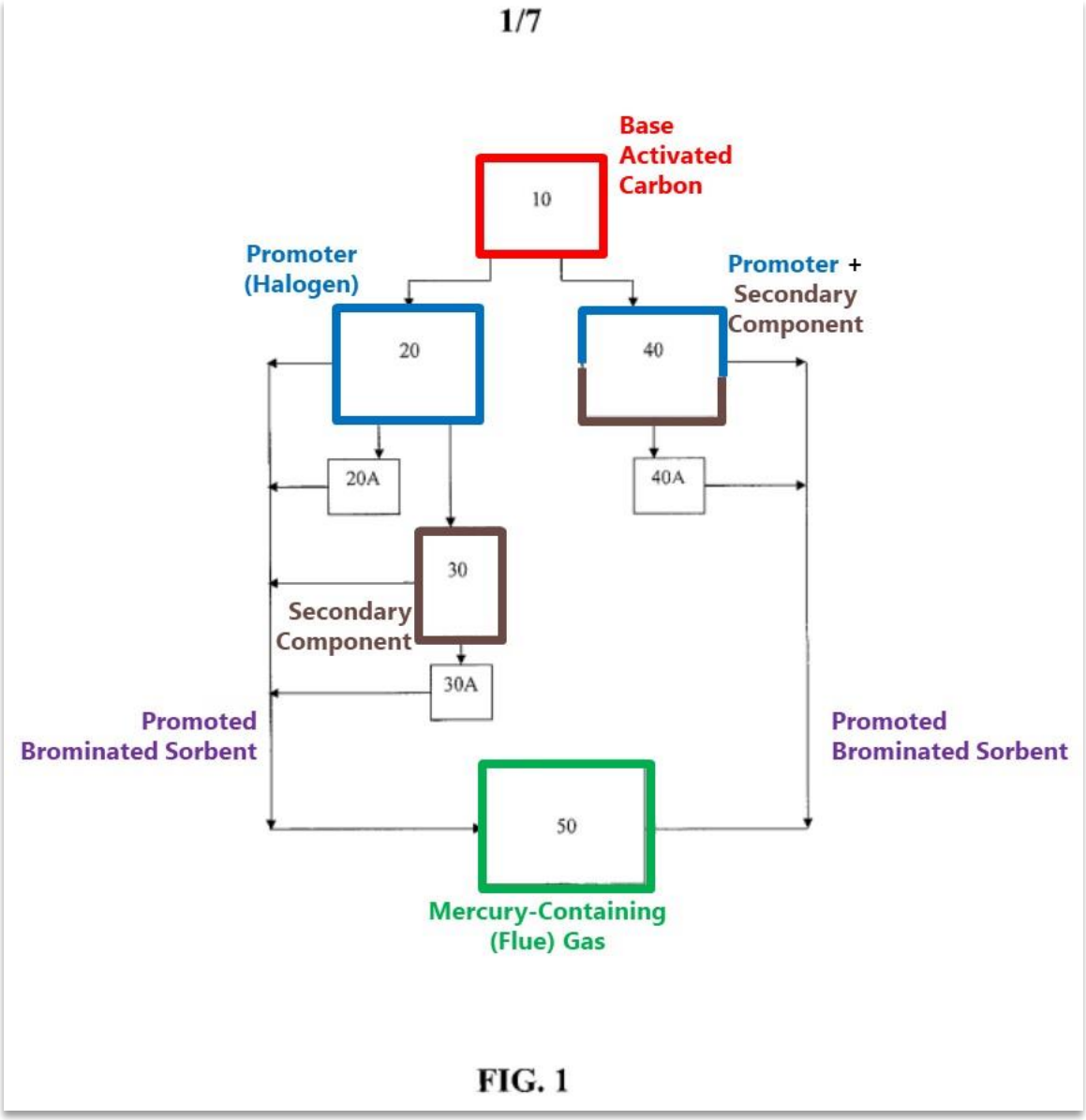
a. The Specification and Parent Applications

192. Other than alterations made to a replacement-Figure 1 during prosecution of the ’219 Application (’147 Patent, discussed below), the figures and description (i.e., everything other than the claims) are substantively identical between the ’558 (which issued into the ’225 Patent), ’270, ’768, ’665, ’219, ’595, and ’163 Applications. Exhibit 1102 is a redline demonstrating the changes between the ’595 and ‘558 applications. Nothing in the text or figures of these applications discloses the following limitations from the independent claims of the ’225 Patent:

- “combusting a mixture comprising coal, pyrolysis char, and an additive comprising HBr, a bromide compound, or a combination thereof, to form the mercury-containing gas” (Claims 1, 17);
- “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);

193. Given that the figures and description are substantively identical between the ’558, ’270, ’768, ’665, ’219, ’595, and ’163 Applications, for ease of discussion I refer primarily to the ’595 Application in my discussion below, but such discussion applies equally to each of the ’558, ’270, ’768, ’665, ’219, and ’163 Applications as well.

194. Nothing in the ’595 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 ’225 Patent claims. This is because the ’595 Application is 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 of the ’595 Application, annotated below:



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."[301] Second, the '595

[301] EX1022 ('595 Application File History) at exhibit page 263.

Application identifies 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."[302] For both embodiments, the '595 Application explains that block 50 is "a flue gas stream [that] is treated with product promoted carbon sorbent prepared as described above."[303] 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 ***before*** introducing them to the flue gas, as represented by block 50.

195. Similarly for Figure 3 of the '595 Application, the halogen 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</u> the non-mercury-containing transport gas <u>into</u> the mercury-containing flue gas. The transport (purple) occurs before the mercury-containing gas (green). Fig. 3 from the '595 Application is annotated below:[304]

[302] EX1022 ('595 Application File History) at exhibit page 263.

[303] EX1022 ('595 Application File History) at exhibit page 264.

[304] EX1022 ('595 Application File History) at exhibit page 297 (Fig. 3).

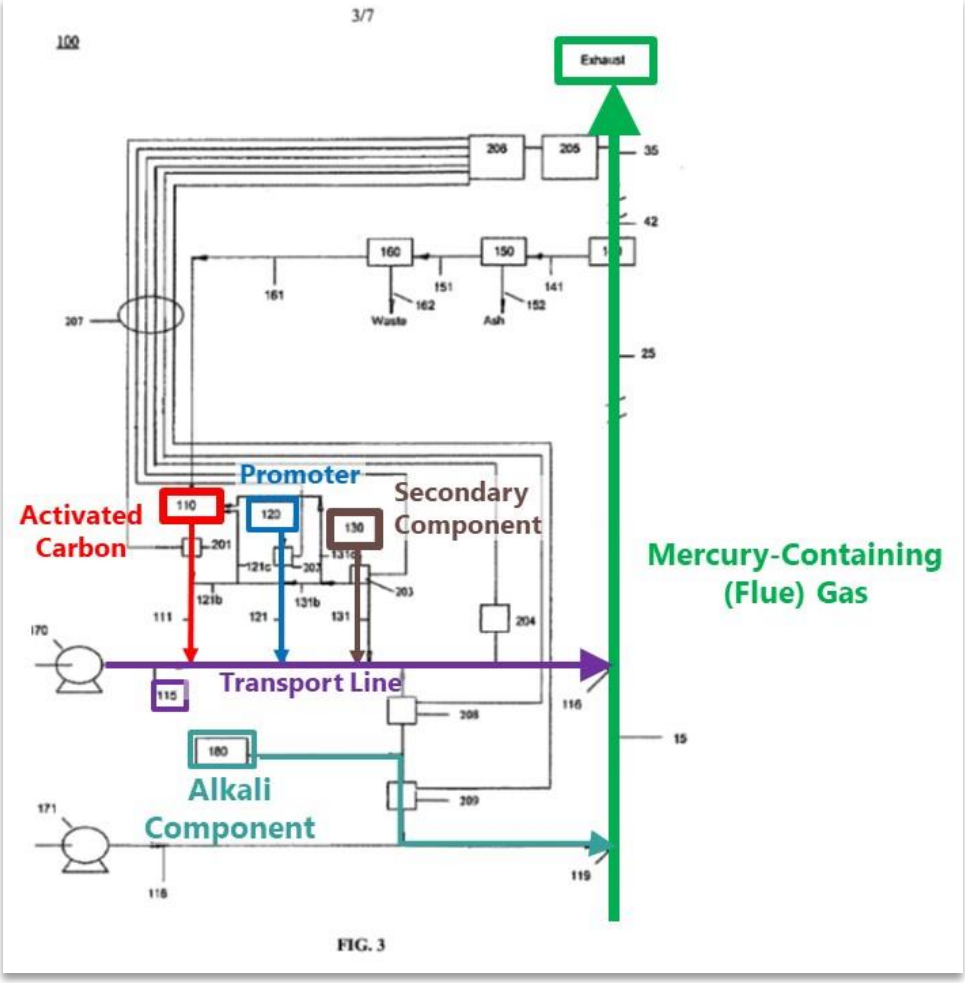


Figure 3 depicts four reservoirs: "base activated carbon reservoir 110" (red), "halogen/halide promoter reservoir 120" (blue), "secondary component reservoir 130" (brown), and "alkali component reservoir 180" (turquoise).[305] The reservoirs 110, 120, and 130 "each connect through respective flow control devices and via associated piping, to transport line 115."[306] Transport line 115 is highlighted purple.

[305] EX1022 ('595 Application File History) at exhibit page 265 (¶ [0054]).

[306] EX1022 ('595 Application File History) at exhibit page 265 (¶ [0055]).

"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, *into contaminated flue gas stream 15* [green]."[307]

196. There is no disclosure of adding bromine-containing species to the coal or to the combustion chamber.[308] Rather, halogen 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 states:

> 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).[309]

Nothing in the above paragraph discusses where to add the halogen 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 halogen-

[307] EX1022 ('595 Application File History) at exhibit page 265 (¶ [0055]).

[308] The named inventors of the '225 Patent, Dr. Olson and Mr. Pavlish, and Patent Owner's expert (Mr. O'Keefe) 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.

[309] EX1022 ('595 Application File History) at exhibit page 280 (¶ [0107]).

promoted sorbent at all. Rather, the quote discusses testing the halogen-promoted sorbent (the patent's alleged "inventive sorbent") that, as discussed above for Figures 1 and 3, 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 halogens to coal, as a POSITA would know that adding activated carbon into 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 before the combustion chamber.

197. The '595 Application discusses "in-flight" production of "halogen promoted carbon sorbent." However, the embodiments and examples in the specification demonstrate contact between halogen and activated carbon before "halogen/halide promoted carbon sorbent particles" are transported to and injected into the mercury-containing gas.[310]

198. In short, nothing in the '595 Application describes adding the halogen promoter independently from the mercury sorbent, let alone to the coal or to the

[310] EX1022 ('595 Application File History) at exhibit page 271 (¶ [0075]); *see e.g.*, *id*. at exhibit page 267 (¶ [0060]).

combustion chamber. As the description and figures of the ’595 Application are substantively identical to that of the ’558, ’270, ’768, ’665, ’219, and ’163 Applications (other than the modification to one of the ’219 Application figures, discussed below), all applications fail to describe adding the halogen promoter independently from the mercury sorbent, let alone to the coal or the combustion chamber as filed.

b. No Disclosure of Claims 1, 14, and 17 in the Specification or the Preceding Non-Provisional Applications

199. As discussed above, there is no disclosure of adding bromine-containing species, such as HBr, in the combustion chamber (i.e., “combustor” recited in Claim 14 of the ’225 Patent). As further discussed above, there is no disclosure in these applications of HBr otherwise being present in the combustion chamber, as any bromine-containing promoter (e.g., affixed to the sorbent) is introduced downstream of the combustion chamber. Neither the ’225 Patent nor the preceding non-provisional applications in its priority chain provide written description support for a combustion chamber comprising HBr, a bromide compound, or a combination thereof, to form the mercury-containing gas.

200. Additionally, Claim 14 of the ’225 Patent, as well as other ’225 Patent claims (e.g., 1, 17) that recite bromine-containing species (e.g., HBr, a bromide compound) in the coal and/or a combustion chamber, were not present in the

originally filed application for the ’225 Patent.[311] The Newly-Added Limitations include:

- “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);
- “combusting a mixture comprising coal, pyrolysis char, and an additive comprising HBr, a bromide compound, or a combination thereof, to form the mercury-containing gas” (Claim 1, 17);

The ’225 Patent application as filed (as well as the disclosure of the preceding parent applications) does not disclose adding the claimed bromine-containing species to the coal and/or combustion chamber.

201. The only disclosure of adding bromine-containing components in the specification and those non-provisional applications involves additions downstream of the combustion process. Notably, the specification and non-provisional applications omit the series of numbered “outline[s] of examples of the invention”—namely, the example number 1E in the Provisional referring to an “additional

[311] *Compare* EX1067 (’225 Patent, as issued) at claims 14, 17, 20, *with* EX1068 (’225 Patent File History) at exhibit page 41 (listing only a single claim in originally filed application).

substance" is not carried over.[312] Nor is Figure 2 of the Provisional. The support for these claim limitations (if any) would be from the Provisional.[313]

c. No Disclosure of Dependent Claims 6-7, 18-20, and 23-24 in the Specification or the Preceding Non-Provisional Applications

202. There is no disclosure in the specifications of the Non-Provisional Applications of (i) adding HBr, a bromide compound, or any bromine-containing ingredients to the coal before the coal enters the combustion chamber (Claims 19-20); or (ii) combusting an additive that further comprises Br_2 (Claim 7). For similar reasons, there is also no disclosure of, as in Claims 6, 18, and 24, "modifying … an amount of the additive" in the combustion chamber. As discussed above, the only disclosure of bromine-containing ingredients in the Non-Provisional Applications involves halogen addition downstream of the combustion process.[314] Named inventors and PO's expert in the Delaware Litigation were asked about the specification of the '147 Patent (a parent to the '225 Patent, filed in 2009, with

[312] *Compare* EX1020 (Provisional) at exhibit pages 5-8, *with* EX1021 ('163 Application File History) at exhibit pages 236-65, *and* EX1022 ('595 Application File History) at exhibit pages 256-84.

[313] I note, though, that the Provisional still does not disclose adding any bromine-containing promoter to the coal itself.

[314] *See supra* §§X.D.1.a-b.

identical specification as the ’225 Patent[315]), and they confirmed the specification provided no examples of disclosing bromine-containing ingredients to coal or the combustion chamber.[316]

203. Additionally, as discussed below with respect to the ’147 Patent[317], there is no disclosure, including in the replacement Figure 1, of “injecting the particulate sorbent material at a sorbent material injection rate and injecting separately the bromine containing promoter into [a mercury-containing gas] whereby in-flight reaction produces the promoted brominated sorbent.” Thus, any contact between the activated-carbon sorbent and the bromine-containing promoter occurs before the sorbent enters the mercury-containing gas, and the sorbent is not “free of contact with a halogen or halide promoter prior to the addition of the sorbent to the mercury-containing gas” (as required by ’225 Patent, Claim 23).

[315] *See* EX1004 (Family Tree).

[316] EX1095 (Olson) at 128:20-25; EX1097 (Pavlish) at 116:22-125:17; EX1093 (O’Keefe 1) at 156:5–170:5.

[317] *See* §X.D.4.

d. The Passages Cited by the Applicants for Support During Prosecution of the ’225 Patent Are Irrelevant or Not Present

204. As described above, the then-pending claims of the ’225 Patent were amended and at times replaced entirely throughout its prosecution. Independent Claims 66, 79, 81, and 82 (ultimately issuing into the independent claims of the ’225 Patent) and their precursors (e.g. cancelled claims 2, 22, and 45 for claim 66) went through substantial changes during the course of prosecution. The applicant did not always provide citations in support of amended or additional claims, but did at times cite paragraphs [0006], [0019], [0049], [0054], [0056]-[0059], [0062], [0066], [0067], [0071], [0072]-[0074], [0077], [0078], [0093], [0119], and Figure 3.[318] Figure 3 is discussed above.

205. The cited paragraphs of the ’558 Application do not discuss bromine-containing species being added to either the combustion chamber, the coal, or anywhere else for combustion. Paragraph [0006] provides the background of the invention, and does not mention halogens. Paragraph [0019] describes options for the promoter, which, in an embodiment, may be “Selected from the group consisting of molecular halogens, hydrohalides, Group V halides, Group VI halides, and combinations thereof.” Paragraph [0049] describes varying options for types of

[318] EX1068 (’225 Patent Prosecution History) at exhibit pages 1297, 1848-1650.

activated carbon to be used, but no halogens. Paragraph [0054] simply describes the characteristics of a promoted sorbent (which is injected downstream into the mercury-containing gas, and not added to coal) and a mechanism for how it reacts with mercury, but does not describe any bromine-containing species being added to either the combustion chamber, the coal, or anywhere else that would allow for combustion of a mixture comprising an additive itself comprising HBr, a bromide compound, or a combination thereof.

206. Paragraphs [0056]-[0059] explain Figure 3. While not cited in support of the independent claims, paragraph [0061] explicitly states "[i]n operation, promoted carbon sorbent and/or an optional alkali component is injected into contaminated flue gas stream," so any promotion happens before injection. Paragraph [0062], still in reference to Figure 3, discusses "several preferred embodiments for preparation and injection of promoted carbon sorbents and/or alkali components in accordance with the present invention." Paragraph [0066] discusses "embodiments wherein the halogen/halide promoter is in gaseous or vapor form," but the example provided states that produced promoted carbon sorbent is "removed…for injection." Paragraph [0067] discusses "the secondary component(s)."

207. Paragraph [0071]-[0073] and [0093] discuss how halogens react with activated-carbon sorbent, but do not describe bromine-containing species being

added to either the combustion chamber, the coal, or anywhere else for combustion. Paragraph [0074] discusses the "optional second component." Paragraph [0077] discusses "in-flight" promotion. Paragraph [0078] discusses the benefits of in-flight promotion, stating that with that "technique, the halogen/halide is introduced to the carbon-air (or other gas) mixture in a transport line (or other part of the sorbent storage and injection system)," but does not disclose adding halogens/halides to coal or a combustion chamber. Paragraph [0119] discusses filtration tools and states "[i]n general, however, the inventive sorbent can be injected where desired (e.g., before, after, or within the boiler)."[319] None of these paragraphs describe any bromine-containing species being added to either the combustion chamber, the coal, or anywhere else for combustion.

208. Paragraph [0049] was cited to provide support for "a mixture comprising…pyrolysis char." As mentioned, paragraph [0049] merely describes optional types of activated carbon. While pyrolysis char is one of these options, and paragraph [0119] states that "the inventive sorbent can be injected where desired,"

[319] A POSITA would not understand this to be any kind of disclosure for adding halogens to coal or a combustion chamber, as a POSITA would know that adding activated carbon into 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 before the combustion chamber.

the claims of the ’225 Patent require adding the activated carbon into the gas after combustion.

209. The applicant had additionally stated that support for the October 6, 2017, amendment to then-pending claim 2 could be found in Figure 2 and pages 2, 3, and 9 of the Provisional. Figure 2 of the Provisional was not present as any figure in the ’558 Application, while the cited pages were at most only carried over in part and in modified fashion.[320]

210. In summary, the paragraphs identified by the applicant from the ’558 Application as supporting the independent claims do not describe any bromine-containing species being added to either the combustion chamber, the coal, or anywhere else for combustion. And as discussed further below regarding the Provisional, to the extent one considered the disclosure in that filing, including Figure 2 of the Provisional, even that disclosure does not fully support the claims of the ’558 Application.

2. The Provisional is Not Fully Incorporated Into the ’558 Application or the Preceding Non-Provisional Applications.

211. The ’558 Application and its preceding non-provisional applications do not provide the entire contents of the Provisional. For example, the applications

[320] *Compare* EX1020 (Provisional) at exhibit page 3 (Example 2) *with* EX1103(Published ’558 Application) at ¶¶ [0066], [0118].

omit the series of numbered "outline[s] of examples of the invention" including example 1E referring to an "additional substance,"[321] As discussed above, Figure 2 of the Provisional was also excluded from the non-provisional applications.

212. Other portions from the Provisional were carried over to the '163 and the '595 Applications but were substantively changed. In particular, the text accompanying Figure 2 of the Provisional was changed as demonstrated by the redline below:[322]

~~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 (fabric filter) or ESP ~~is~~was used to collect particulates in the exhaust of a full-scale commercial pulverized coal-burning facility. A scrubber and sorbent bed ~~are~~were also used to remove undesired constituents from the flue gas stream, before being fed to the stack. In ~~the~~this example ~~shown~~, the halogen/halide promoted carbon sorbent ~~is~~was injected into the flue gas after the boiler. ~~The additive~~In general however, the inventive sorbent can be injected where desired (e.g., before, after, or within the boiler).

As noted in the comparison above, the language of the '163 and the '595 Applications does not refer to an additive, but rather that the "***inventive sorbent*** can

[321] *Compare* EX1020 (Provisional) at exhibit pages 5-8, *with* EX1021 ('163 Application File History) at exhibit pages 236-65, *and* EX1022 ('595 Application File History) at exhibit pages 256-84.

[322] *Compare* EX1020 (Provisional) at exhibit page 15, *with* EX1021 ('163 Application File History) at exhibit page 260 ¶ [00107], *and* EX1022 ('595 Application File History) at exhibit page 280 ¶ [00107].

be injected where desired (e.g., before, after, or within the boiler.)"[323] Thus, the '163 and the '595 Applications merely describe injecting the sorbent (and only after the sorbent has been promoted with the halogen/halide) at various points in relation to the boiler.

213. The '558 Application includes a generic statement of incorporation by reference to the Provisional and the '163 Application, wherein "both applications are hereby incorporated by reference in their entirety for all purposes."[324] However, multiple preceding applications and patents incorporated the Provisional only "by reference," while claiming priority only "to the extent appropriate."[325]

3. The Provisional Does Not Support the '225 Patent Claim Limitations

214. As described above, the '558 Application, as well as earlier applications in its priority chain, did not expressly include the contents of the '640 Provisional, only including a generic statement of incorporation by reference. However, even if

[323] EX1021 ('163 Application File History) at exhibit page 260 (¶ [00107]); EX1022 ('595 Application File History) at exhibit page 280 (¶ [00107]).

[324] EX1103 (Published '558 Application) at ¶ [0001].

[325] EX1033 (U.S. Patent No. 8,512,655) at 1:12-16; EX1034 (U.S. Patent No. 8,821,829) at 1:14-17; EX1035 (U.S. Patent No. 9,757,689) at 1:15-19; EX1065 (U.S. Patent No. 8,168,147) at 1:11-14.

a person of ordinary skill in the art were to consider the technical disclosures of the Provisional, the Provisional fails to disclose limitations from the issued claims of the '225 Patent.

a. Coal, Pyrolysis Char, and a Bromine-Containing Additive

215. The passages cited by the applicants during prosecution of the '091 Application in support of the claims do not, by themselves or collectively, support the limitations from independent Claims 1 and 17 of the '225 Patent of "a mixture comprising coal, pyrolysis char, and an additive comprising HBr, a bromide compound, or a combination thereof," or independent Claim 14 wherein a combustor comprises "pyrolysis char and an additive comprising HBr, a bromide compound, or a combination thereof."

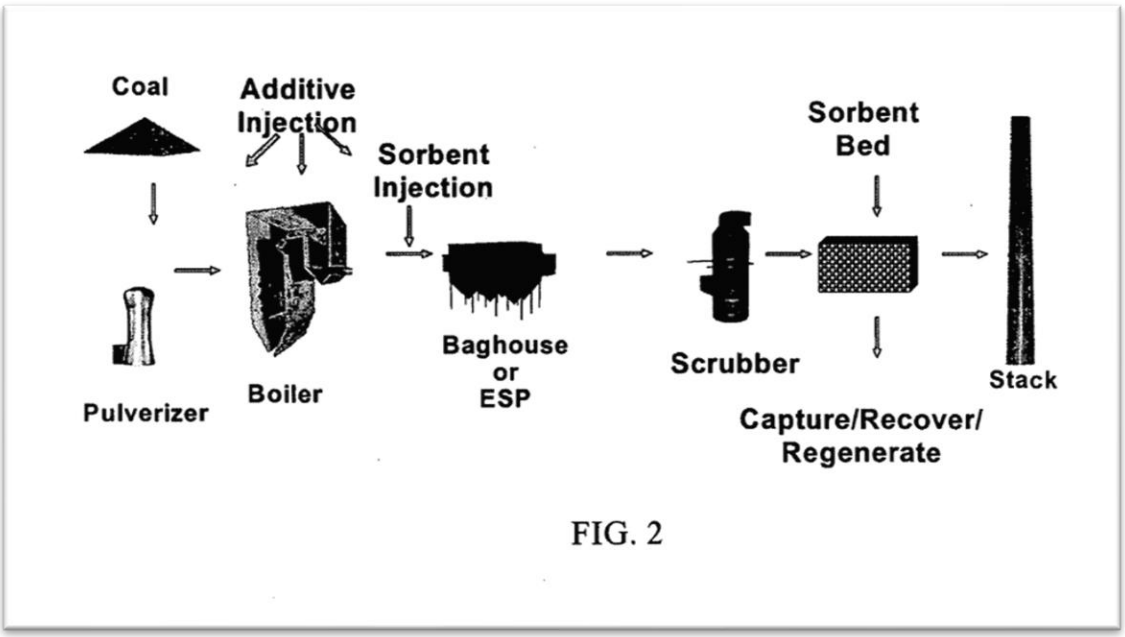


FIG. 2

216. Figure 2 of the Provisional includes a label with "Additive Injection" having three arrows pointing generically in the direction of the boiler of a coal-fired power plant. The Provisional, in relation to this figure, states that "additive can be injected where desired (e.g., before, after, or within the boiler)."[326]

217. Where the Provisional refers to the additive, it describes that these are "additives of base chemistry" that are "comprised of Group I or Group II elements, such as Ca, Na, and others."[327] These additives are explained in more detail by "outline of examples of the invention" number 9, reproduced below as annotated:[328]

> 9. The process of using additives (1-8) in conjunction with sorbents to capture acid gases and other flue gas constituents that block oxidation reactions or consume sorbent sites that would otherwise capture mercury. The additive is a compound comprised of Group I or II elements, such as Ca, Na, and others. These additives of base chemistry may be added to flue gas as a sorbent mixture or co-injected to selectively sorb acid gases or other gas constituents that compete for mercury reactive/sorption sites, thereby improving the effectiveness of activated carbon to capture mercury. In addition, the base additives can augment the treated activated carbon by helping to capture oxidized mercury forms in the flue gas, such as mercuric chloride, or that are produced on the carbon sorbent, such as mercuric bromide, but are released to the gas phase as the sorbent becomes saturated or capacity limited.

Halogens (including bromine) are in Group VII, and not Groups I or II. This makes clear that the "additive" disclosed by the Provisional is not the bromine-containing

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[326] EX1020 (Provisional) at Figure 2, exhibit page 15 (discussing Figure 2).

[327] EX1020 (Provisional) at exhibit page 4 (Abstract).

[328] EX1020 (Provisional) at exhibit page 7 (emphasis added).

promoter itself, but is instead a non-bromine based additive of base chemistry of Ca (Calcium), Na (Sodium), or other alkali—those elements in the first two groups (columns) of the periodic table. The primary function recognized by this alkali additive is to neutralize other contaminants within the flue gas that would otherwise "compete for mercury reactive/sorption sites."[329]

218. Accordingly, Figure 2 and its accompanying text in the '640 Provisional fail to clearly disclose "a mixture comprising coal…and an additive comprising HBr, a bromide compound, or a combination thereof," or "combusting coal in a combustor comprising…an additive comprising HBr, a bromide compound, or a combination thereof."

219. The claims further require that the mixture comprise pyrolysis char (Claims 1 and 17) or that the combustor comprise pyrolysis char (Claim 14). The sole potential reference in the Provisional to pyrolysis char is the statement that "[c]arbon is char recovered from pyrolysis process" in example 1A.[330] In example 1, carbon is described in the context of "modified carbon sorbent."[331] Within the Provisional, sorbent is only added after the boiler, and thus cannot form a mixture

[329] EX1020 (Provisional) at exhibit page 7 (emphasis added).

[330] EX1020 (Provisional) at exhibit page 5.

[331] EX1020 (Provisional) at exhibit page 5.

that is combusted as in Claims 1 and 17, nor can the combustor comprise such sorbent as in Claim 14. Paragraph [00107] of the '595 Application states that in general "the inventive sorbent may be injected where desired (e.g. before, after, or within the boiler)," but this is not found within the Provisional.[332] Additionally, as discussed above, this referred to testing the already-promoted sorbent, and it would be illogical to add activated carbon into or before the combustion chamber.

b. An Additive Comprising HBr, a Bromide Compound, or a Combination Thereof

220. The Provisional also fails to disclose an additive comprising the particular bromine-containing species recited in the claims of the '225 Patent. Of note, the Provisional provides an Example 1E, which recites that the "additional substance is hydrohalide (HI, HBr, HCl), etc., 1%-10% of bromine."[333]

221. First, as explained above, the Provisional refers to an "additional substance" rather than an "additive."[334] 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

[332] EX1022 ('595 Application File History) at exhibit page 280.

[333] EX1020 (Provisional) at exhibit page 6 (Example 1E).

[334] EX1020 (Provisional) at exhibit page 6 (Example 1E).

inventors, John Pavlish, submitted on July 10, 2019 during prosecution of the '517 Patent (as well as other patents proceeding the '225 Patent), "hydrogen bromide" is defined as "the diatomic molecule with the formula HBr. It is a colorless compound and a hydrogen halide."[335] This is different than the bromide compound recited in the claims of the '225 Patent.

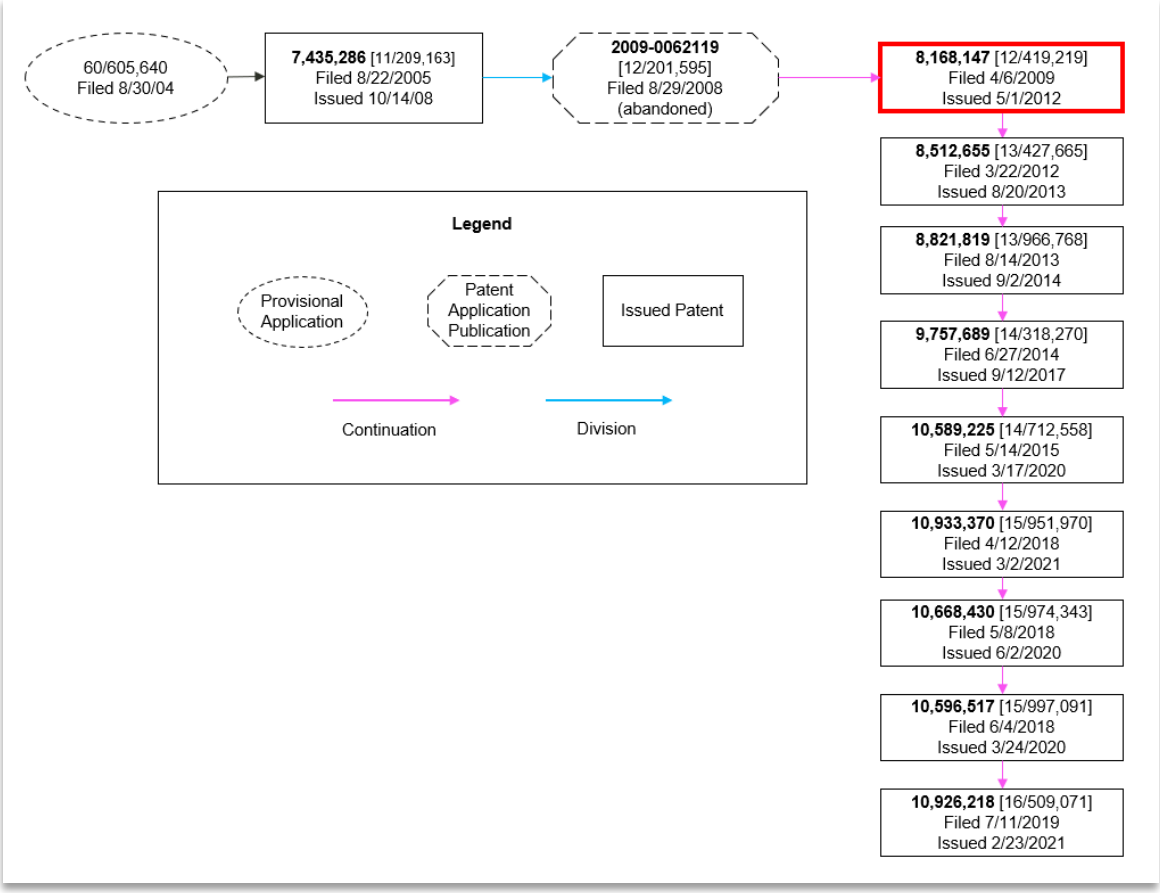
222. The disclosure of HBr in the Provisional does not support "an additive comprising . . . a bromide compound" as required by the independent claims of the '225 Patent. Even though HBr belongs to the group of bromide compounds, there are a nearly infinite number of forms of bromide compounds, because as stated by Mr. Pavlish, a "bromide compound" may be any "chemical compound containing a bromide ion or ligand."[336] 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."

[335] EX1024 ('517 Patent File History) at exhibit pages 323-324 ¶ 12 (7/10/2019 Decl. C from John Pavlish and Nicholas Lentz); EX1026 ('114 Patent File History) at 320 ¶ 12 (3/20/2019 Decl. C from John Pavlish and Nicholas Lentz).

[336] EX1024 ('517 Patent File History) at exhibit page 322 ¶ 9 (7/10/2019 Decl. C from John Pavlish and Nicholas Lentz); EX1026 ('114 Patent File History) at exhibit page 319 ¶ 9 (3/20/2019 Decl. C from John Pavlish and Nicholas Lentz).

4. The Claims of U.S. Patent No. 8,168,147 (EX1065) Are Not Supported by Its Specification

223. I understand that the '219 Application I discuss (U.S. Patent Application No. 12/419,219) ultimately issued into U.S. Patent No. 8,168,147 ('147 Patent).[337] This patent is shown below:[338]



[337] EX1065 (U.S. Patent No. 8,168,147).

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

I have been asked to review the issued claims of the '147 Patent and then assess whether claims of the '147 Patent find support in the specification of the '147 Patent. I have determined that Claims 18 and 19 of the '147 Patent do not have support from the specification of the '147 Patent, and they could only rely on the Provisional for support.

224. The '147 Patent contains a single independent claim (claim 1) directed to "[a] method for separating mercury from a mercury containing gas."[339] Claim 1 requires "promoting at least a portion of a particulate sorbent material comprising activated carbon by chemically reacting the sorbent material with a bromine containing promoter."[340] Claim 17 depends from Claim 1 and further requires "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."[341] Claim 18 depends from Claim 17 and specifies that "the gas stream [of Claim 17] is a mercury

[339] EX1065 ('147 Patent) at claim 1.

[340] EX1065 ('147 Patent) at claim 1.

[341] EX1065 ('147 Patent) at claim 17 (emphasis added).

containing gas."[342] Claim 19 depends from Claim 18 and further specifies that "the gas stream is a transport gas."[343]

225. Through its dependency on claims 1 and 17, the subject matter of claim 18 requires: "injecting the particulate sorbent material at a sorbent material injection rate and injecting separately the bromine containing promoter into [a mercury-containing gas] whereby in-flight reaction produces the promoted brominated sorbent.

226. Through its dependency on claims 1, 17, and 18, the subject matter of claim 19 requires: "injecting the particulate sorbent material at a sorbent material injection rate and injecting separately the bromine containing promoter into [a mercury containing gas that is a transport gas] whereby in-flight reaction produces the promoted brominated sorbent."

227. I have reviewed the specifications, figures, claims, and prosecution histories of the Provisional, the '163 Application, the '595 Application, and the '147 Patent. During my review, I specifically looked for any disclosure of: (a) injecting the sorbent material separately from the bromine containing promoter into a mercury-containing gas stream; such that (b) in-flight reaction in the mercury-

[342] EX1065 ('147 Patent) at claim 18.

[343] EX1065 ('147 Patent) at claim 19.

containing gas produces the promoted brominated sorbent, as required by claim 18 of the '147 Patent. In addition, I also looked for any disclosure of the above in which the mercury-containing gas (as per claim 18) is also a transport gas, as required by claim 19 of the '147 Patent.

228. I determined that none of the other applications between the Provisional and the filing of the '219 Application—the application that led to the '147 Patent—include any disclosure of claims 18 and 19. The only disclosure of claims 18 and 19 in the '147 Patent, or any of the applications from which it claims priority, is found in the language of claims 18 and 19 themselves, which were first introduced in the April 6, 2009 preliminary amendment.

a. No Disclosure of Claims 18 and 19 in the '163 or '595 Applications

229. The '163 Application and the '595 Application, which are parents to the '147 Patent, do not disclose the subject matter of claims 18 and 19 of the '147 Patent.[344] As I discuss above, these applications repeatedly describe treating a base activated-carbon sorbent with a bromine promoter prior to injecting the prepared promoted sorbent into a mercury-containing flue gas, such that: (a) the sorbent

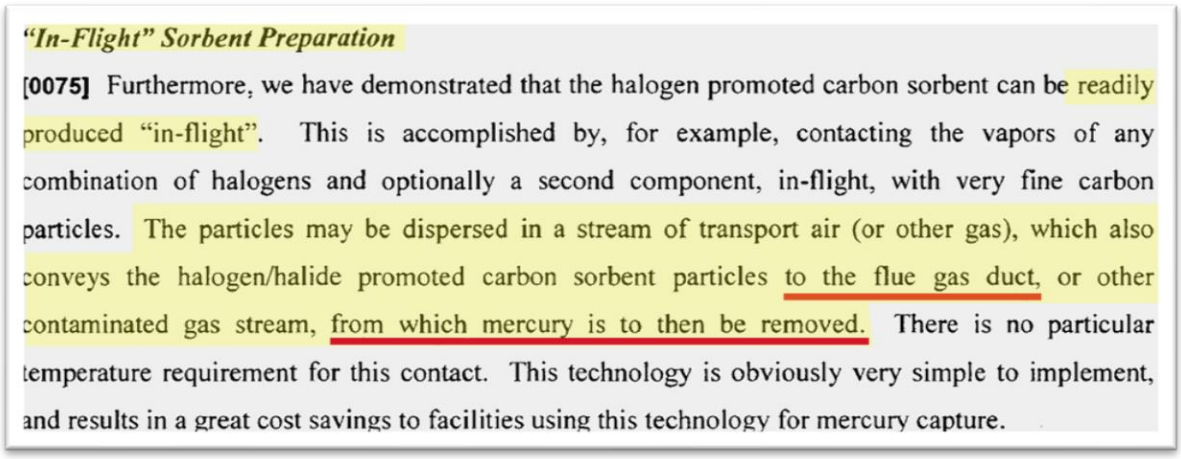
[344] And as discussed above, the '163 Application and '595 Application also do not disclose adding any bromine-containing ingredients to coal upstream of the combustion chamber.

material and bromine containing promoter are not injected "separately" into the mercury-containing gas (they are injected together); and (b) any in-flight reaction between sorbent and promoter occurs prior to injection into the mercury-containing gas, and not in the "gas stream [that] is a mercury-containing gas."

230. The '163 and '595 Applications describe "in-flight" promotion as "contacting the vapors of any combination of halogens and optionally a second component, in-flight with very fine carbon particles."[345] But the only examples provided in those documents of such treatment of activated carbon with a bromine promoter occurs before introduction into the mercury-containing flue gas. According to the description in the priority documents to the '147 Patent, ***first*** the contact between bromine and activated carbon occurs, and ***then*** the "halogen/halide promoted carbon sorbent particles" (i.e., the promoted bromine sorbent of claim 17) are transported ***to*** the mercury-containing gas.[346]

[345] EX1021 ('163 Application File History) at exhibit page 251 ¶ [0075]; EX1022 ('595 Application File History) at exhibit page 271 ¶ [0075].

[346] EX1021 ('163 Application File History) at exhibit page 251 ¶ [0075]; EX1022 ('595 Application File History) at exhibit page 271 ¶ [0075].



"In-Flight" Sorbent Preparation

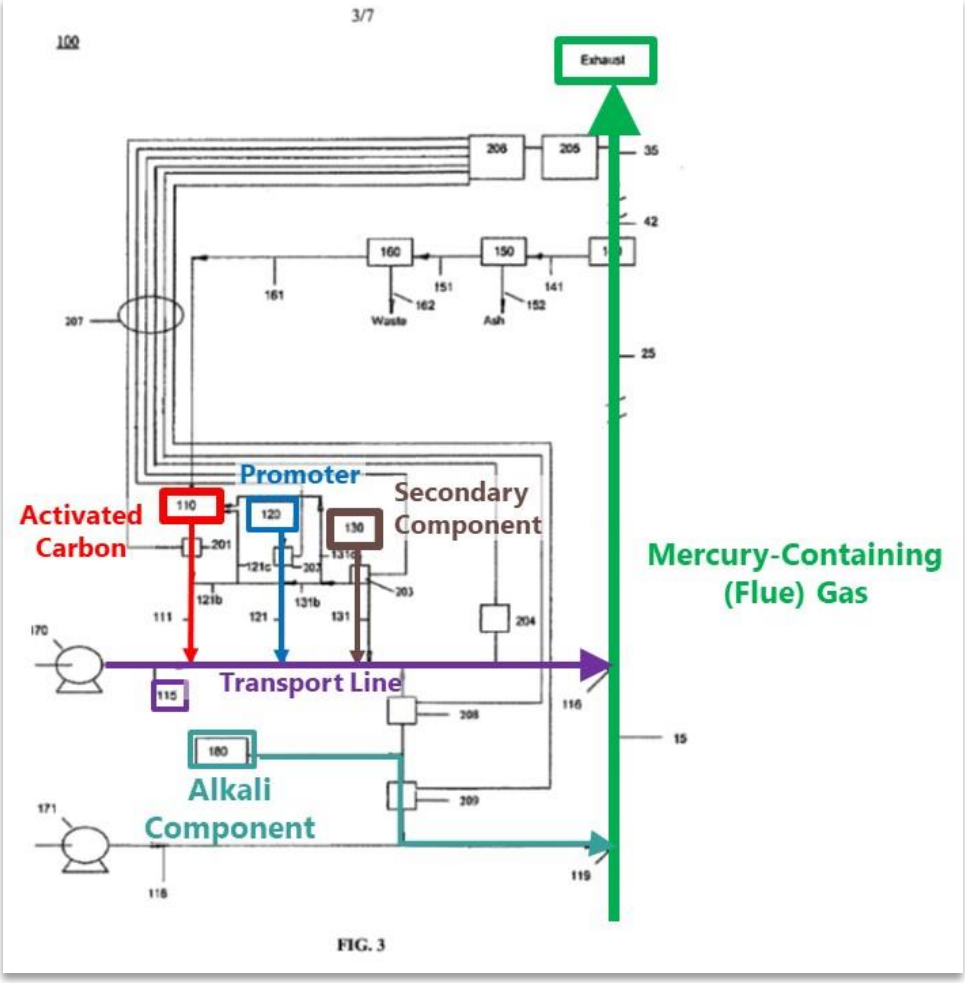
[0075] Furthermore, we have demonstrated that the halogen promoted carbon sorbent can be readily produced "in-flight". This is accomplished by, for example, contacting the vapors of any combination of halogens and optionally a second component, in-flight, with very fine carbon particles. The particles may be dispersed in a stream of transport air (or other gas), which also conveys the halogen/halide promoted carbon sorbent particles to the flue gas duct, or other contaminated gas stream, from which mercury is to then be removed. There is no particular temperature requirement for this contact. This technology is obviously very simple to implement, and results in a great cost savings to facilities using this technology for mercury capture.

The "in-flight" promotion occurs on the way "to" the flue gas duct—before the sorbent contacts the mercury-containing gas.

i. Figure 3 of the '163 and '595 Applications Does Not Disclose Claims 18 and 19

231. The '163 and '595 Applications, with reference to Figure 3, describe that the timing of in-flight promotion occurs before injection into the mercury-containing gas. A transport gas is used to co-inject the bromine-containing promoter and sorbent material from the non-mercury-containing transport gas into the mercury-containing exhaust gas. The transport (purple) occurs before the mercury-containing gas (green). Fig. 3 from the '163 and '595 Applications is annotated below:[347]

[347] EX1021 ('163 Application File History) at exhibit page 274 (Fig. 3) (annotated); EX1022 ('595 Application File History) at exhibit page 297 (Fig. 3).



As shown in Fig. 3, the activated-carbon sorbent (110) and halogen promoter (120) are injected into the mercury-containing flue gas (15) together, and not separately, at point 116. In addition, neither Fig. 3 nor anything else in the '163 and '595 Applications discloses claim 19 of the '147 Patent. Instead, the only support for this embodiment recited in claim 19 is the language of claim 19 itself.

232. In addition to the embodiment of Figure 3, the '163 and '595 Applications provide two other specific embodiments in which the promoter and sorbent may be combined: in another line leading to the pneumatic transport line or

within the activated carbon sorbent reservoir—both before (upstream of) introduction to the mercury containing (flue) gas:

> The halogen/halide may be combined and react with the base activated carbon according to any of several provided methods. The halogen/halide may preferably be combined via line 121 directly into transport line 115, within which it contacts and reacts with the base activated carbon prior to injection point 116. This option is one form of what is referred to herein as "in-flight" preparation of a promoted carbon sorbent in accordance with the invention. Further, the halogen/halide may be combined via line 121b with base activated carbon prior to entering transport line 115. Still further, the halogen/halide may be contacted and react with the base activated carbon by introduction via line 121c into reservoir 110.[348]

Critically, none of the multiple embodiments provided by ’163 and ’595 Applications disclose adding a bromine containing material anywhere other than to the activated carbon sorbent prior to injection into the mercury containing (flue) gas, such that the bromine-containing promoter is injected into the mercury-containing gas together with (and not separately from) the activated carbon.

ii. Figure 1 of the ’163 and ’595 Applications Does Not Disclose Claims 18 and 19

233. None of the other figures of the ’163 and ’595 Applications, including Figure 1, disclose an embodiment where a bromine containing promoter is injected into a mercury containing (gas) stream, or that the mercury-containing gas acts as a

[348] EX1021 (’163 Application File History) at exhibit page 247; EX1022 (’595 Application File History) at exhibit page 267.

transport gas. Figure 1 from the '163 Application is shown to the left,[349] and Figure 1 from the '595 Application is shown to the right:[350]

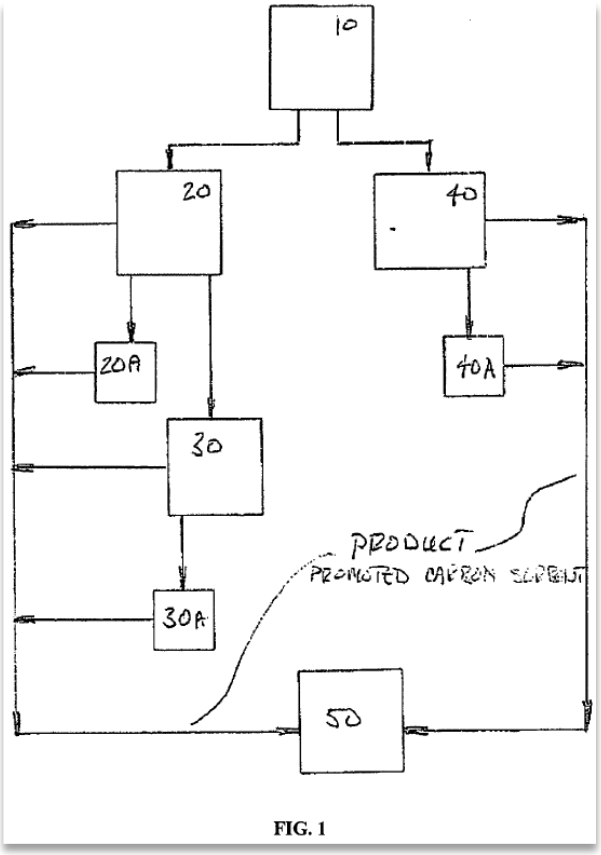


FIG. 1

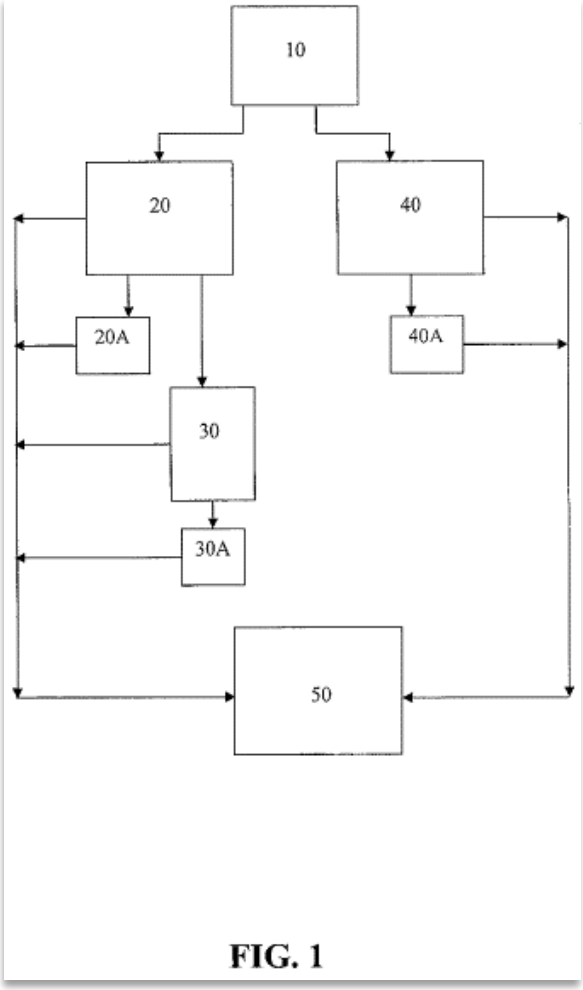


FIG. 1

The '163 and '595 Applications introduce, with reference to Figure 1, two embodiments for adding the base activated carbon (10) to a mercury-containing flue gas stream (50). First, Figure 1 identifies an embodiment along the left path, in

[349] EX1021 ('163 Application File History) at exhibit page 272.

[350] EX1022 ('595 Application File History) at exhibit page 295.

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."[351] Second, they 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."[352] These paths are shown below, in annotated Figure 1 from the '595 Application.[353]

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

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

[353] EX1022 ('595 Application File History) at exhibit page 295 (Fig. 1, annotated).

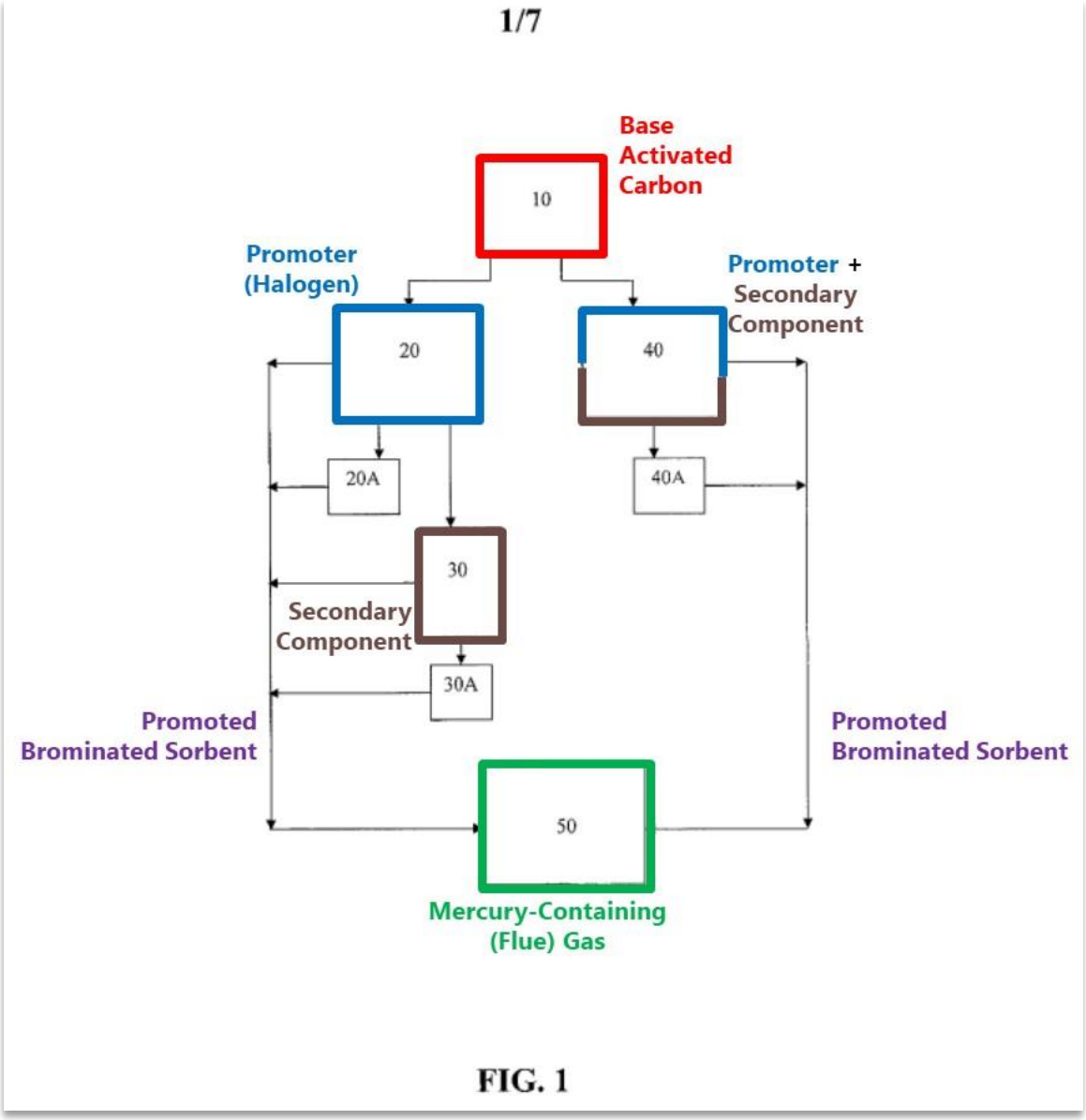


FIG. 1

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."[354]

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

234. 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 before introducing them to the flue gas, as represented by block 50. Accordingly, in both the first (left) embodiment and second (right) embodiment, the halide promoter and activated carbon sorbent are injected together into a transport line, and not "separately …" (as required by Claim 17 of the '147 Patent) into the mercury-containing (flue) gas stream (as required by Claim 18 of the '147 Patent). I have reviewed the entirety of the '163 and '595 Applications and conclude there is no written-description support for injecting the halide promoter directly into the mercury-containing gas, separately from the activated carbon.

iii. Replacement-Figure 1 Was Added in 2009

235. Replacement-Figure 1, as found in the issued '147 Patent, is not the same as the version originally filed in the '163 and '595 Applications and on April 6, 2009, with the '219 Application. Figure 1, as originally filed on April 6, 2009, is reproduced below:[355]

[355] EX1025 ('147 Patent File History) at exhibit page 571.

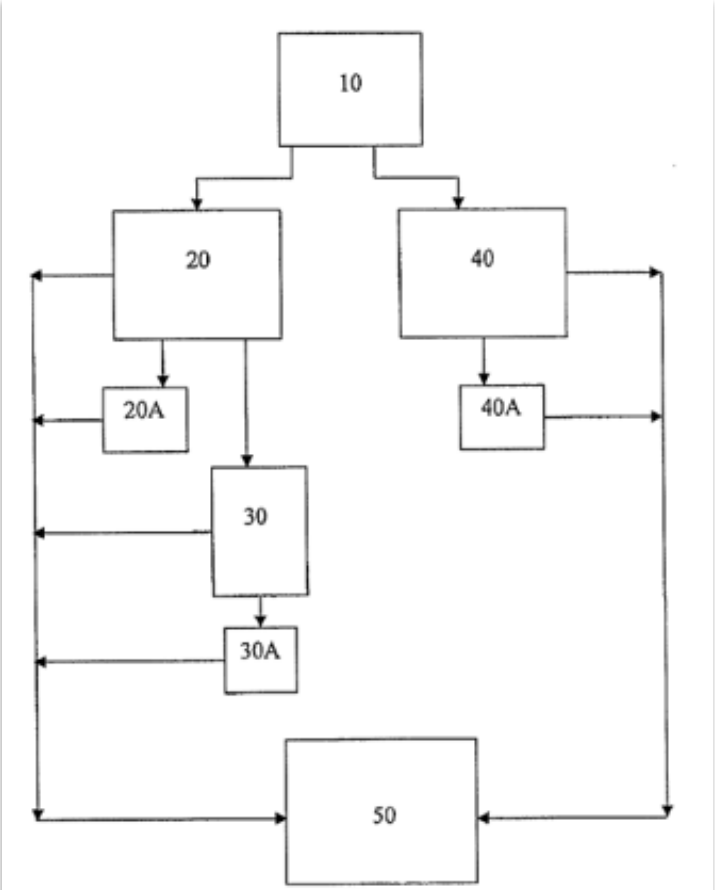


FIG. 1

This version of Figure 1 as filed with the original disclosure of the ’147 Patent is the same in substance to Figure 1 of the ’163 and ’595 Applications. The description of Figure 1 in the ’163 Application and the ’595 Application, discussed above, is identical to that of the ’147 Patent, other than stylistic changes.[356] Importantly, the

[356] *Compare*, EX1021 (’163 Application File History) at exhibit pages 243-44 ¶¶ [0043-51], *and* EX1022 (’595 Application File History) at exhibit pages 263-64 ¶¶ [0043-51], *with* EX1065 (’147 Patent) at 6:40-7:60.

descriptions in the ’163 and ’595 Application are silent regarding any disclosure of a path directly from block 10 (activated carbon) to block 50 (flue gas).

236. After the initial filing of the ’219 Application, the USPTO issued a Notice to File Corrected Application Papers on September 4, 2009.[357] This notice requested corrections to Figures 2 and 4-10 of the application.[358] On November 4, 2009, the applicant filed a complete replacement set of Figures 1-10.[359] For purposes of comparison, the version of Figure 1 that was originally filed on April 6, 2009, with the ’147 Patent is shown on the left.[360] The revised version of Figure 1 that was filed on November 4, 2009[361] is shown on the right, with an annotation in yellow indicating the modification to the figure:[362]

[357] EX1025 (’147 Patent File History) at exhibit pages 557-58.

[358] EX1025 (’147 Patent File History) at exhibit page 557.

[359] EX1025 (’147 Patent File History) at exhibit pages 541-51.

[360] EX1025 (’147 Patent File History) at exhibit page 571.

[361] Notably, this date is after the date of Sjostrom, Eckberg, and Olson-646.

[362] *Compare* EX1065 (’147 Patent) at Fig. 1 (annotations provided in yellow); EX1025 (’147 Patent File History) at exhibit page 542, *with* EX1025 (’147 Patent File History) at exhibit page 571.

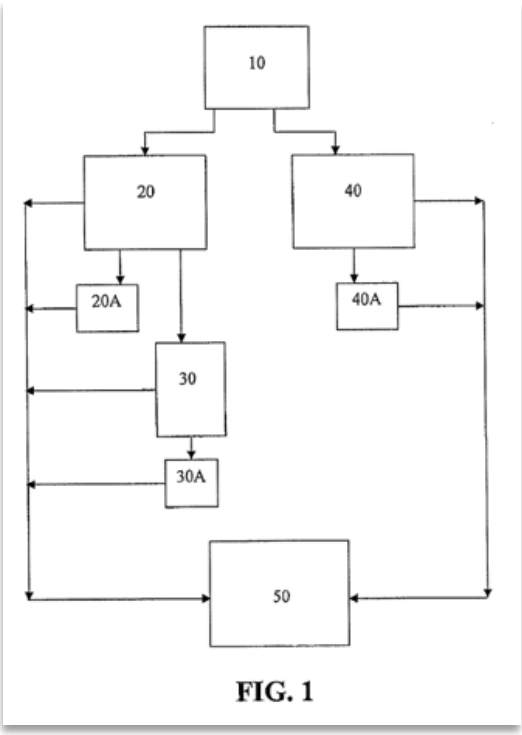


FIG. 1

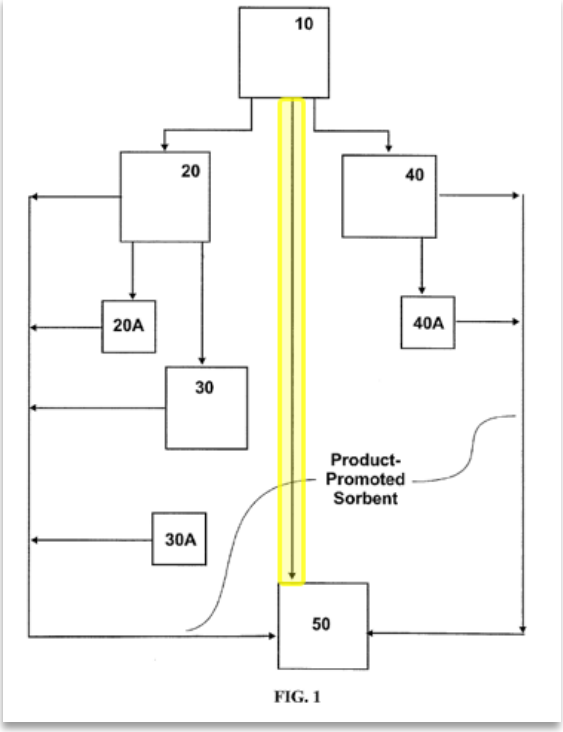


FIG. 1

As discussed above, this third path or embodiment (from block 10 to block 50) was added in the replacement drawing, and is not disclosed in the '219 Application as filed, or in the '163 and '595 Applications. Notably, the '163 and '595 Applications do not describe the embodiment identified by the middle path (highlighted above) of Figure 1, and the original Figure 1 in all these applications does not include that middle path.

237. Because there is no textual support describing the direct line between block 10 (activated carbon) and block 50 (flue gas), highlighted above in yellow, there is no support that the line added in Replacement-Figure 1 teaches adding activated carbon directly to the mercury-containing (flue) gas independently and

separately from the halide promoter as claimed in claims 18 and 19. The '163 and '595 Applications display only the paths 10-20-30-50 and 10-40-50.[363]

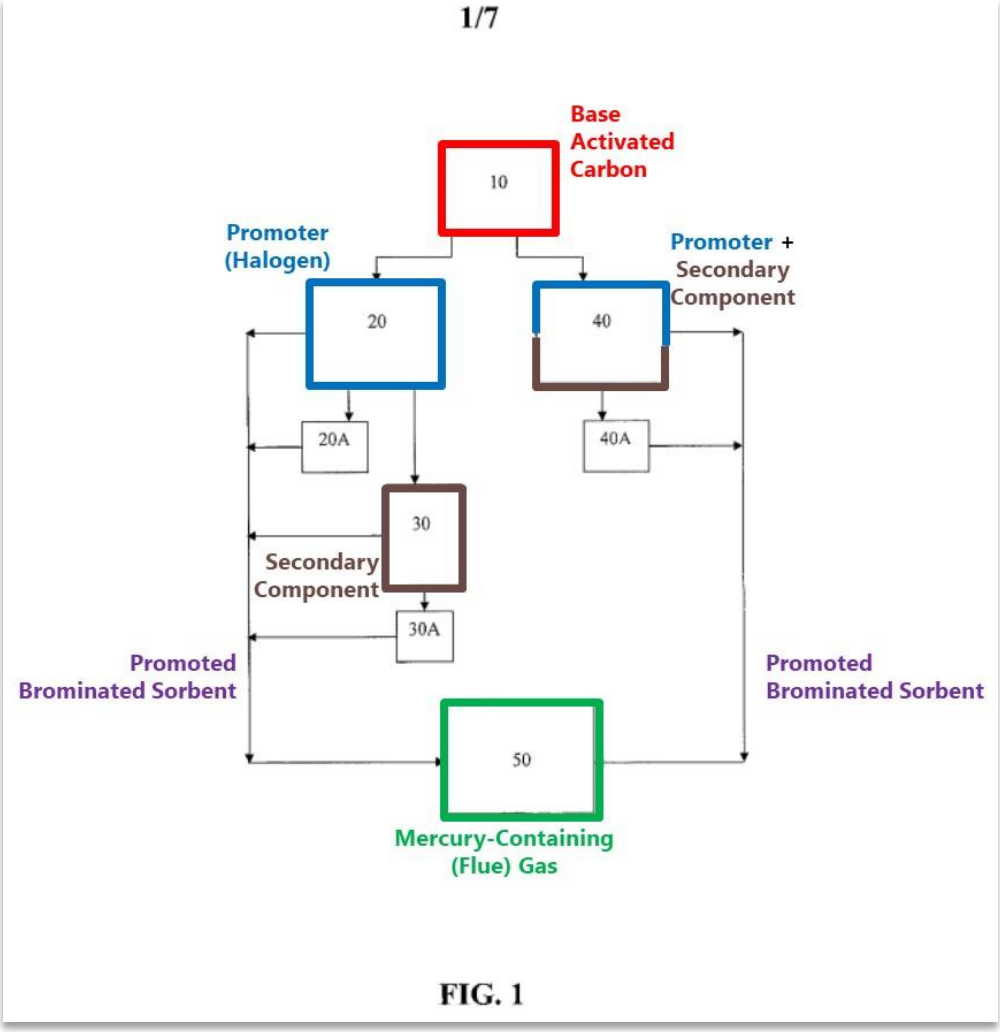


FIG. 1

Based on the explanation of these paths provided by the '163 and '595 Applications, a POSITA would be led to conclude that this unmentioned direct path added to Figure 1 of the '147 Patent between blocks 10 and 50 would be a simplified process

[363] EX1022 ('595 Application File History) at exhibit page 295 (Fig. 1, annotated).

for treating a mercury-containing (flue) gas with a bromine-promoted carbon that is prepared before injection into the mercury containing (flue) gas, consistent with the other embodiments disclosed by the '163 and '595 Applications. Indeed, the only explanation given in the '163 and '595 Applications, or the '147 Patent itself, of what occurs at block 50 makes clear that this is a treatment of a mercury-containing (flue) gas with an already-prepared bromine promoted sorbent:[364]

> Referring still to FIG. **1**, also illustrated are preferred embodiments in which, as illustrated by block **50**, a flue gas stream is treated with product promoted carbon sorbent prepared as described above.

From this paragraph, the only conclusion that is left to be made from the direct line from 10 to 50 is that a flue gas is being treated with a product promoted carbon sorbent that has already been "prepared as described above" (i.e., prepared, in the past-tense, prior to injection into the flue gas).[365]

238. Even if PO could rely on this improperly-added line from box 10 (activated carbon) to box 50 (flue gas), it still fails to support Claims 18-19. At most, the specification refers to this embodiment as one where no halogen promotion

[364] EX1065 ('147 Patent) at 7:12-15 (emphasis added).

[365] EX1065 ('147 Patent) at 7:12-15.

occurs, such as where an alkali component is used instead of a halide promoter.[366] Figure 10 compares "Standard AC" and "Standard AC with Alkali," where the alkali acts as a second sorbent to remove HCl, NOx, and other species in the flue gas so as to not foul any activated carbon.[367] Accordingly, even Replacement-Figure 1 does not illustrate providing activated-carbon sorbent separately from bromine-containing promoter into a mercury-containing gas, with in-flight reaction occurring in the mercury-containing gas.

239. Based on this analysis, it is my opinion that claims 18 and 19 of the '147 Patent do not find written-description support in any of the earlier applications preceding the '147 Patent. Thus, the only support for these claims (if any) would be from the Provisional.

E. ADMITTED PRIOR ART

240. The '225 Patent makes numerous admissions regarding what was known in the art.[368]

241. The '225 Patent admits that activated carbon, including powdered activated carbon, was known in the art.

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[366] EX1065 ('147 Patent) at 10:7-12; Fig. 10.

[367] EX1065 ('147 Patent) at Fig. 10, 20:60-21:16.

[368] See, e.g., EX1001 ('225 Patent) at 13:67–14:4.

> In some preferred embodiments, the activated carbon provided may preferably be any of several types, *as understood by those skilled in the art*. For example, the activated carbon may include *powdered activated carbon*, granular activated carbon, carbon black, unburned carbon, carbon fiber, carbon honeycomb or plate structure, aerogel carbon film, pyrolysis char, an activated carbon or regenerated activated carbon with a mass mean particle size greater than fly ash in a flue gas stream to be treated.[369]

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 baghouse or electrostatic precipitator (ESP) and collected along with ash particulate.[370]

242. The ’225 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 electrostatic precipitators (hereinafter “ESP”), or other particulate removal devices *as are known in the art*.[371]

[369] EX1001 (’225 Patent) at 7:32-40.

[370] EX1001 (’225 Patent) at 1:61-67.

[371] EX1001 (’225 Patent) at 9:7-11.

XI. CLAIM CONSTRUCTION

243. I have reviewed how a POSITA would have understood terms in the Challenged Claims. I note that Magistrate Judge Burke in the District of Delaware provided constructions for two terms in patents from the family of the '225 Patent, including the '225 Patent itself. 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" (claim 1), "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.[372] In reaching this 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

[372] 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)).

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)."[373] Judge Burke concluded that "[t]he plain language of the claims at issue supports Plaintiffs' position" and that the claims "allow for the pyrolysis char to be created within the combustor, so long as it is then present (and combusted) with the coal and the bromine compound."[374]

244. 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.[375] In reaching this construction Magistrate Judge Burke explained that the plain language of the 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

[373] 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)).

[374] 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)).

[375] 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)).

containing promoter'; and (b) the bromine promoter and sorbent material must both be injected downstream of a furnace exit."[376]

245. 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. Except as discussed above for "pyrolysis char," 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]

246. 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

247. 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. 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.

[376] 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)).

2. Vosteen589 Is Analogous Art

248. 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."[377] The specific problem faced by the inventors of the Challenged Patent was "a need for more economical and effective mercury removal technology."[378] 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."[379]

3. Overview of the Disclosure of Vosteen589

249. Vosteen589 describes processes for the "removal of mercury from the flue gases in a flue gas emission control system downstream of the combustion," in

[377] EX1001 ('225 Patent) at 1:29-33.

[378] EX1001 ('225 Patent) at 2:23-24.

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

plants such as "power stations, for example bituminous coal-fired or lignite-fired power stations."[380] 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."[381] 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."[382]

250. 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 strongly to dry sorbents than mercury chloride $HgCl_2$."[383] The adsorbent is part of the "dry emission control system" of Vosteen589, also referred to as a "dry or semi-

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

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

[382] EX1005 (Vosteen589) ¶[0016].

[383] EX1005 (Vosteen589) ¶[0019].

dry adsorption-based emission control stage."[384] As a result, Vosteen589 discloses the ability to remove more than 90% of mercury.[385]

B. THE DOWNS-BOILER REFERENCE [EX1006]

251. 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 '225 Patent.

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

252. 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 ultimate priority to a U.S. Provisional Patent Application No. 60/555,353 ("Downs-Boiler-Provisional"),[386] which was filed on March 22, 2004.

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

[385] EX1005 (Vosteen589) at Figure 5.

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

253. 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.

254. 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 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

255. 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."[387] The specific problem faced by the inventors of the Challenged Patent was "a need for more economical and effective mercury removal technology."[388] So too, the field of endeavor of Downs-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."[389]

3. Overview of the Disclosure of Downs-Boiler

256. 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,

[387] EX1001 ('225 Patent) at 1:29-33.

[388] EX1001 ('225 Patent) at 2:23-24.

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

but are not limited to, powdered activated carbon (PAC)."[390] 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.[391] 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:[392]

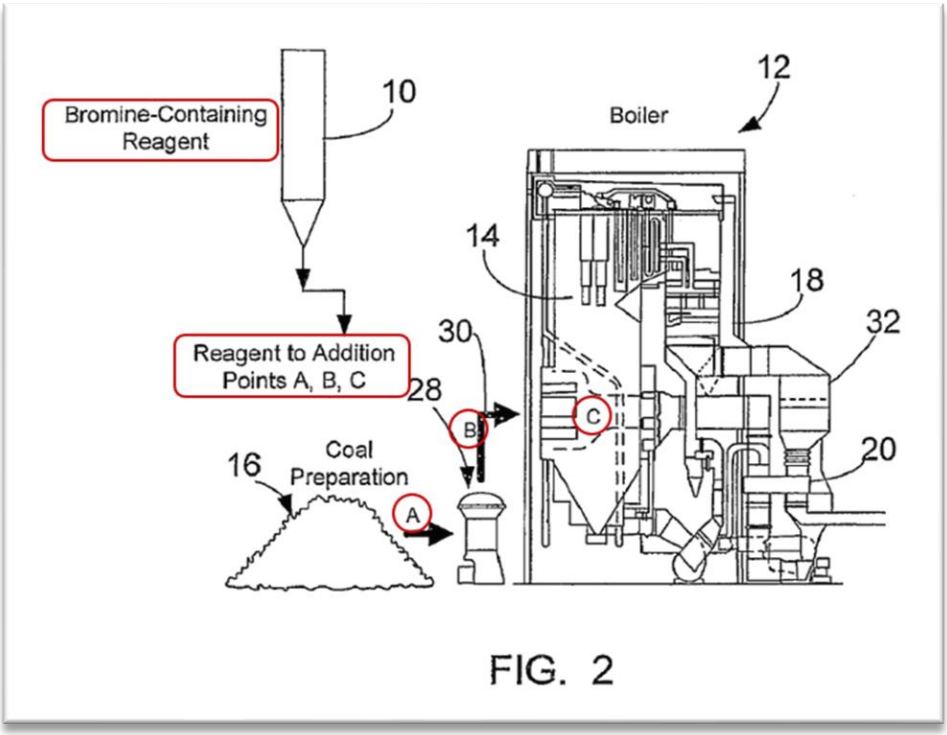


FIG. 2

[390] EX1006 (Downs-Boiler) ¶[0025].

[391] EX1006 (Downs-Boiler) at Abstract; *see also* EX1006 (Downs-Boiler) ¶[0007].

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

257. 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.[393]

Downs-Boiler describes that the bromine-containing reagent can be fed in either "gaseous, liquid, or solid form."[394] The reagent could be made from "alkali metal and alkaline earth metal bromides, hydrogen bromide (HBr) or bromine (Br_2)."[395] Examples of alkali earth metal bromides include calcium bromide ($CaBr_2$).[396]

4. Comparison of Downs-Boiler [EX1006] to Downs-Boiler-Provisional [EX1007]

258. 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-

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

[394] EX1006 (Downs-Boiler) ¶[0022].

[395] EX1006 (Downs-Boiler) ¶[0021].

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

Provisional as the original version.[397] 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-Provisional. All of the subject matter I rely on in Downs-Boiler is supported in Downs-Boiler-Provisional.

259. 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:"

260. Downs-Boiler-Provisional discloses this preamble. The title of the disclosure is "Bromine Addition for the Improved Removal of Mercury from Flue

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

Gas."[398] Downs-Boiler-Provisional further discloses that the "invention promises to significantly reduce the cost of mercury removal at coal-fired electric plants."[399] Downs-Boiler-Provisional discloses that it removes both oxidized mercury and elemental mercury from mercury-containing flue gases.[400] For example, Downs-Boiler-Provisional discusses that "the current invention can offer a cost-effective method of removing elemental mercury from coal combustion flue gases."[401]

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

261. Downs-Boiler-Provisional discloses this element. Again, the title of the disclosure is "Bromine Addition for the Improved Removal of Mercury from Flue Gas."[402] Downs-Boiler-Provisional further describes the ability "to promote the

[398] 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.

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

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

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

[402] 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.

oxidation of elemental mercury if the correct species (in this case bromine species) are present in the flue gases."[403]

262. 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."[404]

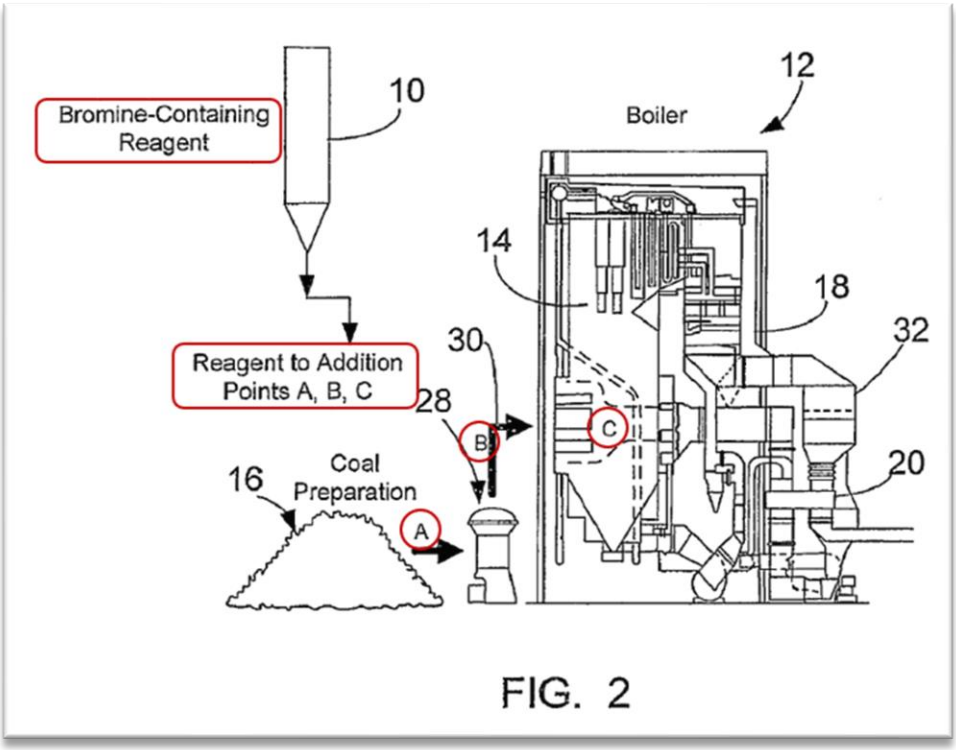


FIG. 2

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

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

263. 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."[405]

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

264. 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 elemental mercury 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, increasing the fraction of mercury appearing in the oxidized and particulate-bound forms enhances the removal of mercury in 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 to remove elemental mercury. Second, the increased fraction of oxidized mercury also enhances the removal of mercury across a PAC

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

> injection process, due to the higher reactivity of oxidized mercury with PAC.[406]

265. 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 shown to promote the oxidation of elemental mercury if the correct species (in this case bromine species) are present in the flue gases."[407]

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

266. 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."[408]

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

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

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

267. 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).[409] Thus, Downs-Broiler-Provision teaches to create oxidized forms of mercury from the elemental mercury by oxidizing the available elemental mercury.[410] 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."[411]

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

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

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

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

268. Downs-Boiler-Provisional discloses this claim element. Once more, the title of the disclosure is "Bromine Addition for the Improved Removal of Mercury from Flue Gas."[412]

269. 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 removal efficiencies are higher for the oxidized form."[413] Downs-Boiler-Provisional further states that "the 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."[414] The mercury-sorbent composition can be removed with "electrostatic precipitators (ESP) or fabric filters (FF), sometimes called

[412] 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.

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

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

baghouses," as well as in "wet and spray dryer absorber (SDA) flue gas desulfurization (FGD) systems."[415]

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

270. The Air & Waste Management Association ("AWMA") Conference has been held annually since 1907.[416] The primary purpose of AWMA is to provide training, information, and networking opportunities to thousands of environmental professionals in 65 countries across the world.[417] 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.[418] I delivered presentations at the 94th conference in 2001 entitled, "Interpreting

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

[416] 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/.

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

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

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.

271. 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 "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.[419] Exhibit 1077 is a true and correct copy of the label and jacket of

[419] 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.

the CD that was mailed to me from the 2002 AWMA Conference. ("AWMA CD Scan").[420]



272. 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

[420] EX1077 (AWMA CD Photo).

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.[421]

273. 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.[422]

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[421] 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.

[422] 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

274. The 2002 AWMA Conference took place on June 23-27, 2002, at the Baltimore Convention Center, in Baltimore, Maryland:[423]



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

[423] 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:[424]

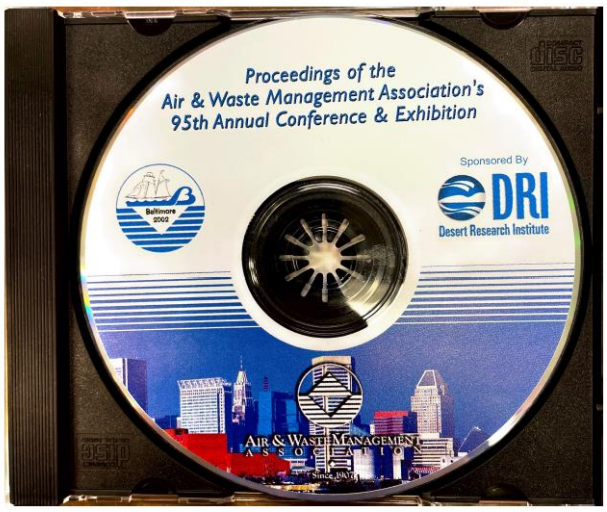


I received the CD from the 2002 AWMA Conference in summer 2002 ("AWMA CD Scan"), and photographs of the physical CD from which the Starns reference (EX1008) was copied, are shown below:[425]

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

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





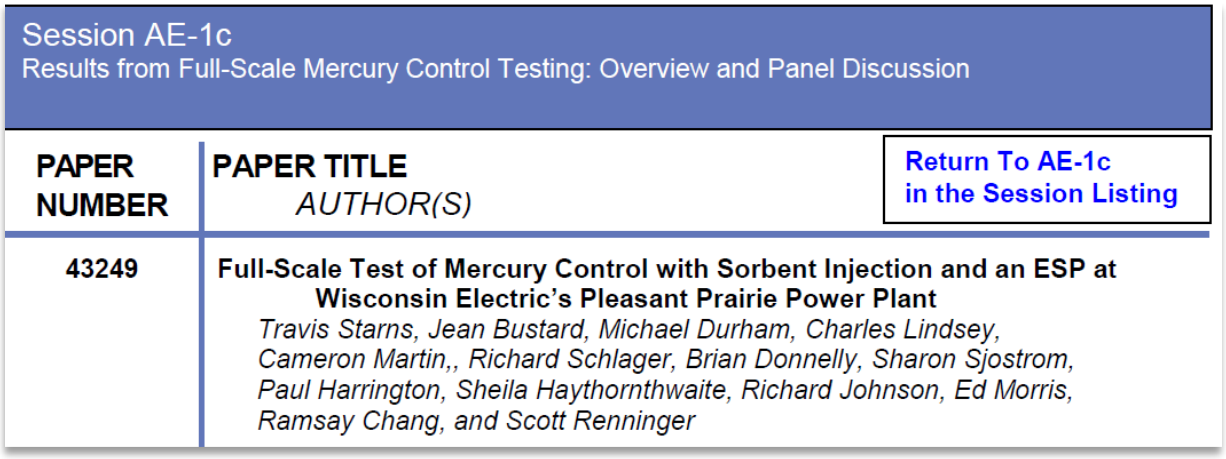
The author listing for the Starns paper is shown below, which is on a file from the physical CD:[426]

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**

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

The session listing, showing the Starns paper, is below[427]:



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

PAPER NUMBER	PAPER TITLE *AUTHOR(S)*	Return To AE-1c in the Session Listing
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*	

275. 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:[428]

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

[428] EX1086 (AWMA Bookstore Homepage), available at https://web.archive.org/web/20020806041256/http://www.awma.org:80/pubs/bookstore/

Welcome to the A&WMA Bookstore

Download a copy of the 2002 Publications Catalog here.

LATEST ADDITIONS



A&WMA 2002 Annual Conference Proceedings

This comprehensive CD-ROM 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.

Annual Conference Proceedings CD-ROMs

2002
2001
2000
1999
1998
1997
1996

Air Pollution Engineering Manual, second edition



276. 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")):[429]

[429] 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. 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

277. 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.[430] 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.[431]

2. Starns Is Analogous Art and Overview of the Disclosure

278. 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

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[430] 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.

[431] 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.

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."[432] The specific problem faced by the inventors of the Challenged Patent was "a need for more economical and effective mercury removal technology."[433] 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."[434] Both references address the problem through using activated carbon sorbents.[435] Starns provides details as to how to inject activated carbon at a coal-fired power plant. Starns teaches specific ACI equipment, which types of activated carbon to use, and where in the process to inject the activated carbon.

[432] EX1001 ('225 Patent) at 1:29-33.

[433] EX1001 ('225 Patent) at 2:23-24.

[434] EX1008 (Starns) at 2 (Abstract and Introduction).

[435] EX1008 (Starns) at 2 (Abstract and Introduction).

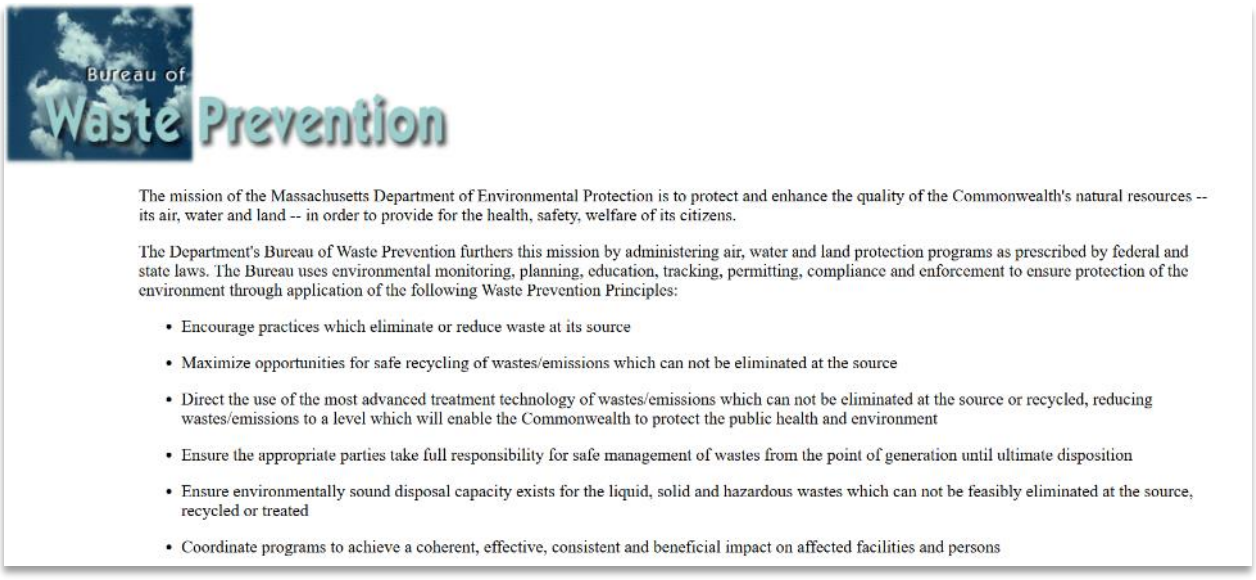
D. MASS-EPA [EX1009]

1. Prior Art Status of Mass-EPA

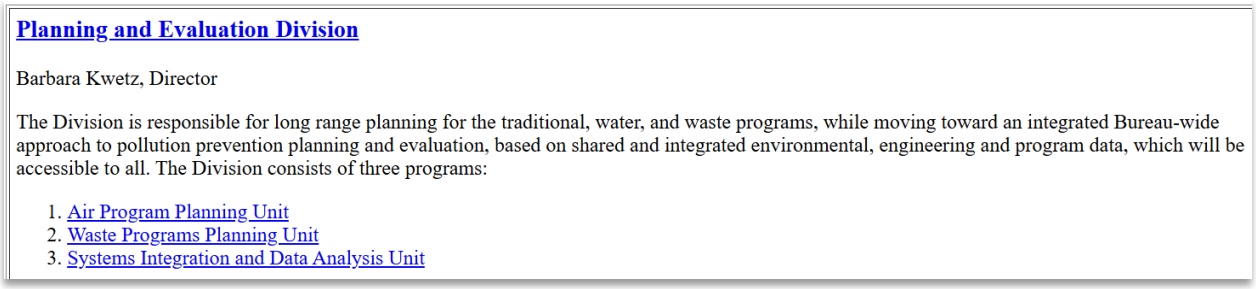
279. Mass-EPA was published by the Massachusetts Department of Environmental Protection, which is an administrative agency of the Commonwealth of Massachusetts with the established goal of protecting and enhancing the quality of Massachusetts' natural resources to provide for the health, safety, and welfare of its citizens.[436] Within the Massachusetts Department of Environmental Protection is the Bureau of Waste Prevention, which administers air, water, and land protection programs:[437]

[436] 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.

[437] 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.



The Bureau of Waste Prevention was comprised of four Divisions: Planning and Evaluation, Business Compliance, Consumer and Transportation, and Program Support.[438] The tasks of the Planning and Evaluation Division were as follows:[439]



[438] 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.

[439] 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.

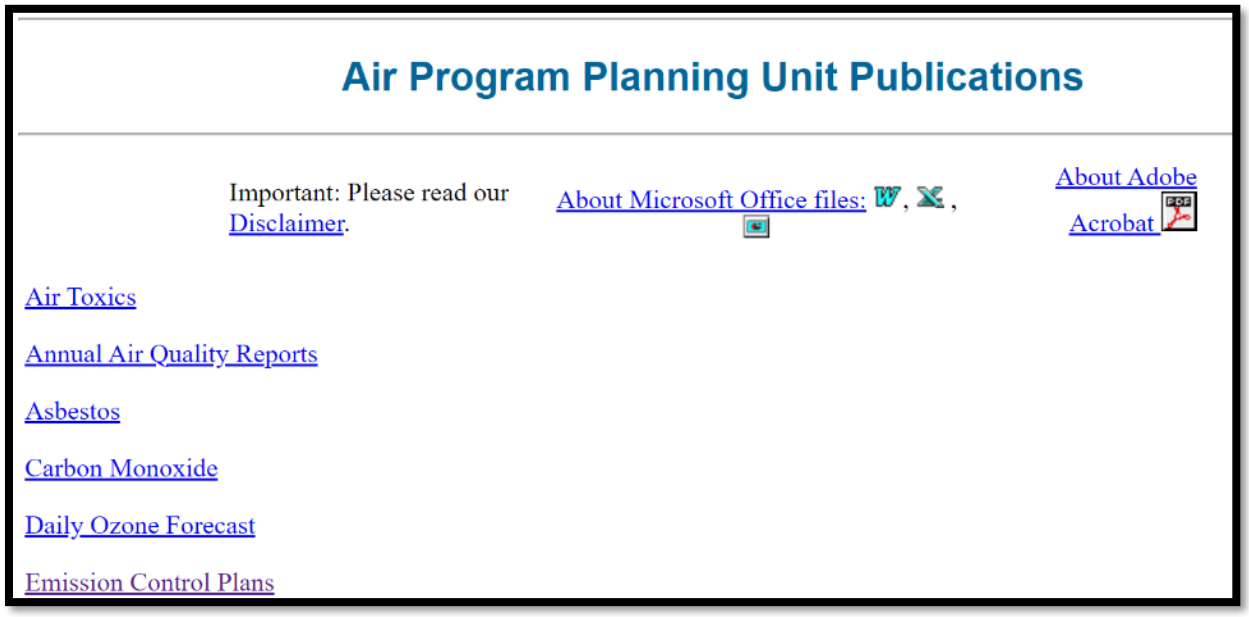
A POSITA would have looked to the Massachusetts EPA, including the Planning and Evaluation Division, as a repository for pollution mitigation, particularly since the goal of it was to provide "shared and integrated environmental, engineering and program data, which will be accessible to all."[440] Within the Planning and Evaluation Division is the Air Program Planning Unit.[441] 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:[442]

[440] 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.

[441] 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.

[442] 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:

About Adobe Acrobat

Air Toxics

Annual Air Quality Reports

Asbestos

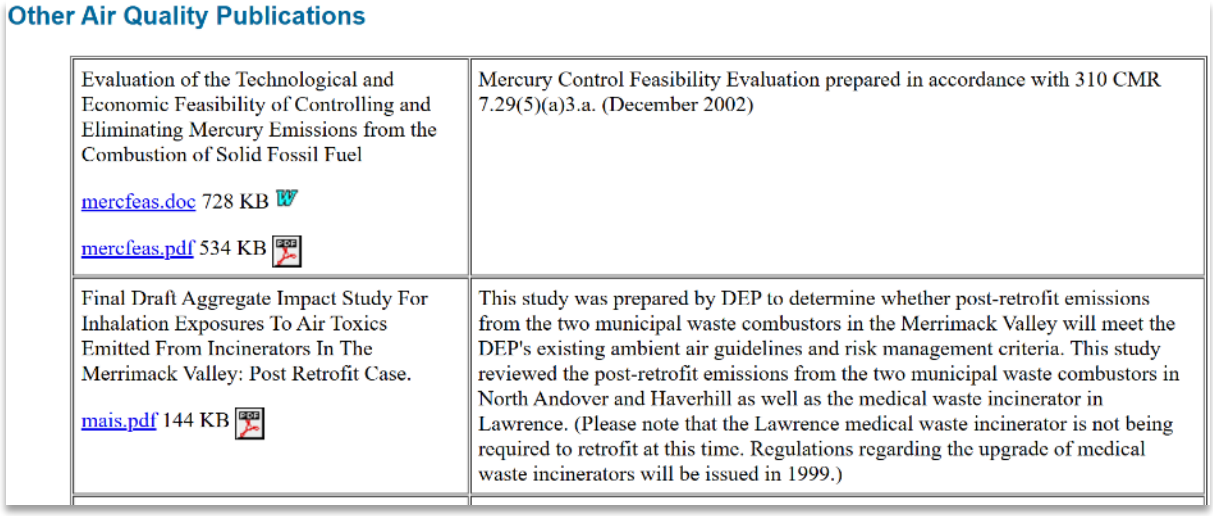
Carbon Monoxide

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.[443]

[443] 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:[444]

[444] 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.

280. 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":[445]

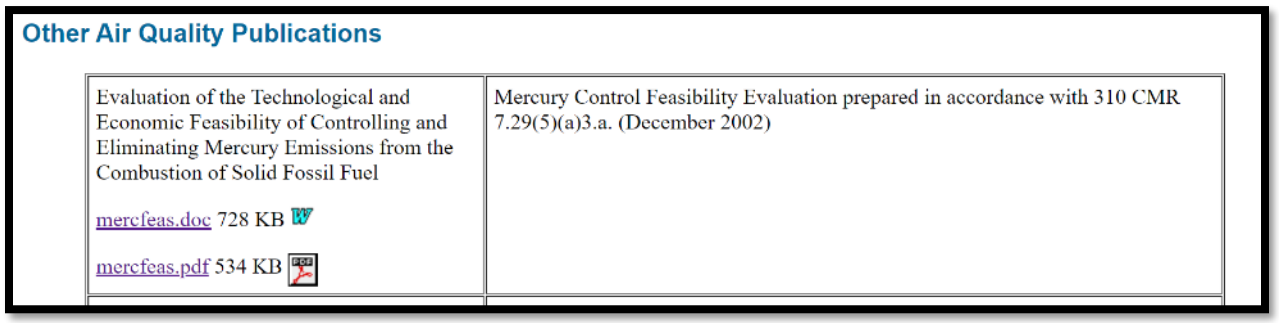
EVALUATION OF THE TECHNOLOGICAL AND ECONOMIC FEASIBILITY OF CONTROLLING AND ELIMINATING MERCURY EMISSIONS FROM THE COMBUSTION OF SOLID FOSSIL FUEL

Pursuant to 310 CMR 7.29 – Emissions Standards for Power Plants

December 2002

[445] EX1009 (Mass-EPA) at 1.

281. 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):[446]



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.[447]

282. 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.

[446] EX1090 (Mass-EPA Internet Archive), available at https://web.archive.org/web/20021220143210/http://www.state.ma.us/dep/bwp/daqc/daqcpubs.htm#ecp.

[447] 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."[448] 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.[449] 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. Mass-EPA Is Analogous Art and Overview of the Disclosure

283. 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

[448] EX1009 (Mass-EPA) at 1.

[449] 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."[450] The specific problem faced by the inventors of the Challenged Patent was "a need for more economical and effective mercury removal technology."[451] 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."[452] 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."[453] Mass-EPA provides details as to how to inject activated carbon at a coal-fired power plant.

[450] EX1001 ('225 Patent) at 1:29-33.

[451] EX1001 ('225 Patent) at 2:23-24.

[452] EX1009 (Mass-EPA) at Abstract, 4.

[453] 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]

284. 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.[454] 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.

285. 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

[454] 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 a 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").[455]

286. 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.

287. 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,

[455] 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.

288. 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.

289. 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

290. The 2005 EUEC took place on January 24-25, 2005, at the Westin La Paloma Resort, in Tucson, Arizona.[456] The conference included four separate presentation tracks: Track A – Air quality; Track B – Global Climate Change; Track C – Renewable Energy; and Track D – Other.[457] Each presenter prepared a Power-Point 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").[458]

[456] EX1030 (EUEC Handout) at 2; EX1061 (EUEC 2005 Home Page).

[457] EX1030 (EUEC Handout) at 2.

[458] EX1031 (EUEC CD Scan).

291. I personally presented at the 2005 EUEC in Track A – Air Quality proceedings and attended most presentations for Track A – Air Quality proceedings.[459] An excerpt of the program schedule discussing my presentation is shown below:[460]

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.[461]

[459] EX1030 (EUEC Handout) at 3.

[460] EX1030 (EUEC Handout) at 32.

[461] EX1031 (EUEC CD Scan).

292. In addition to myself, over 800 people attended the 2005 EUEC, as described in the attendee list included in the EUEC Handout.[462] 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.

293. 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.[463] 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

[462] EX1030 (EUEC Handout) at 106-118.

[463] EX1030 (EUEC Handout) at 23.

the other conference attendees, as reflected in Sjostrom, correlates with the presentation I attended at the 2005 EUEC.[464]

294. 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.[465] 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.[466]

295. 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.[467] The attendees for the A3 session were generally the same as those described above with regards to Track A as a

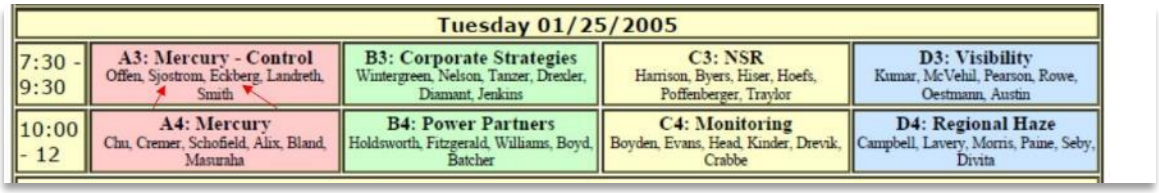
[464] EX1010 (Sjostrom).

[465] EX1030 (EUEC Handout) at 23.

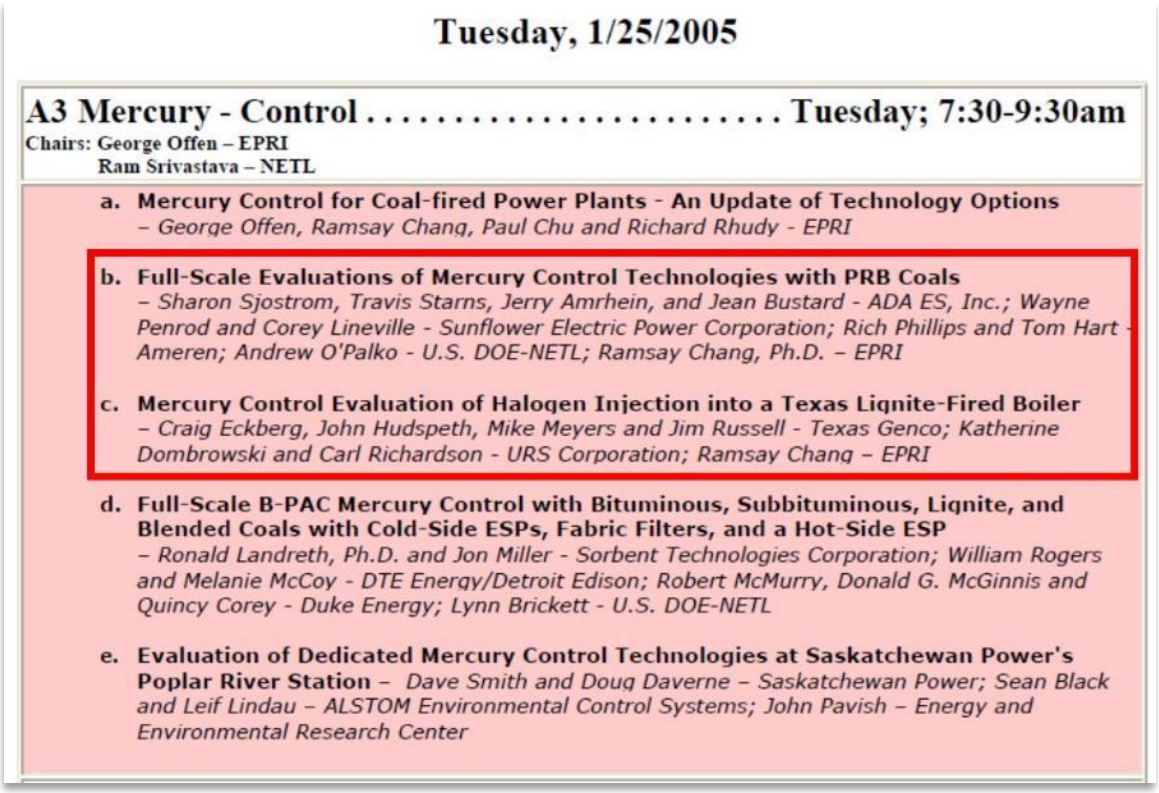
[466] EX1011 (Eckberg).

[467] EX1030 (EUEC Handout) at 23.

whole. In fact, Sjostrom and Eckberg were presented consecutively, in the same room.[468]



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.[469]

[468] EX1030 (EUEC Handout) at 5, 23, 30.

[469] EX1030 (EUEC Handout) at 5, 23, 30.

2. Sjostrom Is Analogous Art and Overview of the Disclosure

296. 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."[470] The specific problem faced by the inventors of the Challenged Patent was "a need for more economical and effective mercury removal technology."[471] 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."[472]

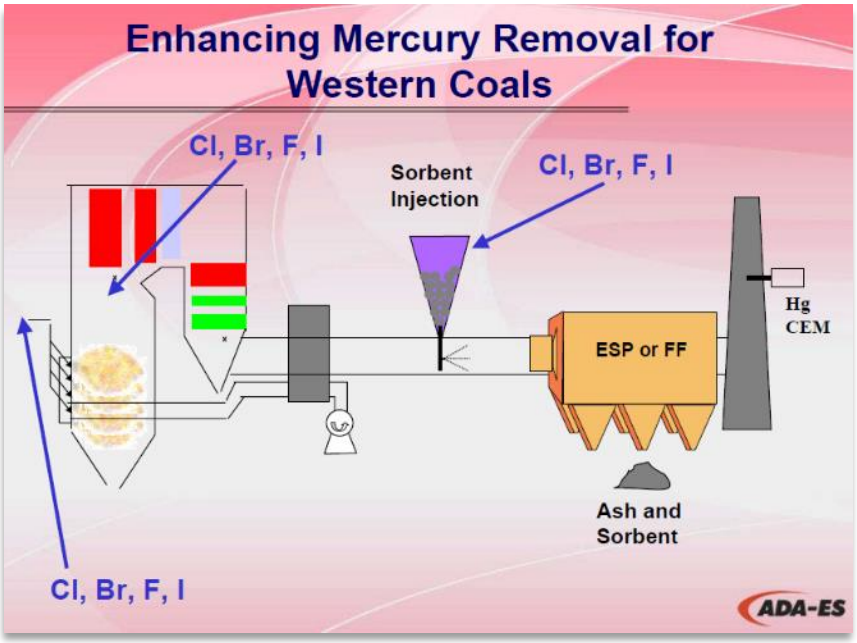
297. Sjostrom discussed the results of full-scale testing that was focused on increasing the halogen concentration, including bromine and iodine, in coal-fired power-plant flue gas for the purpose of mercury removal from the flue gas. Sjostrom disclosed multiple methods of introducing the halogens, and discussed "the effect

[470] EX1001 ('225 Patent) at 1:29-33.

[471] EX1001 ('225 Patent) at 2:23-24.

[472] 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."[473] 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.[474]



In the figure above, the following abbreviations are used:

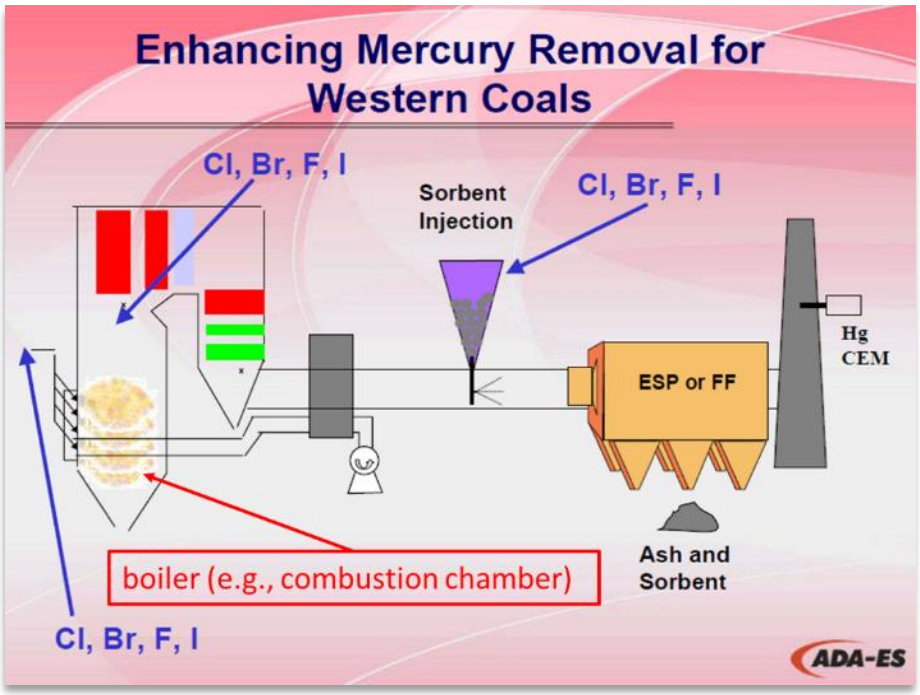
- Cl, Br, F, I: chemicals containing chlorine, bromine, fluorine, and iodine
- ESP or FF: electrostatic precipitator or fabric filter

[473] EX1030 (EUEC Handout) at 23.

[474] EX1010 (Sjostrom) at 4.

- Hg CEM: mercury (Hg) continuous emissions monitor

298. Sjostrom described various mercury control tests conducted at coal-fired power plants.[475] 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.[476]



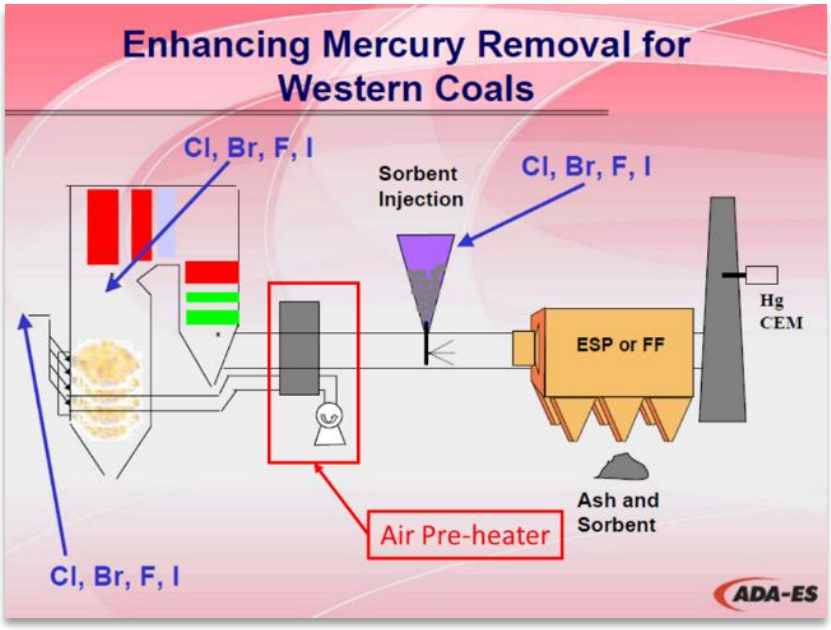
A POSITA would have understood that this unit was a boiler based on the image used to represent the unit in the drawing, which was a common and routine way to

[475] EX1010 (Sjostrom) at 12, 18.

[476] 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.[477]

299. 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.[478]



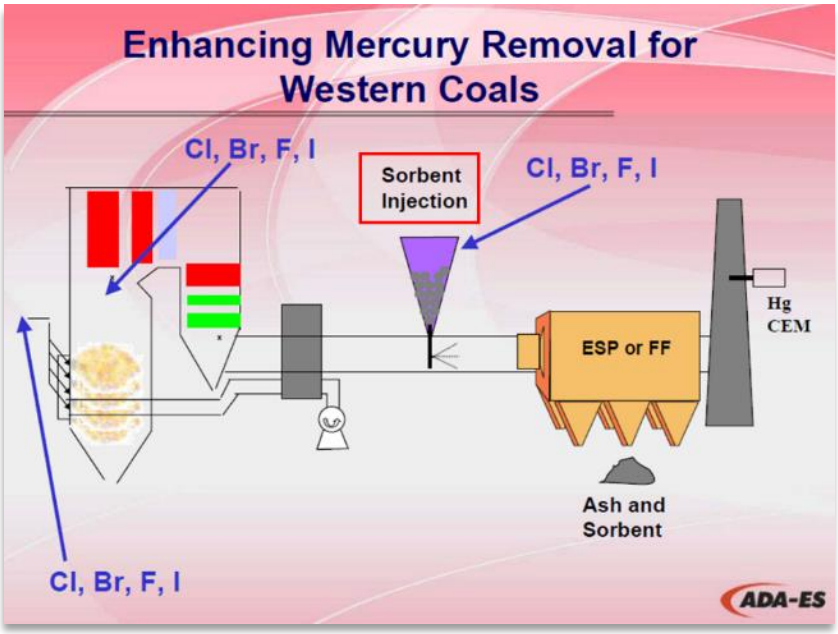
A POSITA would have understood that the labeled component is an air pre-heater based on the image used to portray the unit on the schematic of Sjostrom. For example, the image includes a fan connected to a flow-path loop going into the inlet of the boiler to mix preheated air and coal. The gray box indicates the heat-transfer

[477] EX1010 (Sjostrom) at 23, 25.

[478] 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.

300. 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.[479]

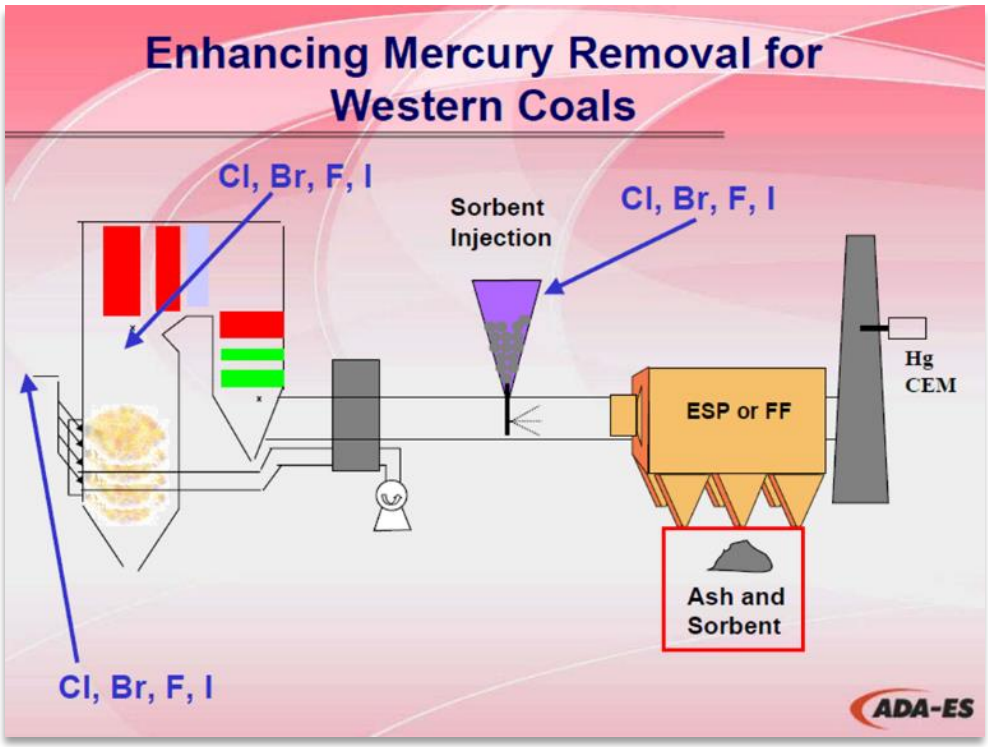


The sorbent used by Sjostrom is "activated carbon injection."[480]

[479] EX1010 (Sjostrom) at 4 (annotations in red).

[480] EX1010 (Sjostrom) at 10, 34.

301. 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").[481]

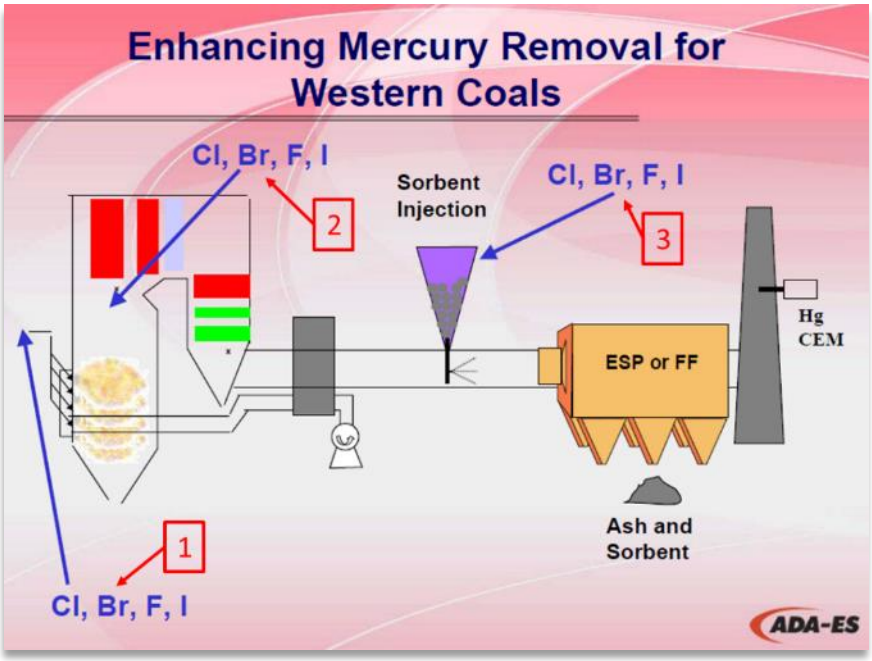


This annotated figure from Sjostrom specifically shows that particulate matter, including the mercury-sorbent composition, would have been separated from the flue gas by the ESP (electrostatic precipitator) or FF (fabric filter), because a

[481] 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.[482]

302. Sjostrom demonstrates that activated-carbon sorbent injection was a well-known way of treating mercury emissions in flue gas.[483] 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).[484]



[482] Technology Background and State of the Art ("Particulate Matter Emissions Controls"), IX.B.5.a.

[483] EX1010 (Sjostrom) at 10-11, 34.

[484] 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.[485] The figure should be read within the larger context of the paper, which specifically refers to "Coal Additives" at Meramec.[486] 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.[487] For example, the schematic of Sjostrom shows the stream splitting into four burner injection lines.[488] The schematic further shows a combustion plume corresponding to Location 1 of each of these four burner injection lines.[489] 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

[485] EX1010 (Sjostrom) at 4 (annotations in red).

[486] EX1010 (Sjostrom) at 23, 25.

[487] EX1010 (Sjostrom) at 4 (annotations in red).

[488] EX1010 (Sjostrom) at 4 (annotations in red).

[489] EX1010 (Sjostrom) at 4 (annotations in red).

combustion chamber.[490,491] Location 3 of Sjostrom teaches adding bromine to the activated-carbon sorbent that is injected into the flue gas.[492]

3. Eckberg Is Analogous Art and Overview of the Disclosure

303. 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."[493] The specific problem faced by the inventors of the Challenged Patent was "a need for more economical and effective mercury removal technology."[494] So too, the field of endeavor of Eckberg, as reflected in its title, is "Mercury Control Evaluation of

[490] EX1010 (Sjostrom) at 4 (annotations in red).

[491] Patent Owner's expert agrees with this understanding of Sjostrom. EX1094 (O'Keefe 2) at 246:21-247:6, 249:6-252:9 (describing Locations 1-3 of Sjostrom).

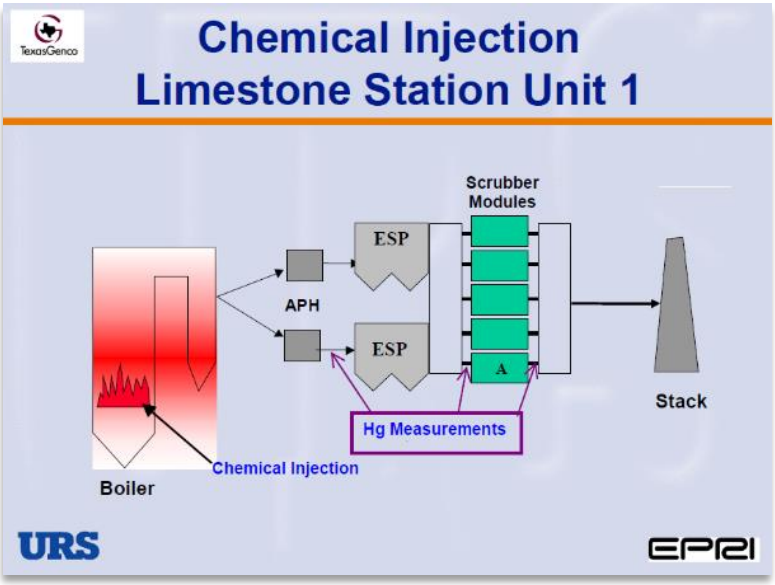
[492] EX1010 (Sjostrom) at 4 (annotations in red).

[493] EX1001 ('225 Patent) at 1:29-33.

[494] EX1001 ('225 Patent) at 2:23-24.

Halogen Injection into a Texas Lignite-Fired Boiler," and the problem faced was a need to "enhance mercury removal."[495]

304. 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."[496] 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").[497]

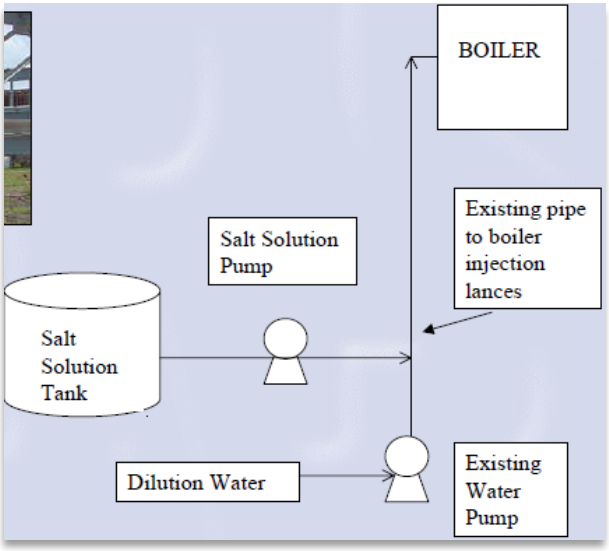


[495] EX1011 (Eckberg) at 1, 3.

[496] EX1030 (EUEC Handout) at 24.

[497] EX1011 (Eckberg) at 5.

305. Eckberg also includes a schematic showing the injection equipment used for the chemical injection.[498]



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%)."[499] $CaBr_2$ 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,

[498] EX1011 (Eckberg) at 8.

[499] 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.[500]

F. THE OLSON-646 REFERENCE [EX1012]

306. 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."[501]

1. Prior-Art Status of the Olson-646 Reference

307. 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

308. 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

[500] EX1011 (Eckberg) at 9.

[501] 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."[502] The specific problem faced by the inventors of the Challenged Patent was "a need for more economical and effective mercury removal technology."[503] 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."[504]

3. Overview of the Disclosure of Olson-646

309. Figure 2 of Olson-646, reproduced below, shows "a theory developed from scientific evidence to explain the nature of the promoting compounds."[505]

[502] EX1001 ('225 Patent) at 1:29-33.

[503] EX1001 ('225 Patent) at 2:23-24.

[504] EX1012 (Olson-646) ¶¶[0004], [0010].

[505] EX1012 (Olson-646) ¶[0054], Figure 2.

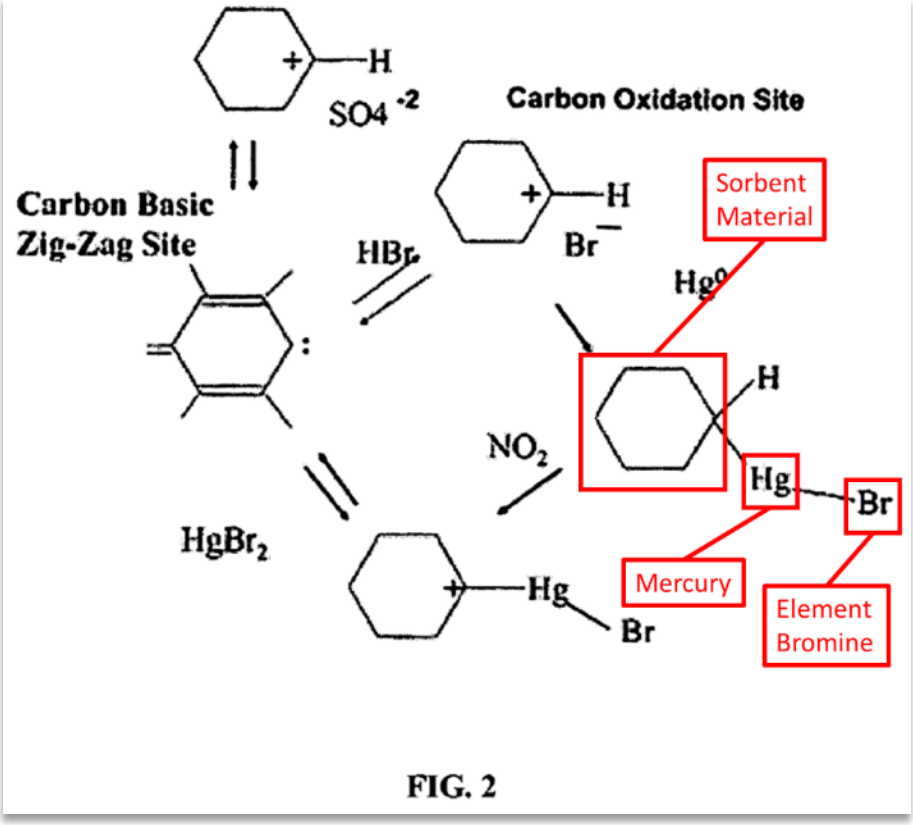


FIG. 2

The text in red was added above. Olson-646 explains that "hydrogen bromide reacts with the unsaturated structure of the activated carbon."[506] Olson-646 teaches that the reaction may take place at "a carbene species on the edge of the graphene sheet structures of the carbon."[507] 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."[508]

[506] EX1012 (Olson-646) ¶[0054].

[507] EX1012 (Olson-646) ¶[0054].

[508] 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.[509] Though more expensive, iodine can also be used.[510]

310. 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.[511]

[509] EX1012 (Olson-646) at Figure 2.

[510] EX1012 (Olson-646) ¶[0093].

[511] EX1012 (Olson-646) at Figure 3.

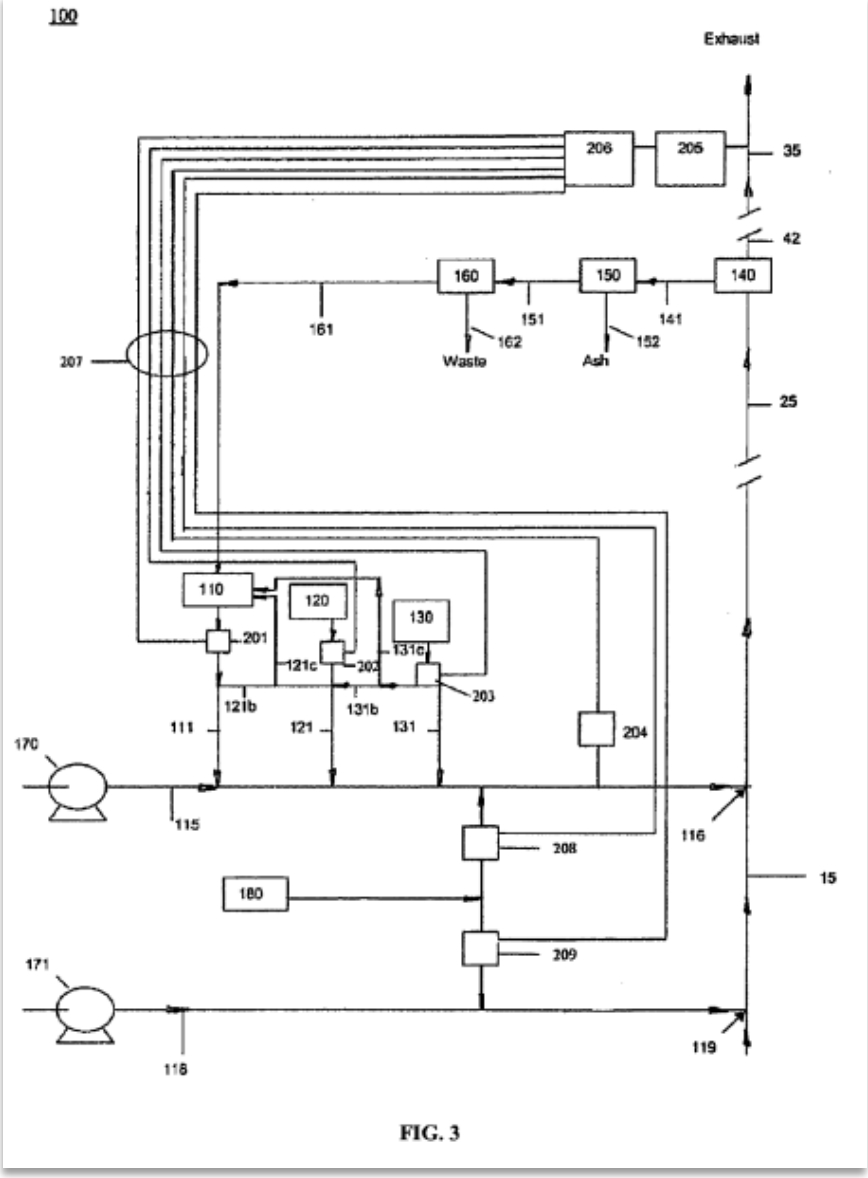


FIG. 3

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."[512]

[512] EX1012 (Olson-646) ¶[0056].

311. 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."[513] Olson-646 explains that a "promoted carbon sorbent and/or an optional alkali component is injected into contaminated flue gas stream 15."[514]

G. THE OLSON-235 REFERENCE [EX1018]

312. 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."[515]

1. Prior-Art Status of the Olson-235 Reference

313. 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.

[513] EX1012 (Olson-646) ¶[0056].

[514] EX1012 (Olson-646) ¶[0061].

[515] EX1018 (Olson-235).

2. Overview of the Disclosure of the Olson-235 Reference

314. Figure 2 of Olson-235, reproduced below, shows "a proposed mechanistic model of the chemical reactions results in the oxidation and capture of mercury."[516]

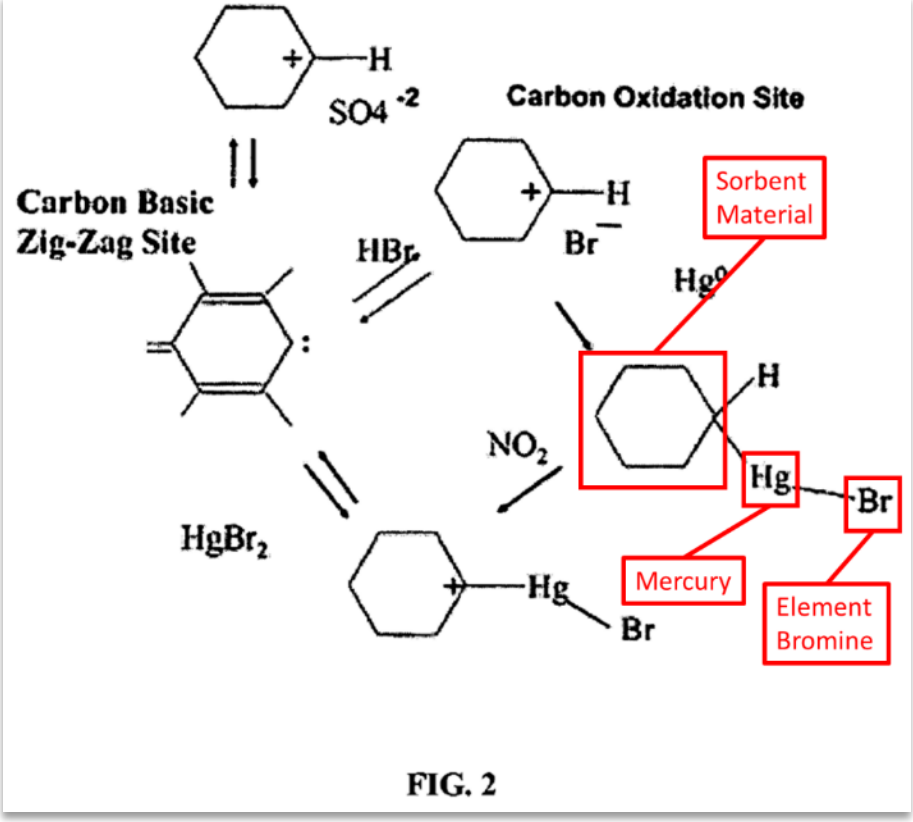


FIG. 2

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."[517] Further,

[516] EX1018 (Olson-235) at 8:63-65, Figure 2.

[517] 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."[518] Figure 2 of Olson-646, reproduced above, shows that the complex includes the activated-carbon sorbent, the element bromine, and the element mercury.[519]

315. 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.[520]

[518] EX1018 (Olson-235) at 16:65-67, 17: 1-2.

[519] EX1018 (Olson-235) at Figure 2.

[520] EX1018 (Olson-235) at Figure 3.

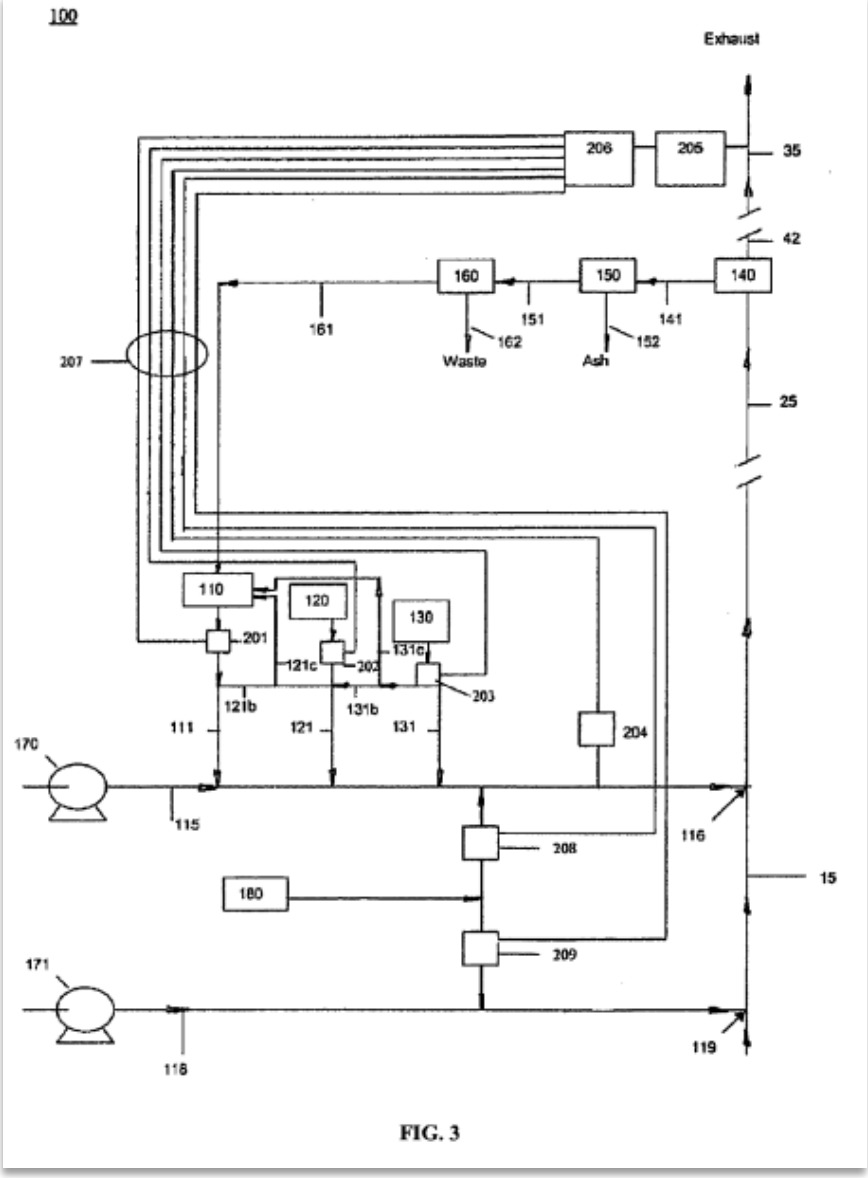


FIG. 3

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."[521]

[521] EX1018 (Olson-235) at 13:10-15.

316. 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."[522] Olson-235 explains that a "promoted sorbent and/or an optional alkali component is injected into contaminated flue gas stream 15."[523]

XIII. GROUND A1 AND GROUND A2: OBVIOUSNESS OVER VOSTEEN589 IN VIEW OF STARNS [GROUND A1] AND VOSTEEN589 IN VIEW OF MASS-EPA [GROUND A2]

317. It is my opinion that Claims 1, 2, 5-15, 17-20, and 22-29 would have been obvious over the combination of Vosteen589 and Starns (Ground A1). Claims 1, 2, 5-15, 17-20, and 22-29 would have also 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.

[522] EX1018 (Olson-235) at 13:15-19.

[523] EX1018 (Olson-235) at 14:30-32.

A. REASONS TO COMBINE

318. 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.

319. 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."[524] Vosteen589 uses halogen-containing ingredients (such as HBr) to oxidize mercury "since the ionic [oxidized] mercury is readily water soluble . . . and is readily adsorbable to a range of adsorbents."[525] 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

[524] EX1005 (Vosteen589) ¶¶[0018]-[0019].

[525] EX1005 (Vosteen589) ¶[0007].

mercury sorption stage." [526] 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."[527] 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 (i.e., collecting) mercury in the mercury-containing gas. Vosteen589 discloses that an example of the sorbent is "finely pulverulent slaked lime/activated carbon."[528] For the coal-fired power plants, Vosteen589 discloses that a "dry electrostatic precipitator (ESP) is used."[529]

320. 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

[526] EX1005 (Vosteen589) ¶[0019].

[527] EX1005 (Vosteen589) ¶[0019].

[528] EX1005 (Vosteen589) ¶[0019].

[529] EX1005 (Vosteen589) ¶[0034].

an exemplary sorbent (finely pulverulent slaked lime/activated 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 '225 Patent.[530] As explained above regarding Technology Background and State of the Art,[531] 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

[530] EX1001 ('225 Patent) at 1:61-67, 7:32-40.

[531] State of the Art ("Sorbents/Activated Carbon"), §IX.C.

an ESP. A POSITA 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)

321. 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."[532] 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.[533]

322. Starns provides details as to how to supply activated carbon to the system and processes of Vosteen589:

[532] EX1008 (Starns) at 1.

[533] EX1008 (Starns) at 2.

- **Injection of the activated carbon:** "injection equipment" that includes a "bulk-storage silo and twin blower/feeder trains ...."[534] 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."[535] One of the "[p]rimary variables" to control how much mercury is removed is "injection concentration" of the sorbent.[536]

[534] EX1008 (Starns) at 7; *see also* EX1008 (Starns) at Fig. 2.

[535] EX1008 (Starns) at 7; *see also* EX1008 (Starns) at Fig. 2.

[536] 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 …."[537]

323. Starns provides the details of ACI—what Starns describes as the "most mature retrofit technology available today"[538]—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.

324. 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 emission system (as used in Starns). As ACI was already a "mature" technology

[537] EX1008 (Starns) at 9.

[538] EX1008 (Starns) at 2.

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.

325. 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."[539] The particle control equipment in Starns is an electrostatic precipitator (ESP), and Starns recommends "using activated carbon injection upstream of an ESP."[540] A POSITA would have been motivated, as Starns suggests, to use activated carbon injection between the combustion chamber (furnace) and the ESP in Vosteen589.[541] The mercury-sorbent composition is eventually removed by

[539] EX1008 (Starns) at 2.

[540] EX1008 (Starns) at 20. Starns also discloses that a fabric filter can be used. EX1008 (Starns) at 19 (Fig. 8).

[541] EX1005 (Vosteen589) ¶¶[0019], [0033], [0037], [0039], [0042], [0047]-[0049], claim 8 (discussing use of an ESP).

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)

326. 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."[542] 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).[543]
>
> 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.[544]

[542] EX1009 (Mass-EPA) at 1.

[543] EX1009 (Mass-EPA) at 31 (section entitled, "Mercury-Specific Control Technologies").

[544] EX1009 (Mass-EPA) at 32 (subsection entitled, "Sorbent Injection").

327. 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.[545]
>
> 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. [546]

Vosteen589 also discloses activated carbon, including with lime.[547] Mass-EPA discloses "activated carbon injection" in numerous other places.[548]

328. Mass-EPA concludes that the "estimated costs for powdered activated carbon injection-based technology, which most likely will reach commercialization for mercury control before other technologies, is within the current control costs for NOx."[549] Thus, a POSITA would have been motivated, with a reasonable

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

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

[547] EX1005 (Vosteen589) ¶[0019].

[548] EX1009 (Mass-EPA) at 31, 35, 36, 49, 52, 56.

[549] EX1009 (Mass-EPA) at 58.

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.

329. 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"[550] 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.

330. A POSITA would have a reasonable expectation of success in combining Vosteen589 with Mass-EPA because, as Mass-EPA described, activated

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

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."[551] 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."[552] Mass-EPA concludes that the "estimated costs for powdered activated carbon injection-based technology, which most likely will reach commercialization for mercury control before other technologies, is within the current control costs for NOx."[553]

331. 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."[554] Introducing the halogens (as described in Vosteen589), 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

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

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

[553] EX1009 (Mass-EPA) at 56.

[554] EX1009 (Mass-EPA) at 39.

of activated carbon to be used for mercury collection and removal and thus lower costs.

B. DISCLOSURE AND TEACHINGS OF THE COMBINATIONS

332. 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.

1. Independent Claim 1

a. Claim 1: Preamble—"A method for treating a mercury-containing gas, the method comprising:"

333. Vosteen589 discloses the preamble. The title of Vosteen589 is, "Process for removing mercury from flue gases."[555] Flue gas is an example of mercury-containing gas, and "removing mercury" refers to treating the mercury-containing gas in order to reduce the mercury emissions. Vosteen589 describes "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.[556] Claim 1 of Vosteen589 also discloses the preamble, as shown in the highlighting below:[557]

[555] EX1005 (Vosteen589) at Title.

[556] EX1005 (Vosteen589) ¶¶[0007]-[0008]; see also Abstract (similar language).

[557] EX1005 (Vosteen589) at Claim 1.

> 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.[558]

Thus, Vosteen589 itself discloses the preamble for both Ground A1 and Ground A2.

334. In the combination of Vosteen589 with Starns (Ground A1), the combination still discloses the preamble, as the purpose of Starns is to help "coal-fired power plants" comply with draft "mercury regulations" from the EPA and "to remove mercury."[559]

335. 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

[558] EX1005 (Vosteen589) at Claim 1.

[559] EX1008 (Starns) at 2 (Abstract and Introduction).

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."[560]

b. Claim 1: Element 1(a)—"combusting a mixture comprising coal, pyrolysis char, and an additive comprising HBr, a bromide compound, or a combination thereof, to form the mercury-containing, gas; and"

336. 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, the title of Vosteen589 is, "Process for Removing Mercury from Flue Gases," which are a mercury-containing gas. Vosteen589 describes removing mercury at "a coal-fired power station of Bayer AG in Uerdingen, which essentially consists of a slag-tap fired boiler …."[561] Vosteen589 later refers to the "coal-fired power station of Bayer AG in Uerdingen (see FIG. 9)" with "two parallel slag-tap fired boilers 91, 91' having temperatures in the combustion chamber around

[560] EX1009 (Mass-EPA) at 3.

[561] EX1005 (Vosteen589) ¶[0034].

1450ºC."[562] Vosteen589 describes his results in Figures 7 and 8 regarding the experiments conducted on "coal combustion (bituminous coal)."[563] This limitation is also disclosed in claim 1 of Vosteen589, highlighted below:[564]

> 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 combusting coal in a combustion chamber to form a mercury-containing gas.

---

[562] EX1005 (Vosteen589) ¶¶[0046]-[0047], Fig. 9; *see also* ¶[0005] ("coal-fired power stations").

[563] EX1005 (Vosteen589) ¶[0048], Figs. 7-8.

[564] EX1005 (Vosteen589) at Claim 1.

337. 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."[565]

338. 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."[566]

339. Vosteen589 describes applying an additive comprising HBr (hydrogen bromide), bromine (Br_2), and bromide compounds (such as sodium bromide, NaBr) by mixing the additive with the coal before the coal enters the combustion chamber, or with the coal in the combustion chamber, or both. Vosteen589 describes that bromine-containing ingredients are mixed with the coal in 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

[565] EX1008 (Starns) at 2 (Abstract and Introduction).

[566] EX1009 (Mass-EPA) at 1.

> 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 ….[567]
>
> 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. [568]
>
> 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. [569]
>
> 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.[570]

Vosteen589 also describes that the bromine-containing ingredients (including a "bromine compound" and hydrogen bromide) can be added to the mixture in the combustion chamber either through injection into the pre-combustion air (upstream of the furnace) or by addition to the coal itself:

[567] EX1005 (Vosteen589) ¶[0006].

[568] EX1005 (Vosteen589) ¶[0009].

[569] EX1005 (Vosteen589) ¶[0013].

[570] EX1005 (Vosteen589) ¶[0014].

> 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. [571]
>
> [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. [572]

340. 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): [573]

> 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,

[571] EX1005 (Vosteen589) ¶[0013].

[572] EX1005 (Vosteen589) ¶[0014].

[573] EX1005 (Vosteen589) at claims 1-2.

> 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.

341. It would have been inherent, or at least obvious, for the mixture being combusted to comprise not only coal and Br-containing ingredients, but also comprise pyrolysis char. It was known long before the earliest priority date of the '225 Patent that pyrolysis char necessarily forms during the combustion of coal, including even under the most favorable conditions.[574] Thus, at least some quantity of the mixture of coal and bromine-containing ingredients (introduced into the combustion chamber) is further mixed with the pyrolysis char formed in the chamber. This mixture of coal, pyrolysis char, and bromine-containing ingredients entrains air and, since the flame temperatures inside the combustion chamber are several hundred degrees hotter than the ignition temperatures for both coal and pyrolysis char, the mixture spontaneously burns as it is contacted by oxygen in the air. Thus, Vosteen589 discloses this claim element for both Ground A1 and Ground A2.

[574] Technology Background and State of the Art, §IX.H;
EX1100 (Coal Chemsitry) p. 673.

342. Patent Owner's expert in the Delaware Litigation, Mr. O'Keefe, further confirmed—in both his expert report and his deposition concerning the '225 Patent—the inherency of pyrolysis char in the bromine-coal mixture being combusted:

> Q. Just continuing on, on '225, claim 1. How would a person of skill in the art know whether there is any pyrolysis char in the mixture that was being combusted?
>
> A. Whenever you combust coal you create pyrolysis char.
>
> Q. It's always there whenever you combust coal?
>
> A. Right. It depends, you know, whether it's completely turned into ash or not, you know, by the combustion process.
>
> Q. … Pyrolysis char is an inherent result from the combustion of coal; is that correct?
>
> A. Correct. Correct.
>
> Q. Now, does claim 1 require any particular amount of pyrolysis char?
>
> A. No.
>
> Q. How would a person with skill in the art know if there was enough pyrolysis char to accomplish the goals of claim 1?
>
> A. Well, during combustion there's always pyrolysis char. You know, the question is whether it's entirely burned off or not during the combustion process. …
>
> Q. And looking at claim 1, is it important to know whether the pyrolysis char was all combusted or not?

A. No.[575]

In his infringement report, Mr. O'Keefe further stated that "when coal is combusted, it produces some amount of pyrolysis char."[576]

c. Claim 1: Element 1(b)—"adding a particulate sorbent material comprising activated carbon into the mercury-containing gas."

343. 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 collect mercury in the flue gas, and even gives activated carbon as a specific example. The mercury is collected by being adsorbed onto an activated-carbon sorbent added to the mercury-containing gas. Starns and Mass-EPA each provide additional details as to how that sorbent is added to a system like those of Vosteen589 and Starns, namely, activated carbon injection (ACI).

344. 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

[575] EX1094 (O'Keefe) at 233:33-235:9.

[576] EX1092 (O'Keefe Report) at 163 ('225 Patent Cl. 1b).

gas" or as "dry cleanup."[577] Vosteen589 describes that the sorbent is added 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 downstream of the combustion . . . ."[578] The flue gas was formed as a result of combustion of coal in the combustion chamber.

345. Vosteen589 describes that a sorbent is used for the dry emission control system, namely that the system works "based on the adsorption of ionic mercury compounds."[579] The halogen-containing ingredients are used to oxidize mercury from its metallic (Hg) into its ionic form (such as $HgBr_2$),[580] because "the ionic mercury … is readily adsorbable to a range of adsorbents."[581] In another passage, Vosteen589 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

[577] EX1005 (Vosteen589) ¶¶[0017]-[0019]; see also EX1005 (Vosteen589) ¶¶[0005]-[0007] (describing "removal of mercury from the flue gases in a flue gas emission control system downstream of the combustor").

[578] EX1005 (Vosteen589) ¶[0007].

[579] EX1005 (Vosteen589) ¶[0019].

[580] EX1005 (Vosteen589) ¶[0019].

[581] EX1005 (Vosteen589) ¶[0007].

mercury sorption stage."[582] 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 collecting mercury in the mercury-containing gas, 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,"[583] and provides as an exemplary sorbent "finely pulverulent slaked lime/activated carbon."[584]

346. Vosteen589 repeatedly refers to a flue gas cleaning system. In Claim 1 of Vosteen589, for example, "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."[585] Vosteen589 refers to "clean gas

[582] EX1005 (Vosteen589) ¶[0019].

[583] EX1005 (Vosteen589) ¶¶[0003], [0007], [0019].

[584] EX1005 (Vosteen589) ¶[0019].

[585] EX1005 (Vosteen589) at Claim 1; *see also* EX1005 (Vosteen589) ¶[0006].

downstream of the wet and/or dry flue gas emission control system."[586] 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."[587] The "dry cleanup stage" and "dry sorbent" includes, for example, the activated carbon 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."[588] The "cleanup" and "removal" referred to by Vosteen589 in the passages above refer to separating (i.e., collecting) the mercury-laden sorbent from the mercury-containing flue gas.

347. Thus, Vosteen589 discloses the need for a dry-emission control system that works using sorbent including activated carbon to collect the mercury. However, Vosteen589 is not concerned with the specific details of how to implement that dry-emission control system and how to add the sorbent to the system. As explained above regarding Technology Background and State of the Art,[589] a

[586] EX1005 (Vosteen589) ¶[0022].

[587] EX1005 (Vosteen589) ¶[0005].

[588] EX1005 (Vosteen589) ¶[0034]; *see also* EX1005 (Vosteen589) ¶¶[0019], [0033]-[0034], [0039], [0042], [0047]-[0049], cl. 8 (discussing use of ESPs).

[589] State of the Art, §IX.C.

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)

348. Starns describes injecting (i.e., adding) a particulate 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 injecting activated carbon ahead of particle control devices (PCD) to remove mercury and to determine the cost and impacts of this technology."[590] Starns provides "injection equipment" that includes a "bulk-storage silo and twin blower/feeder trains ...."[591] The silo is shown below:[592]

[590] EX1008 (Starns) at 2 (Abstract).

[591] EX1008 (Starns) at 7-8; *see also* EX1008 (Starns) at Fig. 2.

[592] EX1008 (Starns) at 7-8; *see also* EX1008 (Starns) at Fig. 2.



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…."[593] A "powdered" activated carbon is a particulate sorbent material.

349. The particle control devices (PCD) in Starns includes an electrostatic precipitator (ESP), and Starns recommends "using activated carbon injection upstream of an ESP."[594] It is a mercury-laden sorbent that is removed by the ESP,

[593] EX1008 (Starns) at 9.

[594] EX1008 (Starns) at 20.

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."[595] 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.[596] Each of these were well-known components in coal-fired power plants to remove particulate matter (such as the mercury-laden sorbent 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-laden sorbent is collected and 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.

[595] EX1008 (Starns) at 2.

[596] EX1005 (Vosteen589) ¶¶[0019], [0033], [0037], [0039], [0042], [0047]-[0049], claim 8 (discussing use of an ESP).

(2) Ground A2 (Combination of Vosteen589 with Mass-EPA)

350. Mass-EPA describes injecting (i.e., adding) a particulate 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.[597]
>
> 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. [598]
>
> 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.[599]
>
> Technologies based on injection of powdered activated carbon (PAC) have been investigated most and are likely to reach commercialization for mercury removal from coal-fired utility boiler flue gas before other technologies.[600]

A "powdered" activated carbon is a particulate sorbent material. Mass-EPA describes that the activated-carbon sorbent is injected downstream of the combustion

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

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

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

[600] EX1009 (Mass-EPA) at 49.

chamber, in that it repeatedly refers to the activated-carbon injection as "post combustion pollution control."[601] For example, Mass-EPA states:

> Post-combustion, flue gas technologies employ three basic methods to capture mercury:
>
> 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).[602]

Mass-EPA explains that the activated carbon is "injected." Mass-EPA discloses "activated carbon injection" in numerous other places.[603]

351. Mass-EPA further explains that "[t]he 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)."[604] The "particulate-bound form of mercury" refers to the mercury adsorbed (i.e., collected) onto the activated-carbon sorbent. Mass-EPA continues, "An ESP or a FF is always installed

[601] EX1009 (Mass-EPA) at 6, 21, 22, 23.

[602] EX1009 (Mass-EPA) at 6-7.

[603] EX1009 (Mass-EPA) at 31, 35, 36, 49, 52, 56.

[604] EX1009 (Mass-EPA) at 20.

downstream of a semi-dry scrubber or dry injection point to remove the sorbent from the flue gas."[605] 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.[606] Each of these were well-known components in coal-fired power plants to remove particulate matter (such as the mercury-laden sorbent 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 the separation system (where the sorbent is removed). The mercury-laden sorbent is collected and 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.

[605] EX1009 (Mass-EPA) at 27.

[606] EX1005 (Vosteen589) ¶¶[0019], [0033], [0037], [0039], [0042], [0047]-[0049], claim 8 (discussing use of an ESP).

2. Claims Depending from Claim 1

a. Claim 2: "The method of claim 1, wherein the pyrolysis char is a promoted pyrolysis char."

352. According to Patent Owner's expert in the Delaware litigation, "pyrolysis char forms in the presence of bromine that has been added to the coal. Thus, it is promoted pyrolysis char."[607]

b. Claim 5: "The method of claim 1, further comprising using a particle separation device to remove mercury from the flue gas and comprising collecting greater than 70 wt % of the mercury in the mercury-containing gas to produce a cleaned gas."

353. Claim 5 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. As discussed above for Claim Element 1(b), Vosteen589 "clean[s] gas downstream of the … dry flue gas emission control system," meaning the mercury/sorbent has been separated.[608] The mercury/sorbent

[607] EX1092 (O'Keefe Report) at 163.

[608] EX1005 (Vosteen589) ¶[0022].

composition is separated downstream from the combustion chamber in a particle-control device (PCD) (i.e., particle separation device), such as ESP or fabric filter.[609]

354. Vosteen589 describes "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."[610] 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.[611] Shown in Figure 5, reproduced below, Vosteen589 discloses removing more than 98% of the mercury from the mercury-containing gas.[612]

[609] EX1005 (Vosteen589) ¶¶[0019], [0033]-[0034], [0039], [0042], [0047]-[0049], cl. 8 (discussing use of ESP).

[610] EX1005 (Vosteen589) ¶[0005].

[611] EX1005 (Vosteen589) ¶[0037].

[612] EX1005 (Vosteen589) at Figure 5; *see also* ¶¶[0028], [0042].

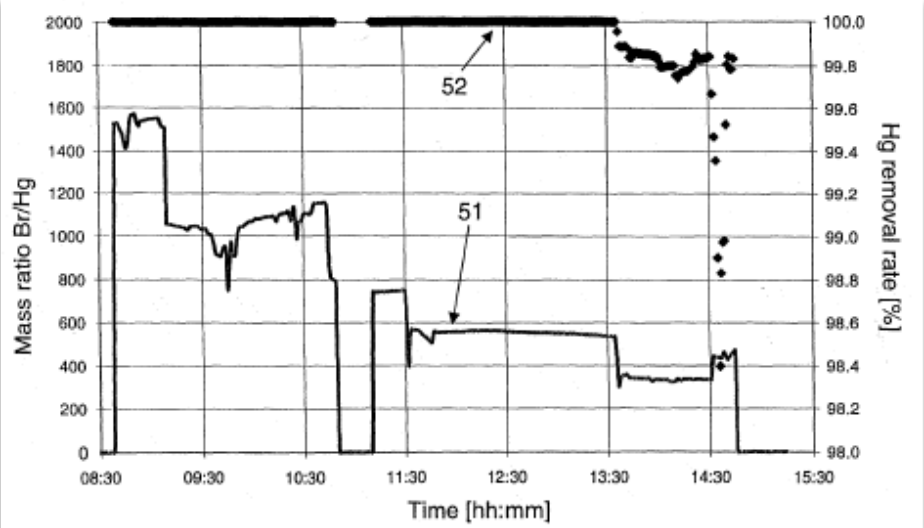


Fig. 5

The Y-axis on the right is labeled "Hg removal rate [%]."[613] 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."[614]

355. 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,

[613] EX1005 (Vosteen589) ¶[0042] (describing Figure 5).

[614] EX1005 (Vosteen589) ¶[0049].

> 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).[615]

Figure 8 of Vosteen589 is shown below:

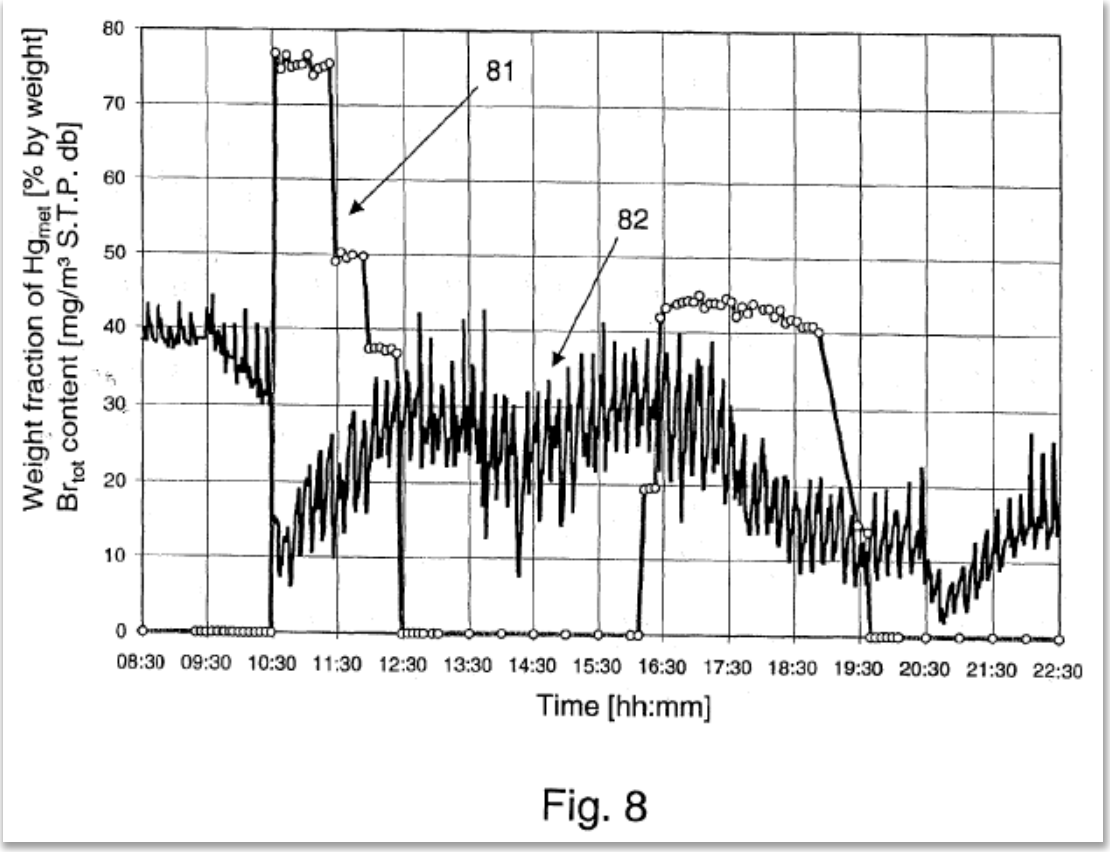


Fig. 8

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 to produce a cleaned gas:

> As high a proportion as possible of ionic mercury is advantageous, since the ionic mercury is readily water soluble,

[615] EX1005 (Vosteen589) ¶¶[0048]-[0049].

> that is to say it can be scrubbed out, and is readily adsorbable to a range of adsorbents.[616]

356. 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 mercury sorption stage."[617] 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 the activated carbon injection of Mass-EPA (Ground A2). Specifically, Vosteen589 discloses that "lignite-fired power stations"[618] 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.[619] Under such circumstances, Hg capture on inherent unburned carbon is minimal. Consequently, a person of ordinary skill in the art

[616] EX1005 (Vosteen589) ¶[0007].

[617] EX1005 (Vosteen589) ¶[0019].

[618] EX1005 (Vosteen589) ¶[0008].

[619] *See* Technology Background and State of the Art, §IX.B.1.

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 separation device, as Vosteen589 teaches, ensures that virtually all the Hg captured in a particle separation device would be bound to the sorbent. Furthermore, Vosteen589 also teaches how to modify the bromine addition level to achieve Hg removal up to essentially complete removal, including 70% removal.

357. 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 activated carbon.[620] When combined with the improved oxidation through the halogenation of Vosteen589, the removal would be even greater than the 70%. In addition, the activated carbon injection in Starns takes place with solely a dry emissions system, and the activated carbon injection is particularly suited as "mercury control technology for coal-fired utility plants that do not have scrubbers for SO_2 control."[621]

358. 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

[620] EX1008 (Starns) at 20.

[621] EX1008 (Starns) p. 2 (Abstract).

and Brayton Point plants.[622] When combined with the improved oxidation through the halogenation of Vosteen589, the removal would be even greater than the 70%. The activated carbon injection in Mass-EPA 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.[623] 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."[624] The entire range of removals with the highest ACI concentration are greater than 70%. Through routine process optimization and routine experimentation, a person of ordinary skill in the art would have adjusted the bromine addition 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

[622] EX1009 (Mass-EPA) at 11-12 (Chart 2 and accompanying discussion).

[623] EX1009 (Mass-EPA) at 70.

[624] EX1009 (Mass-EPA) at 74.

and exceed (for purposes of safety margin) the EPA's proposed rules requiring a 70% removal of mercury.

359. In addition to the mercury removal percentages disclosed by Vosteen589, Starns, and Mass-EPA, Claim 5 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.[625] As described in the Technology Background and State of the Art regarding EPA Regulations and government-funded research,[626] 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 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 addition 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.

[625] EX1005 (Vosteen589) ¶¶[0002], [0015].

[626] Technology Background and State of the Art, §§ IX.D – IX.F.

c. Claim 6: "The method of claim 5, further comprising: measuring the mercury content of the mercury-containing gas; and modifying, in response to the measured mercury content: an injection rate of injecting the sorbent into the mercury-containing gas, an amount of the additive in the mixture, or a combination thereof."

360. Vosteen589 discloses this claim element. Vosteen589 describes continuously measuring mercury content of the mercury-containing gas and, in response, modifying the addition 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.[627]

[627] EX1005 (Vosteen589) ¶[0022].

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. A POSITA would have modified the addition rate to keep mercury below the "strict limiting values [that] exist for the legally permissible emission of mercury" to avoid regulatory penalties.[628] 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 flue gas emission control system is performed…."[629] Measurements of the mercury content are depicted in Figures 2–8 of Vosteen589,[630] 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.[631]

[628] EX1005 (Vosteen589) ¶[0002].

[629] EX1005 (Vosteen589) ¶[0022].

[630] EX1005 (Vosteen589) at Figs. 2-8.

[631] EX1005 (Vosteen589) at Claim 10.

The above quotes explain that the mercury is "continuously" measured, which further teaches that those measurements are used for a reason (e.g., to modify the amount of bromine-containing additive to use).

(1) Ground A1 (Combination of Vosteen589 with Starns)

361. 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 modifying the sorbent concentration in the flue gas based on continuous mercury-content 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., modify both sorbent concentration and halogen concentration in response to mercury-content measurements).

362. Starns discloses measuring "vapor phase mercury concentrations" in the flue gas using a "Semi-Continuous Emissions Monitor (S-CEM)," which was

"operate[d] continuously."[632] The S-CEM was used to modify 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.[633]

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-term testing in Figures 3-6.[634] Exemplary Figure 4 is shown below, which shows the direct connection between mercury emissions and sorbent concentration:[635]

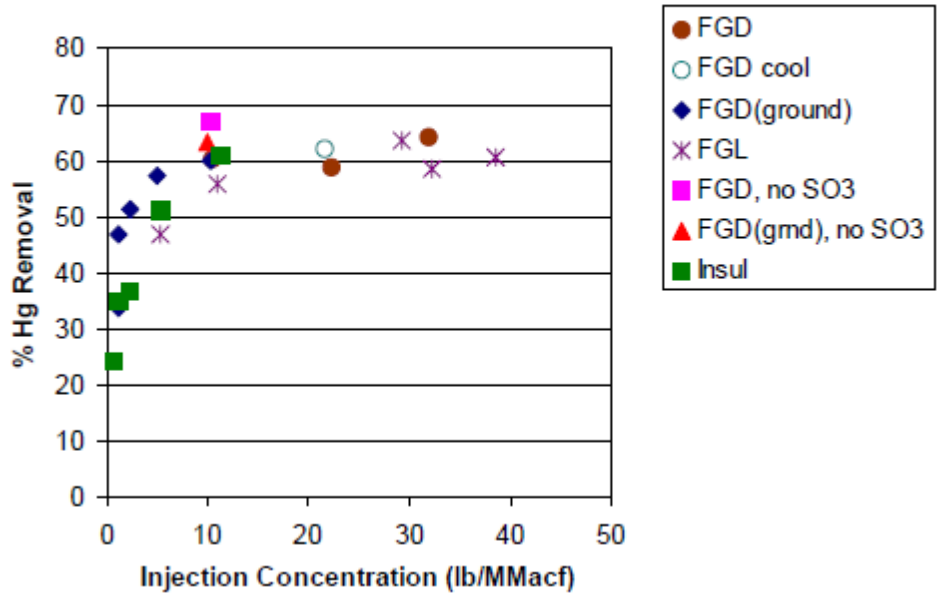
[632] EX1008 (Starns) at 8.

[633] EX1008 (Starns) at 11.

[634] EX1008 (Starns) at Figs. 3-6; *see also* EX1008 (Starns) at 20.

[635] EX1008 (Starns) at 13.

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 measuring the mercury content of the gas in response to the measured sorbent concentration. Modifying the rate of addition of the sorbent in response to the mercury content of the mercury-containing gas is also obvious over Starns. A POSITA reviewing the measurement data, as presented by Figures 3-6 of Starns, would have understood that the continuously measured mercury content (dependent variable in the graphs) is the information that would be used to modify a rate of 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 measured mercury content of the mercury-containing 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 measuring 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."[636]

363. The normal desire of a POSITA to improve on a given process would have been to modify 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,[637] it would have been obvious that some amount of modification to the rate of injection of the sorbent into the flue gas would be

[636] EX1008 (Starns) at 7.

[637] See Technology Background and State of the Art, IX.B.1.

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)

364. 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 continuously measured output (mercury content). Mass-EPA discloses a control scheme interoperable with Vosteen589, modifying the sorbent concentration in the flue gas based on continuous mercury-content 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., modify both sorbent concentration and halogen concentration in response to mercury-content measurements).

365. 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."[638] Mass-EPA recognized that a reason to continuously measure mercury was to understand the sorbent injection rate to use:

[638] EX1009 (Mass-EPA) at 60.

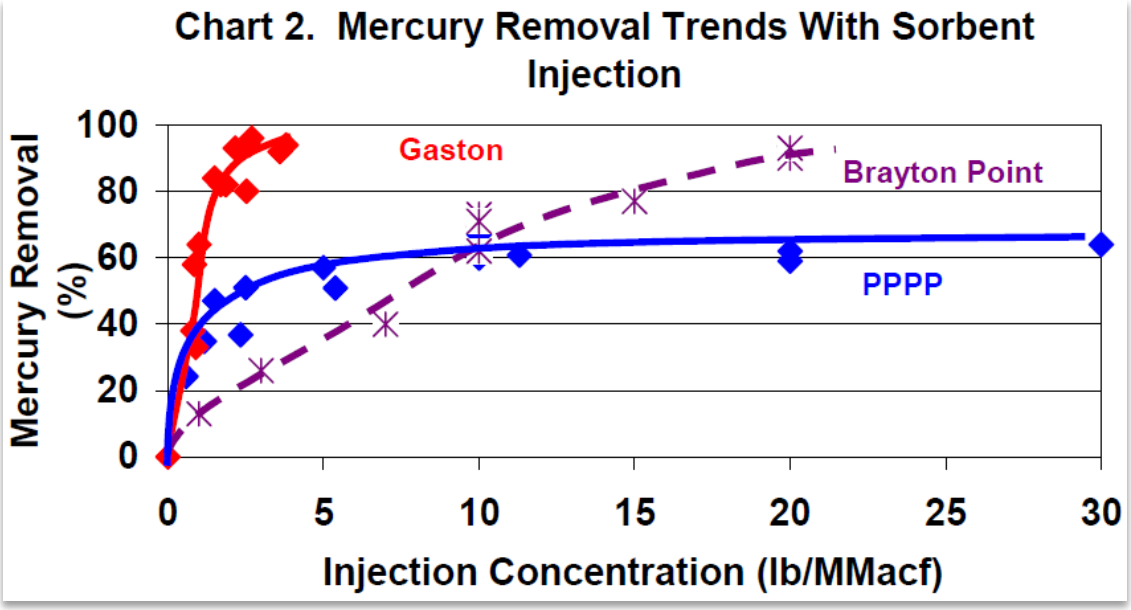
> [A] fraction of a pound increase in carbon injection rate increase[es] mercury removal from the gas by [as] much as 30%.[639]
>
> With respect to both the removal trend and the sorbent costs, preliminary results for Brayton Point indicate that the higher the amount of sorbent injected, the more mercury 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. [640]

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:[641]

[639] 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").

[640] EX1009 (Mass-EPA) at 11.

[641] 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 mercury removal as a function of [sorbent] injection rate."[642]

366. 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

[642] 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."[643] In other words, measure mercury content and, based on that measurement, modify the rate of injecting the sorbent into the mercury-containing gas.

367. 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 modify an injection rate of the sorbent (the independent variable) into the mercury-containing gas, in response to the measuring 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 measurement data, such as the data presented by Chart 2 of Mass-EPA, would have understood that the measured mercury content is the information that would be used to modify a rate of addition of the sorbent by either selecting a given rate or by interpolating an intermediate value in response to the measured mercury content of the mercury-containing 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 POSITA would have been motivated to

[643] EX1009 (Mass-EPA) at 13.

modify sorbent-injection rate to keep mercury content of the mercury-containing gas below a desired level, targeting "an overall reduction of 75%."[644]

368. 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,[645] 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.

d. Claim 7: "The method of claim 1, wherein the additive further comprises Br_2."

369. As discussed above for Element 1(a), the additive further comprises Br_2. Vosteen589 discloses that Br_2 is fed to the combustion chamber. Vosteen589 states, "It is not critical for the inventive process in what form the bromine supplied

[644] EX1009 (Mass-EPA) at 5.

[645] See Technology Background and State of the Art, § IX.B.1.

is present. It is possible to use free or organically bound or inorganically bound bromine. The bromine or the bromine compounds can be fed individually or in a mixture."[646] A POSITA would understand that "free … bromine" is another word for molecular bromine, or Br_2. This understanding is reinforced by Vosteen589's repeated disclosure of "bromine and/or a bromine compound," in which the "bromine" refers to Br_2.[647]

e. Claim 8: "The method of claim 1, wherein the sorbent material is chosen from powdered activated carbon, granular activated carbon, carbon black, carbon fiber, aerogel carbon, pyrolysis char, and combinations thereof."

370. Claim 8 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.[648] 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.

[646] EX1005 (Vosteen589) ¶[0009].

[647] EX1005 (Vosteen589) ¶[0006], cls. 1, 4.

[648] EX1005 (Vosteen589) ¶[0019].

371. 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."[649]

372. 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."[650]

f. Claim 9: "The method of claim 1, further comprising adding an alkaline component to the mercury-containing gas, the alkaline component chosen from alkali elements, alkaline earth elements, alkali salts, alkaline earth salts, and combinations thereof."

373. Claim 9 would have been obvious over the combination of Vosteen589 in view of Starns (Ground A1) and Vosteen589 and Mass-EPA (Ground A2).

374. Regarding Ground A1 and Ground A2, Vosteen589 repeatedly discloses adding "lime" or "slaked lime" to the mercury-containing flue gas,

[649] EX1008 (Starns) at 2.

[650] EX1009 (Mass-EPA) at 22; *see also* p. 32 ("Powdered Activated Carbon … has been the most extensively studied sorbent for mercury adsorption.").

including by mixing the lime with activated-carbon sorbent.[651] Lime contains calcium oxide (CaO), and slaked lime contains calcium hydroxide ($Ca(OH)_2$), each of which are alkaline components, specifically alkaline earth salts. As I describe above regarding Technology Background and State of the Art,[652] a POSITA would have known that lime and slaked lime are alkaline 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. A POSITA would have been motivated to mix the lime and slaked lime with activated-carbon sorbent, to eliminate competition for mercury binding sites on the activated-carbon sorbent.

375. With respect to Ground A1, Starns refers to "injection of sorbents such as powdered activated carbon (PAC) into the flue gas."[653] A POSITA would have understood that when the activated-carbon sorbent is mixed with lime or slaked lime (as in Vosteen589), that lime or slaked lime would also be added to the mercury-containing gas.

[651] EX1005 (Vosteen589) ¶[0019].

[652] Technology Background and State of the Art, §IX.A.4, §IX.B.5.b, §IX.G.1.

[653] EX1008 (Starns) at 2.

376. With respect to Ground A2, Mass-EPA discloses co-injection of not only activated carbon sorbents, but also alkaline 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.[654]
>
> 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. [655]
>
> 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. [656]

The "sodium carbonate" and "lime" are examples of an alkali salt and an alkaline earth salt, respectively. Such sorbents 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.

[654] EX1009 (Mass-EPA) at 37.

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

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

g. Claim 10: "The method of claim 1, further comprising contacting the sorbent material with a mercury-stabilizing reagent chosen from S, Se, H_2S, SO_2, H_2Se, SeO_2, CS_2, P_2S_5, and combinations thereof."

377. Vosteen589 discloses this claim. Vosteen589 "ensured that a sufficient supply of sulphur dioxide [i.e., SO_2] for the inventive process was available."[657] Vosteen589 seeks for the combustion of coal to "take place in the presence of a sulphur compound, in particular sulphur dioxide" that then makes its way into the flue gas.[658] The sulfur dioxide facilitates the bromine reacting with mercury.[659] A POSITA would have known that the sulfur compound, such as SO_2, forms very early in the combustion process within the combustion chamber. Small portions of this SO_2 are converted into SO_3 while flue gas is cooled along a gas cleaning system, and also along an SCR. But the bulk of the SO_2 formed in a combustion chamber is present along an entire cleaning system and would be available to contact the downstream activated-carbon sorbent, injected by both Starns (Ground 1) and Mass-EPA (Ground 2)

[657] EX1005 (Vosteen589) ¶[0036].

[658] EX1005 (Vosteen589) ¶[0006].

[659] EX1005 (Vosteen589) ¶¶[0010], [0012].

h. Claim 11: "The method of claim 1, further comprising contacting the sorbent material with a secondary component chosen from halogens, hydrogen halides, Group V halides, Group VI halides, and combinations thereof."

378. This limitation is disclosed by Vosteen589 in Ground A1 and Ground A2. Vosteen589 discloses multiple examples of secondary components added to the mercury-containing flue gas downstream of the combustion chamber, including additional bromine-containing ingredients and other halogens such as chlorine and iodine. Each of these are in addition to the bromine-containing ingredients being applied to the coal and combustion chamber.

379. Beyond adding the bromine-containing species to the combustion chamber and/or coal, as discussed above, Vosteen589 discloses that the bromine materials are also 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 recirculated substream, in particular recirculated flue gas, recirculated ash and recirculated fly ash.[660]

[660] EX1005 (Vosteen589) ¶[0014].

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 is fed to the if appropriate multistage furnace and/or to the flue gas in a plant section downstream of the furnace."[661] Hydrogen bromide (HBr) is an example of a hydrogen halide.

380. Other secondary components 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."[662] Vosteen589 also discloses that, in addition to the bromine-containing ingredients added to coal or a combustion chamber, "the combustion is carried out additionally in the presence of chlorine and/or a chlorine compound and/or a mixture of various chlorine compounds and/or iodine and/or an iodine compound and/or a mixture of various iodine compounds."[663] The "iodine" and "chlorine" are each halogens. These materials would contact the activated-carbon sorbent, which is also injected

[661] EX1005 (Vosteen589) at Claim 1; *see also* EX1005 (Vosteen589) ¶[0006].

[662] EX1005 (Vosteen589) ¶[0016], cl. 6.

[663] EX1005 (Vosteen589) at cl. 6.

downstream of the combustion chamber.[664] Contact among added halogens and activated carbon sorbents downstream of the combustion chamber is inevitable because once any halogen appears in flue gas, it remains in the gas phase. Adsorption is the only available means to extract halogen vapors from flue gas, and activated carbon is a much stronger sorbent for halogens than any of the minerals in flyash, which hardly adsorb any halogen vapors at all under gas cleaning conditions. This is why halogen vapors in a combustion chamber will be available to contact activated carbon sorbents injected downstream.

381. 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)."[665] The modified activated carbons "doped with" chlorine and iodine describes a sorbent material that has been contacted with chlorine and iodine (i.e., halogens).

i. Claim 12: "The method of claim 11, wherein the secondary component is chosen from halogens, halide salts, HI, HBr, HCl, and combinations thereof."

382. Vosteen589 and Mass-EPA disclose Claim 12 for the same reasons discussed above for Claim 11. The secondary components of hydrogen bromide

[664] EX1095 (Olson), 98:23-100:3, 231:3-9 (discussing in-flight promotion).

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

(HBr, disclosed by Vosteen589) and chlorine and iodine (halogens, disclosed by both Vosteen589 and Mass-EPA) each satisfy this claim.

j. Claim 13: "The method of claim 11, wherein the secondary component is chosen from I_2, HI, and combinations thereof."

383. Vosteen589 discloses Claim 13 for the same reasons discussed above for Claim 11. As discussed for Claim 11, Vosteen589 discloses the addition of "iodine and/or an iodine compound."[666] A POSITA would recognize that an "iodine compound" refers to "I" bonded with I or another element, but that "iodine" by itself refers to molecular iodine (I_2).

k. Claim 18: "The method of claim 1, further comprising modifying, in response to a measured mercury content, an injection rate of injecting the sorbent into the mercury-containing gas, an amount of the additive in the mixture, or a combination thereof."

384. Claim 18 is obvious for the reasons discussed for Claim 6.

l. Claim 19: "The method of claim 1, wherein the coal comprises added sorbent enhancement additive that comprises the bromide compound."

385. Vosteen589 discloses this limitation in Ground A1 and Ground A2. As I explain regarding Claim Element 1(a), Vosteen589 describes applying a sorbent enhancement additive to coal. That additive includes aqueous sodium bromide

[666] EX1005 (Vosteen589) ¶[0016] and claim 6.

(NaBr) and hydrogen bromide (HBr).[667] Each of these are express examples of a halide sorbent enhancement additive that comprise a bromide compound, as further evidenced by their recitation in this claim ("sorbent enhancement additive comprises the bromide compound").

m. Claim 20: "The method of claim 1, wherein the coal is combusted in a combustion chamber at a coal-combustion facility, wherein the HBr, bromide compound, or combination thereof, is added to the coal before the coal enters the combustion chamber, wherein the addition of the HBr, bromide compound, or combination thereof, to the coal is performed at the coal-combustion facility."

386. This claim is disclosed by Vosteen589 (Ground A1 and Ground A2). As described above for Claim Element 1(a), Vosteen589 discloses wherein the coal is combusted in the combustion chamber at a coal-combustion facility, wherein the additive comprising HBr, a bromide compound, or combination thereof, is added to the coal before the coal enters the combustion chamber. The combustion chamber is located at a coal-combustion facility, such as the "coal-fired power station of Bayer AG in Uerdingen (see Fig. 9)."[668] The Uerdingen facility "consists of a slag-tap fired boiler and a flue gas emission control system typical of a power station consisting

[667] EX1005 (Vosteen589) ¶¶[0006], [0009], [0013], [0014].

[668] EX1005 (Vosteen589) ¶[0045], Fig. 9.

of a dry electrostatic precipitator (ESP) ….”[669] A coal-fired power station with a coal-fired combustion chamber is an example of a coal-combustion facility. The HBr, bromide compound, or combination thereof is added to the coal before the coal enters the combustion chamber, as I describe above for Claim Element 1(a), which is at the coal-combustion facility.

387. With respect to Ground A1, this claim is also obvious over Starns. The sorbent injection occurred at a coal-combustion facility. 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.”[670] “Wisconsin Electric Power Company, a subsidiary of Wisconsin Energy, owns and operates Pleasant Prairie Power Plant.”[671]

388. With respect to Ground A2, this claim is also obvious over Mass-EPA. The impetus for the mercury removal feasibility study was, “As coal is burned in electric utility boilers, the mercury (Hg) in the coal volatilizes to form gaseous elemental mercury (Hg^0).”[672] The document reports on EPA cost models “for a retrofit of PAC injection-based technology to a series of model-plant scenarios

[669] EX1005 (Vosteen589) ¶[0034].

[670] EX1008 (Starns) at Title.

[671] EX1008 (Starns) at 4.

[672] EX1009 (Mass-EPA) at 8.

representative of coal-fired electric utility power plants operating in the United States."[673]

n. Claim 22: "The method of claim 1, wherein the sorbent is contacted with a halogen or halide promoter prior to the addition of the sorbent to the mercury-containing gas."

389. Claim 22 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 by contacting the base sorbent with the promoter 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.[674]

390. Claim 22 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)."[675] Mass-EPA explains that exemplary forms of the

[673] EX1009 (Mass-EPA) at 53.

[674] *See* Technology Background and State of the Art, §IX.C, §IX.G (including EX1029 (Stock)).

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

impregnated activated carbon are "chlorine-impregnated activated carbon."[676] 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."[677] Chlorine and iodine are each types of halogens, and the activated carbon reacts with these halogens and is promoted.[678]

391. 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."

[676] EX1009 (Mass-EPA) at 34 & n.44.

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

[678] See Technology Background and State of the Art, §IX.C.3.

o. Claim 23: "The method of claim 1, wherein the sorbent is free of contact with a halogen or halide promoter prior to the addition of the sorbent to the mercury-containing gas."

392. Claim 23 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(b), each of these 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.[679]

393. 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.[680]

[679] See Technology Background and State of the Art, §IX.B.1.

[680] EX1008 (Starns) at 3.

394. For Ground A2, the same activated carbon was used: "Norit FGD," specifically "Norit America's 'Darco FGD.'"[681] A POSITA would have recognized that the Norit Darco FGD is substantially free of halogen and halide promotion prior to injection. Articles dating back to at least 1998 confirm that the chemical composition of "Norit Darco FGD" does not have halogens.[682] This is further taught by the two alternatives taught by Mass-EPA: "activated carbon (or the impregnated activated carbon)."[683] The impregnated carbon has been contacted with halogens, and the plain "activated carbon" is free of contact with halogens.

p. Claim 24: "The method of claim 6, wherein the measurement of the mercury content of the mercury-containing gas comprises continuous measurement."

395. As discussed above for Claim 6, each of Vosteen589, Starns, and Mass-EPA expressly discloses measuring mercury content of the mercury-containing gas "continuously."

[681] EX1009 (Mass-EPA) at 73, 74.

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

[683] EX1009 (Mass-EPS) at 32.

q. Claim 25: "The method of claim 1, wherein the coal comprises subbituminous coal."

396. This claim would have been obvious over Vosteen589 (Ground A1 and Ground A2). The context for the inventions in Vosteen589 is for use in "power stations, for example bituminous coal-fired or lignite-fired power stations."[684] As I describe in the "Types of Coal" subsection within the "Technology Background and State of the Art" section, a POSITA would have understood that the four broad classifications of coal, organized from highest to lowest rank are: anthracite; bituminous; subbituminous; and lignite. In general, bituminous coals (and anthracites) have the highest native halogen levels whereas lignites (and subbituminous coals) tend to have much lower values. A POSITA would recognize that any Hg control technology directed at both bituminous coals and lignites would also work for subbituminous coals, since both subbituminous coals and lignites have lower halogen contents than bituminous coals. Thus, an invention that would be effective for removing mercury for bituminous coals and lignites, as disclosed in Vosteen589, would also work for the intermediate-rank subbituminous coals.

397. With respect to Ground A1, this claim would have been further obvious over Vosteen589 in view of Starns. Starns discloses that the mercury removal

[684] EX1005 (Vosteen589) ¶[0008].

occurred for units that "fire a variety of Powder River Basin (PRB) low sulfur, sub-bituminous coals."[685]

398. With respect to Ground A2, this claim would have been further obvious over Vosteen589 in view of Mass-EPA. Mass-EPA discusses throughout the document about the need to remove mercury from "subbituminous" coal. For example, Mass-EPA discusses that "Powder River Basin (PRB) subbituminous coal" was burned at a facility that achieved "73% mercury removal upon injection of sorbent, an increase from the 5.3% removal seen without sorbent injection."[686] Mass-EPA states that the need for mercury remediation is particularly acute with subbituminous coal, in view of its relatively low native halogen concentration:

> Combustion of bituminous coal results in a flue gas that contains moderate to high levels of Hg^{2+}. In contrast, subbituminous and lignite coals typically generate relatively low concentrations of Hg^{2+} and high concentrations of Hg^0 in the flue gas. The bituminous coals contain relatively high concentrations of chlorine and lower amounts of alkaline material (calcium and sodium) compared to both subbituminous and lignite coals. The high chlorine concentration in the bituminous coal is believed to result in the oxidization of Hg^0 to form Hg^{2+}, primarily $HgCl_2$. The flue gas from combustion of subbituminous and lignite coals tends to have relatively low concentrations of Hg^{2+} because chlorine in the flue gas of these coals tends to react with the

[685] EX1008 (Starns) at 4.

[686] EX1009 (Mass-EPA) at 77.

> alkaline materials resulting in little, if any, chlorine being available for the oxidization of Hg.[687]

In view of the additional teachings of Mass-EPA, adding the halogens to the coal, as proposed by Vosteen589 would beneficially increase the halogen concentration in the flue gas.

r. Claim 26: "The method of claim 1, wherein the coal comprises lignite coal."

399. This claim would have been obvious over Vosteen589 (Ground A1 and Ground A2). The context for the inventions in Vosteen589 is for use in "power stations, for example bituminous coal-fired or lignite-fired power stations."[688]

400. With respect to Ground A2, this claim would have been further obvious over Vosteen589 in view of Mass-EPA. Mass-EPA discusses that the need for mercury remediation is particularly acute with lignite coal, in view of its relatively low native halogen concentration:

> Combustion of bituminous coal results in a flue gas that contains moderate to high levels of Hg^{2+}. In contrast, subbituminous and lignite coals typically generate relatively low concentrations of Hg^{2+} and high concentrations of Hg^0 in the flue gas. The bituminous coals contain relatively high concentrations of chlorine and lower amounts of alkaline material (calcium and sodium) compared to both subbituminous and lignite coals. The high chlorine concentration in the bituminous coal is believed to

[687] EX1009 (Mass-EPA) at 24; see also p. 29 (similar discussion).

[688] Ex1005 (Vosteen589) ¶[0008].

> result in the oxidization of Hg^0 to form Hg^{2+}, primarily $HgCl_2$. The flue gas from combustion of subbituminous and lignite coals tends to have relatively low concentrations of Hg^{2+} because chlorine in the flue gas of these coals tends to react with the alkaline materials resulting in little, if any, chlorine being available for the oxidization of Hg.[689]

In view of the additional teachings of Mass-EPA, adding the halogens to the coal, as proposed by Vosteen589 would beneficially increase the halogen concentration in the flue gas.

s. Claim 27: "The method of claim 1, wherein the mixture is combusted in a combustion chamber of a coal-combustion facility upstream of a scrubber, a particulate control system, or a combination thereof, wherein the particulate sorbent is added to the mercury-containing gas before the mercury-containing gas encounters the scrubber, the particulate control system, or the combination thereof."

401. This claim would have been obvious over the combination of Vosteen589 and Starns (Ground A1) and Vosteen589 and Mass-EPA (Ground A2). 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 control system. As described above for Claim Element 1(a) and Claim 20, the mixture is combusted in a combustion chamber of a coal-combustion facility.

[689] EX1009 (Mass-EPA) at 9, 19, 24-25, 39.

402. As described above for Claim Element 1(b), Vosteen589 discloses an embodiment, which makes use of an electrostatic precipitator (ESP),[690] which is a type of particulate control system downstream of the combustion chamber. Vosteen589 explains that "mercury adsorption intensifies on the fly ash of ESPs."[691] Vosteen589 also explains that "[m]ercury bromide $HgBr_2$ adsorbs more strongly to dry sorbents than mercury chloride $HgCl_2$."[692] The dry sorbents disclosed by Vosteen589 include "granulated activated carbon" and "pulverulent slaked lime/activated carbon."[693] A person of ordinary skill in the art would have understood that, as taught by Vosteen589, adsorption of $HgBr_2$ by activated carbon 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 particulate control system, such as a fabric filter or ESP.[694] Vosteen589 also discloses the use of a scrubber.[695]

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[690] EX1005 (Vosteen589) ¶¶[0019], [0034], [0047], Fig. 9 (item 96), claim 8; *see also* EX1005 (Vosteen589) ¶¶[0033], [0042], [0048]-[0049].

[691] EX1005 (Vosteen589) ¶[0019].

[692] EX1005 (Vosteen589) ¶[0019].

[693] EX1005 (Vosteen589) ¶[0019].

[694] *See* Technology Background and State of the Art, § IX.B.5.a.

[695] EX1005 (Vosteen589) ¶¶[0003], [0006].

i. Ground A1 (Vosteen589 and Starns)

403. This claim would have further been obvious over Vosteen589 in view of Starns. Starns recommends "using activated carbon injection upstream of an ESP."[696] A POSITA would have been motivated, as Starns suggests, to use activated carbon injection between the combustion chamber (furnace) and an ESP (electrostatic precipitator) in Vosteen589.[697] Starns states that the activated-carbon sorbent is carried "from the feeders to distribution manifolds located on the ESP inlet duct, feeding the injection probes,"[698] further demonstrating that the injection of sorbent into the mercury-containing gas occurs upstream of a particulate separator.

ii. Ground A2 (Vosteen589 and Mass-EPA)

404. 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.[699] The Mass-EPA recognized that devices already present for controlling other pollutants (such

[696] EX1008 (Starns) at 20.

[697] EX1005 (Vosteen589) ¶¶[0019], [0033], [0037], [0039], [0042], [0047]-[0049], claim 8 (discussing use of an ESP).

[698] EX1008 (Starns) at 7.

[699] EX1009 (Mass-EPA) at 7.

as SOx or NOx) can also be useful to provide some mercury capture, including "Electro Static Precipitator (ESP)."[700]

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)

405. 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.[701] Mass-EPA teaches injecting activated carbon "upstream" of the ESP and refers to the "injection of a sorbent into the exhaust system and subsequent collection of the particulates in a PM [particulate matter] control device."[702] This again demonstrates that the sorbent injection into the mercury-containing gas occurs upstream of a particulate control system.[703]

[700] EX1009 (Mass-EPA) at 7.

[701] EX1009 (Mass-EPA) at 50.

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

[703] EX1009 (Mass-EPA) at 53, 54.

t. Claim 28: "The method of claim 26, wherein the particulate control system comprises an electrostatic precipitator, a baghouse, a fabric filter, or a combination thereof."

406. This claim is disclosed by the combinations of Vosteen589 with Starns (Ground A1) and Vosteen589 with Mass-EPA (Ground A2). As described for Claim 27, the combination of Vosteen589 in view of Starns (Ground A1) and the combination of Vosteen589 in view of Mass-EPA (Ground A2) each utilizes an electrostatic precipitator as a particulate separator.

u. Claim 29: "The method of claim 19, wherein the combustion chamber is a coal combustion furnace."

407. Vosteen589 discloses this claim in Ground A1 and Ground A2. The combustion chamber in Vosteen589 is a coal-combustion furnace:

> 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. . . . The compound can also be fed during the combustion process. If the furnace comprises a plurality of stages, for example a primary and secondary furnace, the bromine compound can be introduced, likewise in solid or liquid form, into one or both combustion chambers, for example into the rotary kiln and/or the afterburning chamber.[704]

[704] EX1005 (Vosteen589) ¶[0013]; see also EX1005 (Vosteen589) at Abstract, claim 1.

3. Independent Claim 14

408. Claim 14 copies Claim 1, but modifies Element 1(a) slightly as shown in the redline below:

~~1~~14. A method for treating a mercury-containing gas, the method comprising:

combusting coal in a ~~mixture~~combustor comprising ~~coal,~~ pyrolysis char~~,~~ and an additive comprising HBr, a bromide compound, or a combination thereof, to form the mercury-containing~~,~~ gas; and

adding a particulate sorbent material comprising activated carbon into the mercury-containing gas.

I discuss these differences below.

a. Claim 14: Preamble—"A method for treating a mercury-containing gas, the method comprising:"

409. The language of the preamble of Claim 14 is identical to the preamble of Claim 1. This limitation is disclosed for the same reasons as stated above for Claim 1.

b. Claim 14: Element 14(a)—"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; and"

410. The language of Claim Element 14(a) is nearly 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 14(a). As discussed above for Claim

Element 1(a), Vosteen589 discloses that the mixture is combusted in a boiler/furnace (i.e., "a combustor").

c. Claim 14: Element 14(b)—"adding a particulate sorbent material comprising activated carbon into the mercury-containing gas"

411. The language of Claim Element 14(b) 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 14(a).

4. Claims Depending from Claim 14

a. Claim 15: "The method of claim 14, wherein the pyrolysis char is a promoted pyrolysis char."

412. Claim 15 is obvious for the same reasons discussed above for Claim 2.

5. Independent Claim 17

413. Claim 17 copies Claim 1, but modifies Element 1(b) to remove "particulate" as shown in the redline below:

~~1~~17. A method for treating a mercury-containing gas, the method comprising:

combusting a mixture comprising coal, pyrolysis char, and an additive comprising HBr, a bromide compound, or a combination thereof, to form the mercury-containing~~,~~ gas; and

adding a ~~particulate~~ sorbent material comprising activated carbon into the mercury-containing gas.

Accordingly, the explanation I provide above for Claim 1 applies equally to Claim 17.

XIV. GROUND A3: ANTICIPATION BY DOWNS-BOILER

414. It is my opinion that Downs-Boiler anticipates each of Claims 1, 2, 5, 7, 8, 14, 15, 17, 19, 20, and 25-29 of the '225 Patent. In the subsections below, I rely on the disclosure of Downs-Boiler. The material I rely on was also disclosed and supported by Downs-Boiler-Provisional, so parallel citations to Downs-Boiler-Provisional are also included.

1. Independent Claim 1

a. Claim 1: Preamble—"A method for treating a mercury-containing gas, the method comprising:"

415. Downs-Boiler discloses the preamble. The title of Downs-Boiler is "Bromine Addition for the Improved Removal of Mercury from Flue Gas.[705] Flue gas is an example of a mercury-containing gas, and "removal of mercury" refers to treating a mercury-containing gas in order to reduce mercury emissions. The mercury is reduced by separating it from the mercury-containing gas. 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

[705] EX1006 (Downs-Boiler) at Title; EX1007 (Downs-Boiler-Provisional) at Title.

> oxidation of mercury, thereby enhancing the overall removal of mercury in downstream pollution control devices.[706]

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"[707] The reduction of mercury in the flue gas as described by Downs-Boiler is by separating the mercury along with a sorbent:[708]

> 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.

416. Downs-Boiler characterizes its disclosed "invention" as "a cost-effective method of removing elemental mercury from coal combustion flue gases."[709]

[706] EX1006 (Downs-Boiler) ¶[0007]; EX1007 (Downs-Boiler-Provisional) ¶[0013].

[707] 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.").

[708] EX1006 (Downs-Boiler) ¶[0004]; EX1007 (Downs-Boiler-Provisional) ¶[005].

[709] EX1006 (Downs-Boiler) ¶[0018]; EX1007 (Downs-Boiler-Provisional) ¶[021].

b. Claim 1: Element 1(a)—"combusting a mixture comprising coal, pyrolysis char, and an additive comprising HBr, a bromide compound, or a combination thereof, to form the mercury-containing, gas; and"

417. 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."[710] Downs-Boiler 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:[711]

[710] EX1006 (Downs-Boiler) ¶[0001]; see also EX1007 (Downs-Boiler-Provisional) ¶[002].

[711] EX1006 (Downs-Boiler) ¶¶[0010]-[0014], Figures 2, 4-6; see also EX1006 (Downs-Boiler) ¶¶[0002], [0015], [0020]; EX1007 (Downs-Boiler-Provisional) ¶¶[0003], [0009], [0012]-[0016], [0018], [0023], Figures 2, 4-6.

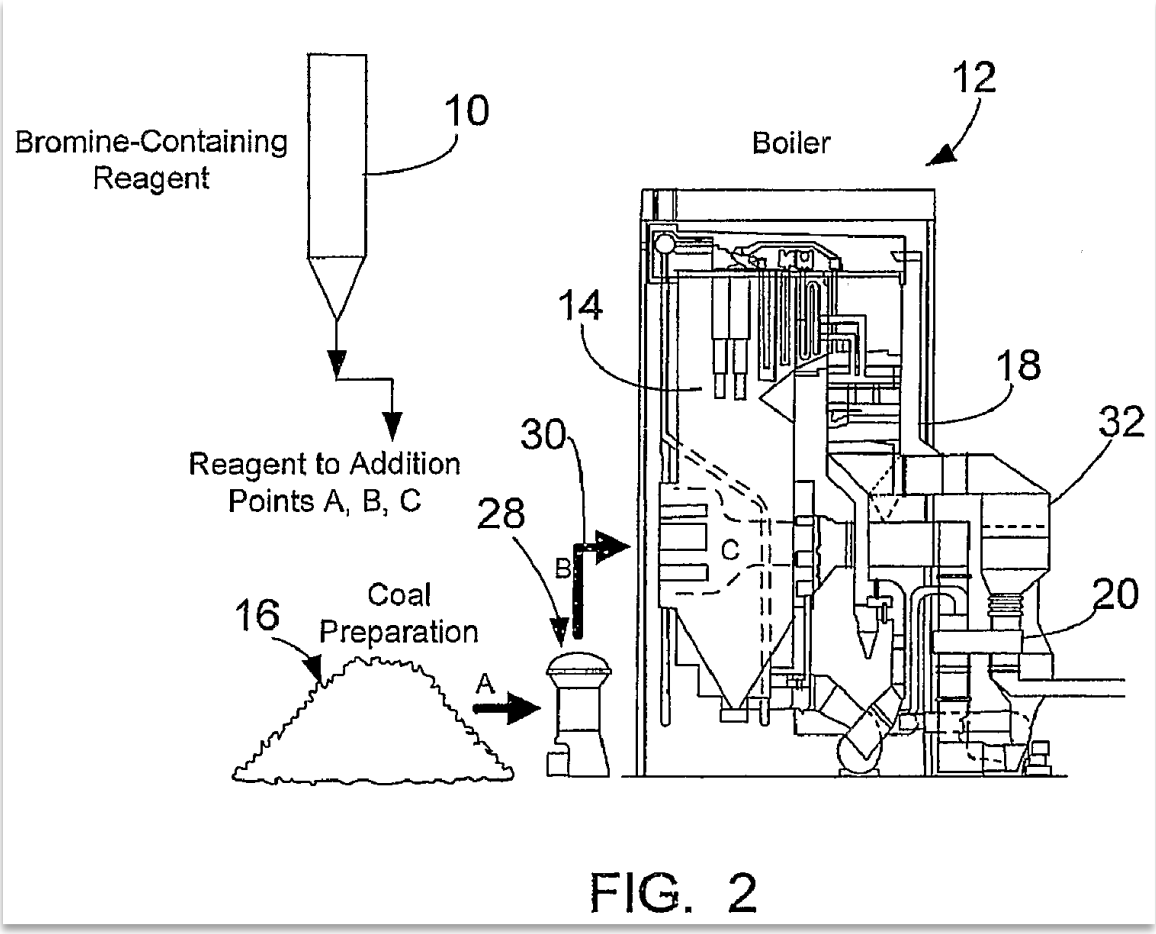

Bromine-Containing Reagent
10
12
Boiler
14
18
32
30
28
B
C
Reagent to Addition Points A, B, C
16
Coal Preparation
A
20

FIG. 2

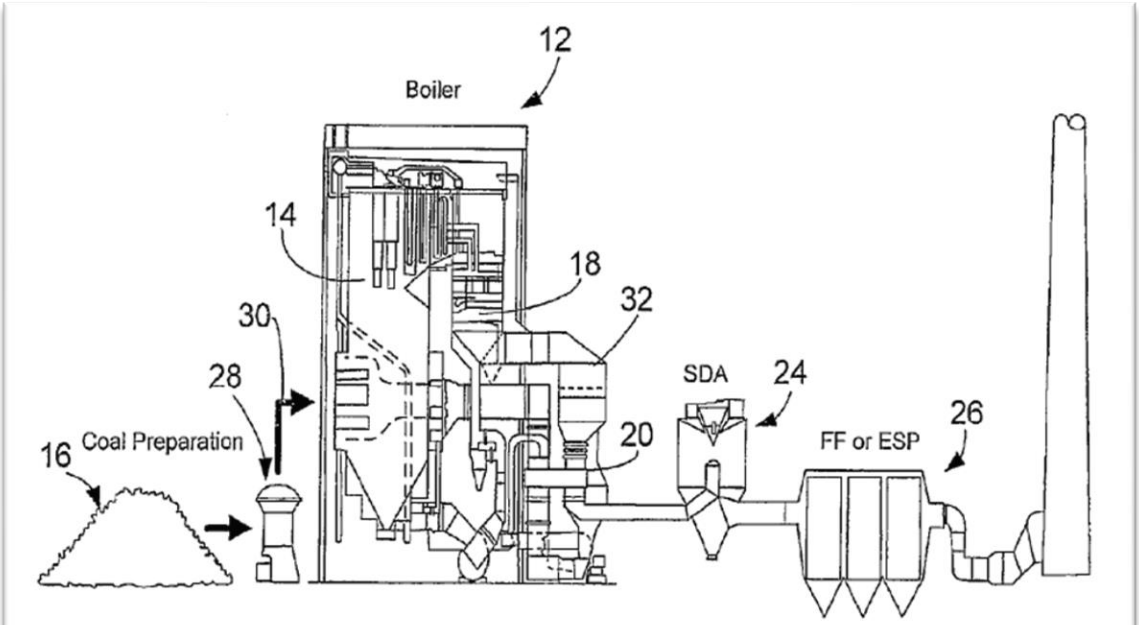

12
Boiler
14
18
32
30
28
SDA
24
26
20
FF or ESP
16
Coal Preparation

FIG. 4

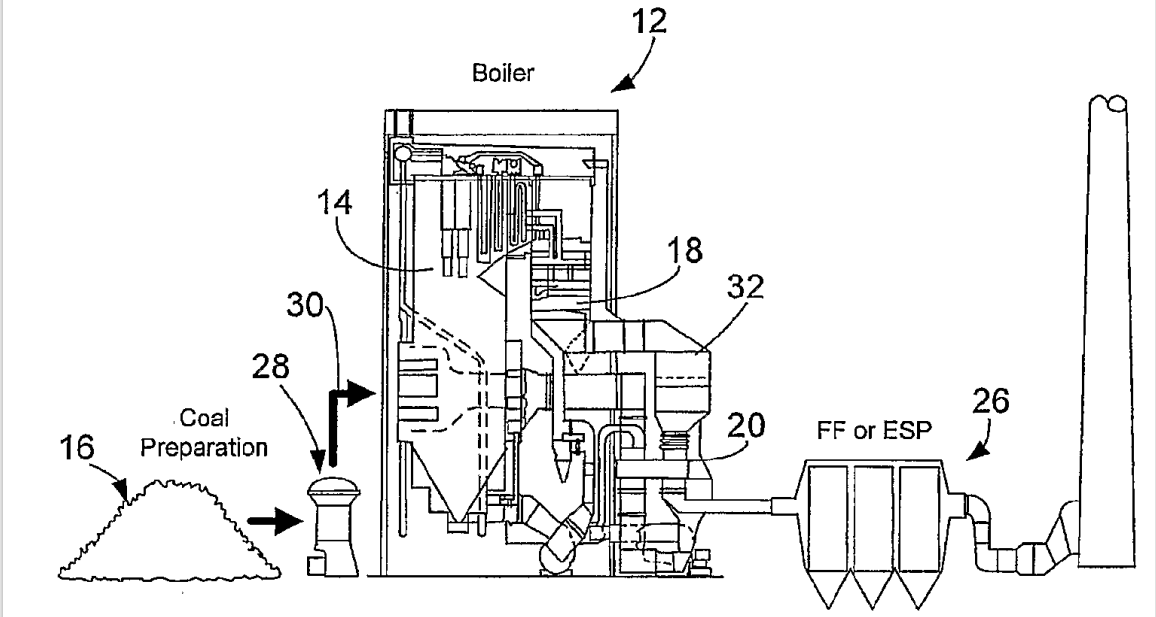

12
Boiler
14
18
32
30
28
26
Coal
Preparation
20
FF or ESP
16

FIG. 5

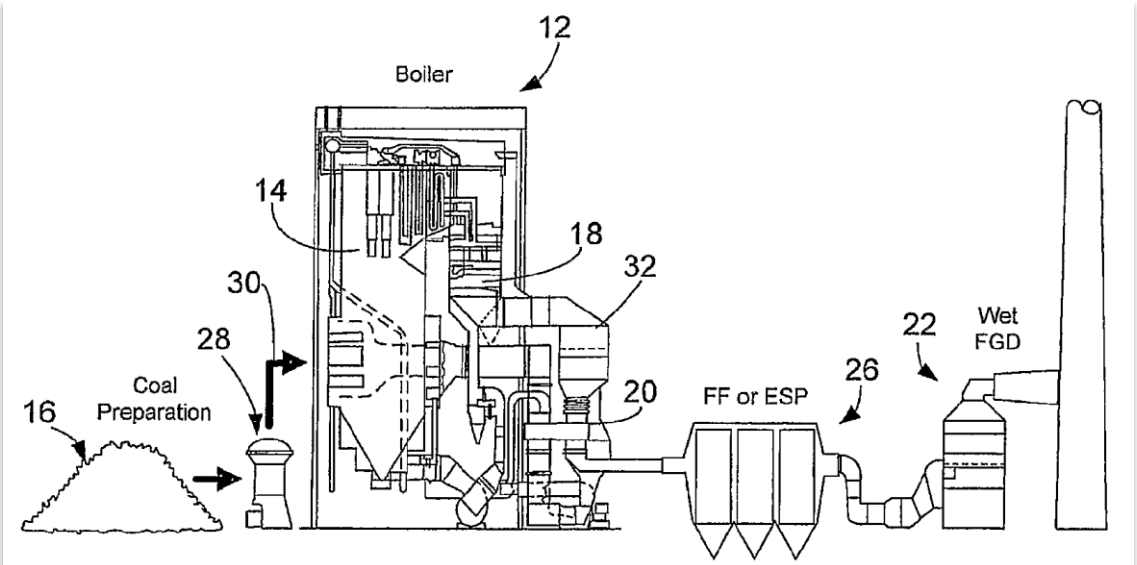


FIG. 6

418. 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:[712]

> 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.

419. Downs-Boiler describes combusting common ranks of coal used by the electric utility industry and, specifically, that "the coal-fired boiler fuel 16 may

[712] EX1006 (Downs-Boiler) ¶[0015]; see also EX1006 (Downs-Boiler) ¶[0007] ("bromine-containing compounds, added to the coal, or to the boiler combustion furnace"); EX1007 (Downs-Boiler-Provisional) ¶¶[0009], [0018].

include bituminous, subbituminous, and lignite coals and blends, thereof."[713] Finally, Downs-Boiler states that "[m]ercury appears in coal combustion flue gases in both solid and gas phases."[714] 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.

420. Downs-Boiler discloses adding HBr and/or a bromide compound to the combustion chamber and/or to the coal before the coal enters the combustion chamber.

421. First, Downs-Boiler discloses Br_2, HBr, a bromide compound, or a combination thereof, added to the coal before the coal enters 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 (HBr) or bromine (Br_2)."[715] Downs-Boiler also specifically

[713] EX1006 (Downs-Boiler) ¶[0020]; see also EX1007 (Downs-Boiler-Provisional) ¶[0023].

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

[715] EX1006 (Downs-Boiler) ¶[0021]; see also EX1007 (Downs-Boiler-Provisional) ¶[0024].

discloses calcium bromide ($CaBr_2$) as another suitable bromide compound for use as the bromine-containing reagent.[716]

422. This bromine-containing reagent is applied to the coal before the coal enters 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."[717] 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."[718] Thus, upstream of the combustion chamber, such 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.

---

[716] EX1006 (Downs-Boiler) ¶[0018]-[0019]; see also EX1007 (Downs-Boiler-Provisional) ¶[0021-22].

[717] EX1006 (Downs-Boiler) ¶[0015]; see also EX1006 (Downs-Boiler) ¶[0007]; EX1007 (Downs-Boiler-Provisional) ¶¶[009], [0018].

[718] EX1006 (Downs-Boiler) ¶[0019], Figure 2; see also EX1007 (Downs-Boiler-Provisional) ¶[0022], Figure 2.

423. 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 "[b]romine species released during the combustion process enhance the oxidation of mercury as the combustion gases pass through the furnace 14."[719] That the bromine-containing reagent is "sprayed on the crushed coal 16 before the coal is pulverized for combustion" additionally "ensures even distribution of the [bromine-containing] reagent 10 across the boiler furnace" (i.e., in the combustion chamber).[720]

424. 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 "bromine containing reagent 10 is added to

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

[720] EX1006 (Downs-Boiler) ¶[0019]; see also EX1007 (Downs-Boiler-Provisional) ¶[0022].

the boiler 12 combustion furnace 14, either directly or by premixing with the incoming coal 16."[721] 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."[722] 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."[723] Thus, the combustion chamber comprises at least one or a combination of Br_2, HBr, and a bromide compound (e.g., calcium bromide ($CaBr_2$)).

425. 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 before the coal enters the 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 and in the combustion chamber.

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

[722] EX1006 (Downs-Boiler) ¶[0019]; see also EX1007 (Downs-Boiler-Provisional) ¶[0021].

[723] EX1006 (Downs-Boiler) ¶[0022]; see also EX1007 (Downs-Boiler-Provisional) ¶[0025].

426. Furthermore, as illustrated in Figure 2, reproduced below as annotated, Downs-Boiler illustrates that the bromine-containing reagent may be mixed in at "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).[724]

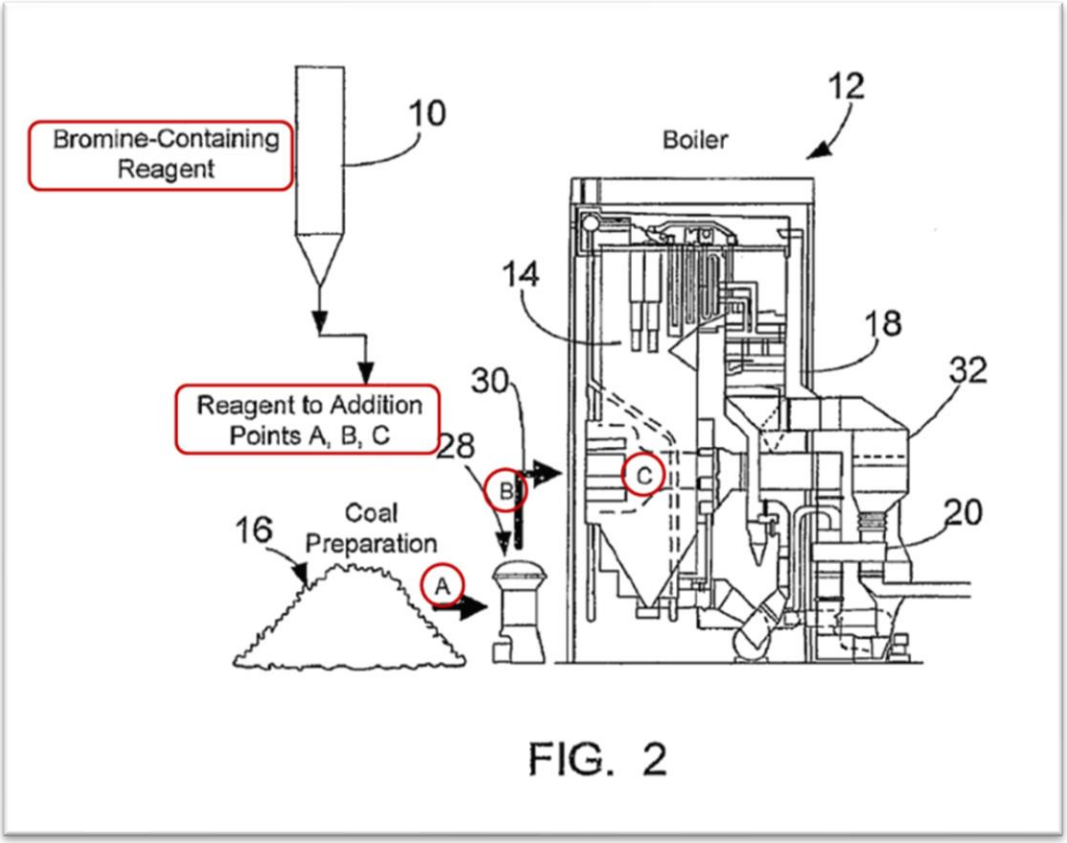


FIG. 2

427. 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

[724] EX1006 (Downs-Boiler) ¶[0019], Figure 2 (annotated); see also EX1007 (Downs-Boiler-Provisional) ¶[0022], Figure 2.

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."[725]

428. It would have been inherent for the mixture being combusted to comprise not only coal and Br-containing ingredients, but also comprise pyrolysis char. It was known long before the earliest priority date of the '225 Patent that pyrolysis char necessarily forms during the combustion of coal, including even under the most favorable conditions.[726] Thus, at least some quantity of the mixture of coal and bromine-containing ingredients (introduced into the combustion chamber) is further mixed with the pyrolysis char formed in the chamber. This mixture of coal, pyrolysis char, and bromine-containing ingredients entrains air and, since the flame temperatures inside the combustion chamber are several hundred degrees hotter than the ignition temperatures for both coal and pyrolysis char, the mixture spontaneously burns as it is contacted by oxygen in the air. Accordingly, Downs-Boiler discloses each and every limitation of Claim Element 1(a).

[725] EX1006 (Downs-Boiler) ¶[0019]; see also EX1007 (Downs-Boiler-Provisional) ¶[0022].

[726] Technology Background and State of the Art, §IX.H; EX1100 (Coal Chemsitry) p. 673.

429. Patent Owner's expert in the Delaware Litigation, Mr. O'Keefe, further confirmed—in both his expert report and his deposition concerning the '225 Patent—the inherency of pyrolysis char in the bromine-coal mixture being combusted:

> Q. Just continuing on, on '225, claim 1. How would a person of skill in the art know whether there is any pyrolysis char in the mixture that was being combusted?
>
> A. Whenever you combust coal you create pyrolysis char.
>
> Q. It's always there whenever you combust coal?
>
> A. Right. It depends, you know, whether it's completely turned into ash or not, you know, by the combustion process.
>
> Q. … Pyrolysis char is an inherent result from the combustion of coal; is that correct?
>
> A. Correct. Correct.
>
> Q. Now, does claim 1 require any particular amount of pyrolysis char?
>
> A. No.
>
> Q. How would a person with skill in the art know if there was enough pyrolysis char to accomplish the goals of claim 1?
>
> A. Well, during combustion there's always pyrolysis char. You know, the question is whether it's entirely burned off or not during the combustion process. …
>
> Q. And looking at claim 1, is it important to know whether the pyrolysis char was all combusted or not?

A. No.[727]

In his infringement report, Mr. O'Keefe further stated that "when coal is combusted, it produces some amount of pyrolysis char."[728]

c. Claim 1: Element 1(b)—"adding a particulate sorbent material comprising activated carbon into the mercury-containing gas."

430. Downs-Boiler discloses this claim element. Downs-Boiler discloses adding activated carbon into a mercury-containing flue gas downstream of the combustion chamber and contacting mercury with the sorbent to form a mercury-laden sorbent.

431. Downs-Boiler discloses injecting a particulate sorbent material comprising activated carbon, referring to the example of "powdered activated carbon (PAC)" (i.e., a particulate sorbent material).[729] 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 PAC

[727] EX1094 (O'Keefe) at 233:33-235:9.

[728] EX1092 (O'Keefe Report) at 163 ('225 Patent Cl. 1b).

[729] EX1006 (Downs-Boiler) ¶[0025]; see also EX1007 (Downs-Boiler-Provisional) ¶[0028].

injection process."[730] 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]."[731] As explained by Downs-Boiler, the disclosed injected activated-carbon sorbent materials (e.g., sorbent injection systems using PAC) are part of "downstream pollution control systems such as . . . PAC injection systems."[732] Here, "downstream" is relative to the location of the combustion chamber (also referred to as the "boiler" or "furnace"), and thus after generation of the mercury-containing gas.[733] 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 is injected into a mercury-containing gas: "injection of

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

[731] EX1006 (Downs-Boiler) ¶¶[0004], [0015], [0016], and [0025]; see also EX1007 (Downs-Boiler-Provisional) ¶¶[005], [0018], [0019], and [0028].

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

[733] EX1006 (Downs-Boiler) ¶¶[0012]-[0014] (discussing "downstream" with respect to the "boiler"); see also EX1007 (Downs-Boiler-Provisional) ¶¶[0014]-[0016].

a carbonaceous sorbent (e.g., powdered activated carbon, or PAC) into the flue gas upstream of the dust collector to adsorb vapor-phase mercury."[734]

432. In the context of conventional mercury removal by PAC injection, Downs-Boiler explains that adsorption (i.e., contact) of the mercury by the sorbent occurs in the mercury-containing (flue) gas system (i.e., downstream of the combustion chamber):[735]

> 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.

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.

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

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

433. Downs-Boiler recognizes that the sorbent "bond[s] with adsorbed mercury species" and that the strength of this bond is improved by halogens.[736] 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-bound mercury.[737] This increase in the fraction of particulate-bound mercury is explained as leading to a mercury-laden sorbent due to the increased "reactivity of oxidized mercury with PAC."[738]

2. Claims Depending from Claim 1

a. Claim 2: "The method of claim 1, wherein the pyrolysis char is a promoted pyrolysis char."

434. According to Patent Owner's expert in the Delaware litigation, "pyrolysis char forms in the presence of bromine that has been added to the coal. Thus, it is promoted pyrolysis char."[739]

[736] EX1006 (Downs-Boiler) ¶[0004]; EX1007 (Downs-Boiler-Provisional) ¶[005].

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

[738] EX1006 (Downs-Boiler) ¶[0016]; EX1007 (Downs-Boiler-Provisional) ¶[0019].

[739] EX1092 (O'Keefe Report) at 163.

b. Claim 5: "The method of claim 1, further comprising using a particle separation device to remove mercury from the flue gas and comprising collecting greater than 70 wt % of the mercury in the mercury-containing gas to produce a cleaned gas."

435. Downs-Boiler discloses this claim. 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) to produce a cleaned gas.[740]

[740] EX1006 (Downs-Boiler) Figure 3 (annotated); see also EX1007 (Downs-Boiler-Provisional) Figure 3.

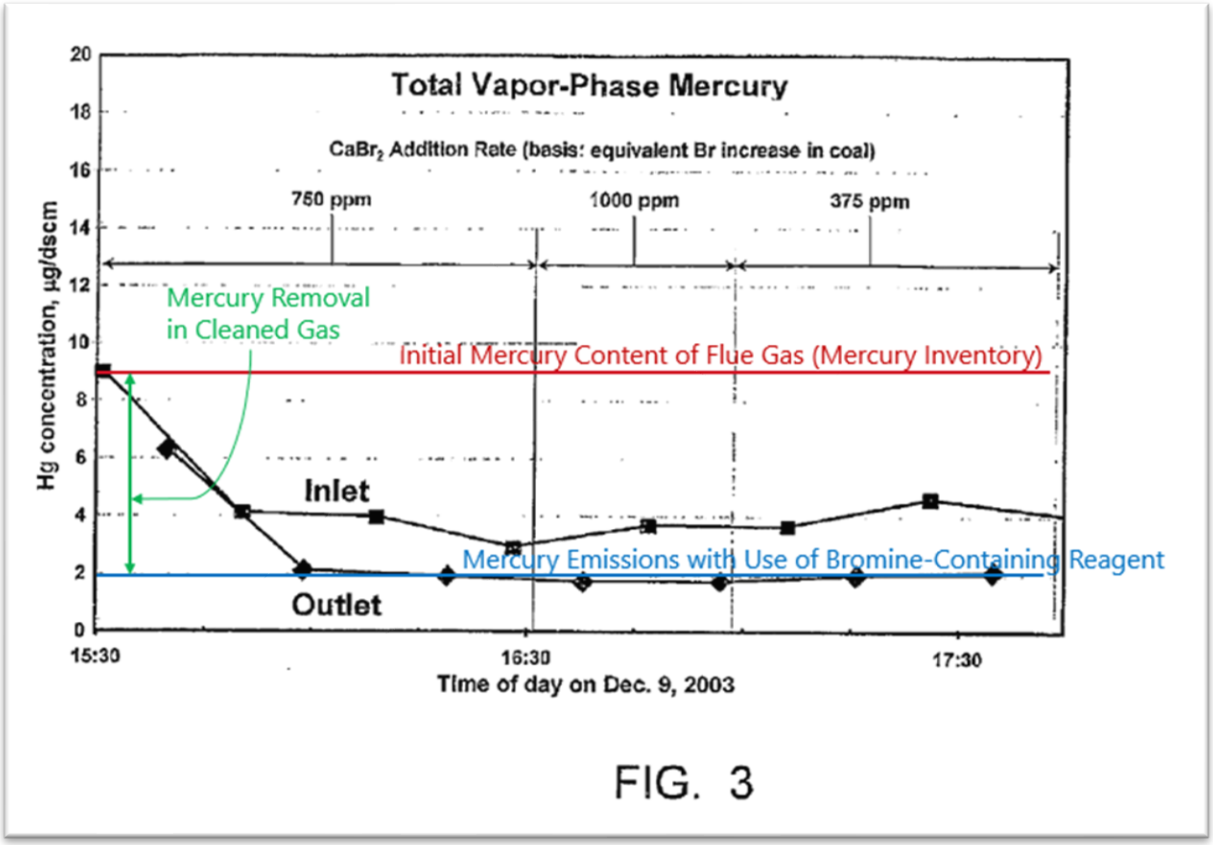


FIG. 3

Therefore, Downs-Boiler resulted in mercury collection of approximately 7 µg/dscm (green). This collection 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 removed—or in other words: collecting greater than 70 wt% of the mercury in the mercury-containing gas.

c. Claim 7: "The method of claim 1, wherein the additive further comprises Br_2."

436. Downs discloses "bromine (Br_2)" as the additive.[741]

d. Claim 8: "The method of claim 1, wherein the sorbent material is chosen from powdered activated carbon, granular activated carbon, carbon black, carbon fiber, aerogel carbon, pyrolysis char, and combinations thereof."

437. Downs-Boiler discloses this claim. 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."[742]

e. Claim 19: "The method of claim 1, wherein the coal comprises added sorbent enhancement additive that comprises the bromide compound."

438. This claim is disclosed by Downs-Boiler. As I explain above regarding Claim Element 1(a), Downs-Boiler discloses a bromine-containing reagent added to the coal. Downs-Boiler also discloses that the bromine-containing reagent may

[741] EX1006 (Downs-Boiler) ¶¶[0018]-[0019], [0021]; EX1007 (Downs-Boiler-Provisional) ¶¶[0021]-[0022], [0024].

[742] EX1006 (Downs-Boiler) ¶[0025]; see also EX1007 (Downs-Boiler-Provisional) ¶[0028].

comprise "alkali metal and alkaline earth metal bromides, hydrogen bromide (HBr) or bromine (Br_2)," [743] and "an aqueous solution of calcium bromide" ($CaBr_2$). [744] A POSITA would also have understood that at least the HBr, alkali metal bromides, and alkaline earth bromides are examples of bromide compounds.

439. As disclosed by Downs-Boiler, these bromide compounds 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 premixing with the incoming coal 16." [745] 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

[743] EX1006 (Downs-Boiler) ¶[0021]; see also EX1007 (Downs-Boiler-Provisional) ¶[0024].

[744] EX1006 (Downs-Boiler) ¶¶[0018]-[0019], [0021], Figure 2; see also EX1007 (Downs-Boiler-Provisional) ¶[0021-22, 0024], Figure 2.

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

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."[746]

440. Downs-Boiler further instructs that "mercury removal may be further enhanced by utilizing a sorbent injection system in conjunction with the present invention."[747] 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."[748].

f. Claim 20: "The method of claim 1, wherein the coal is combusted in a combustion chamber at a coal-combustion facility, wherein the HBr, bromide compound, or combination thereof, is added to the coal before the coal enters the combustion chamber, wherein the addition of the HBr, bromide compound, or combination thereof, to the coal is performed at the coal-combustion facility."

441. This claim is disclosed by Downs-Boiler. As described above for Claim Element 1(a), Downs-Boiler discloses wherein the coal is combusted in the

[746] EX1006 (Downs-Boiler) ¶[0019], Figure 2; see also EX1007 (Downs-Boiler-Provisional) ¶[0022], Figure 2.

[747] EX1006 (Downs-Boiler) ¶[0025]; see also EX1007 (Downs-Boiler-Provisional) ¶[0028].

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

combustion chamber at a coal-combustion facility, wherein the additive comprising the HBr, bromide compound, or combination thereof, is added to the coal before the coal enters the combustion chamber. Downs-Boiler refers to the "electric utility plant configuration representing a boiler equipped with … downstream particulate collection means."[749] Downs-Boiler's goal is to "reduce the cost of mercury removal at coal-fired electric plants."[750] An electric utility plant with a coal-fired combustion chamber is an example of a coal-combustion facility. The HBr, bromide compound, or combination thereof is added to the coal upstream of the combustion chamber, as I describe above for Claim Element 1(a), which is at the coal-combustion facility.

g. Claim 25: "The method of claim 1, wherein the coal comprises subbituminous coal."

442. This claim is disclosed by Downs-Boiler. Downs-Boiler discloses use of "western U.S. subbituminous coal,"[751] which is a type of subbituminous coal.

[749] EX1006 (Downs-Boiler) ¶[0012]-[0014]; EX1007 (Downs-Boiler-Provisional) ¶[0026].

[750] EX1006 (Downs-Boiler) ¶[0016]; EX1007 (Downs-Boiler-Provisional) ¶[0019].

[751] EX1006 (Downs-Boiler) ¶[0017]; EX1007 (Downs-Boiler-Provisional) ¶[0020].

Downs-Boiler later states that "the coal-fired boiler fuel 16 may include bituminous, subbituminous, and lignite coals and blends thereof."[752]

h. Claim 26: "The method of claim 1, wherein the coal comprises lignite coal."

443. This claim is disclosed by Downs-Boiler. Downs-Boiler states that "the coal-fired boiler fuel 16 may include bituminous, subbituminous, and lignite coals and blends thereof."[753]

i. Claim 27: "The method of claim 1, wherein the mixture is combusted in a combustion chamber of a coal-combustion facility upstream of a scrubber, a particulate control system, or a combination thereof, wherein the particulate sorbent is added to the mercury-containing gas before the mercury-containing gas encounters the scrubber, the particulate control system, or the combination thereof."

444. Downs-Boiler discloses this limitation. As described above for Claim Element 1(a) and Claim 20, the mixture is combusted in a combustion chamber of a coal-combustion facility. As described above for Claim Element 1(b), and as illustrated by Figures 4-6 of Downs-Boiler (representative Figure 6 reproduced below as annotated), Downs-Boiler describes a coal-combustion facility that can

[752] EX1006 (Downs-Boiler) ¶[0020]; EX1007 (Downs-Boiler-Provisional) ¶[0023].

[753] EX1006 (Downs-Boiler) ¶[0020]; EX1007 (Downs-Boiler-Provisional) ¶[0023].

have a number of downstream pollution control devices including particulate control 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).[754]

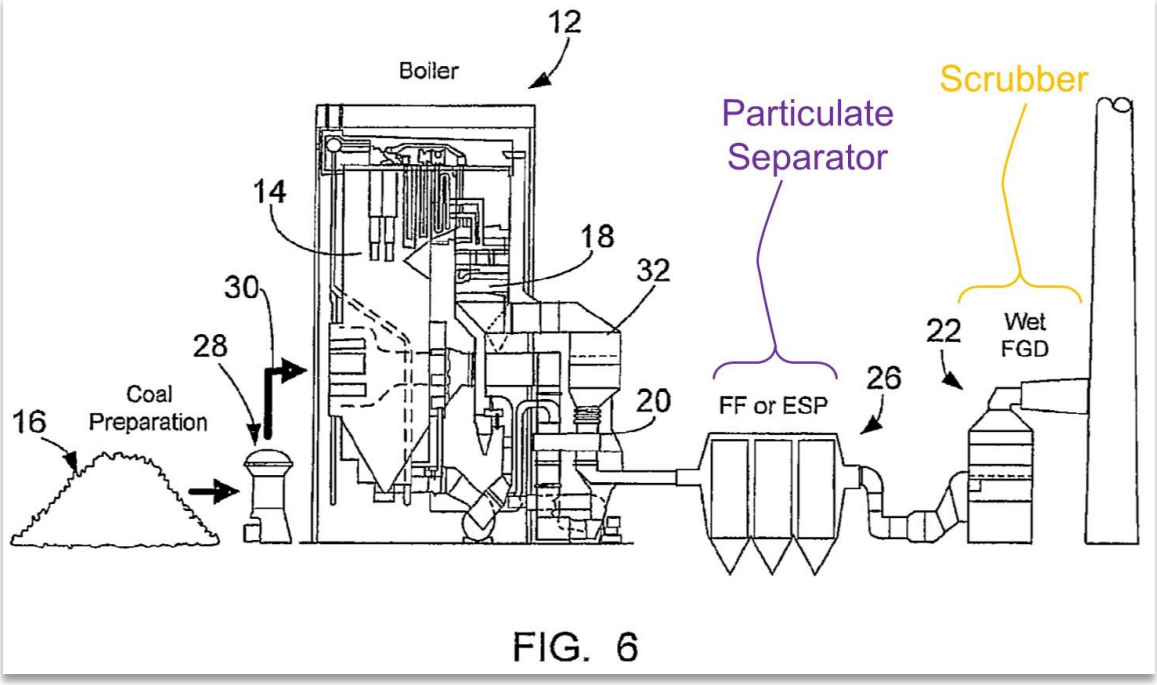


FIG. 6

445. The use of the bromine-containing reagent as disclosed by Downs-Boiler "thereby enhance[es] the overall removal of mercury in downstream pollution control devices."[755] Specifically, Downs-Boiler explains that a particular advantage

[754] EX1006 (Downs-Boiler) Figure 6 (annotated); see also EX1006 (Downs-Boiler) Figures 4-5, ¶¶[0003]-[0004], [0023]; EX1007 (Downs-Boiler-Provisional) Figures 4-6, ¶¶[004][005], [0026].

[755] EX1006 (Downs-Boiler) ¶[0007]; see also EX1007 (Downs-Boiler-Provisional) ¶[009].

of the disclosed invention is that it "enhances removal of mercury across particulate collectors 26 such as fabric filters (FF) and electrostatic precipitators (ESP)."[756] 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 the flue gases in a downstream particulate collector."[757] The activated-carbon sorbent would be injected upstream of the ESP, so that it could be "subsequently removed" by that ESP.

j. Claim 28: "The method of claim 26, wherein the particulate control system comprises an electrostatic precipitator, a baghouse, a fabric filter, or a combination thereof."

446. This claim is disclosed by Downs-Boiler. As described for claim 27, the Downs-Boiler discloses an electrostatic precipitator (ESP) and a fabric filter (FF) as the particulate control system.

k. Claim 29: "The method of claim 19, wherein the combustion chamber is a coal combustion furnace."

447. This claim is disclosed by Downs-Boiler for the reasons discussed above in Claim Element 1(a). The combustion chamber in the Downs-Boiler is a

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

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

coal-combustion furnace (i.e. a "combustion furnace 14").[758] This is also shown in Figures 2 and 4-6 of Downs-Boiler.[759] Figure 5 is copied below.

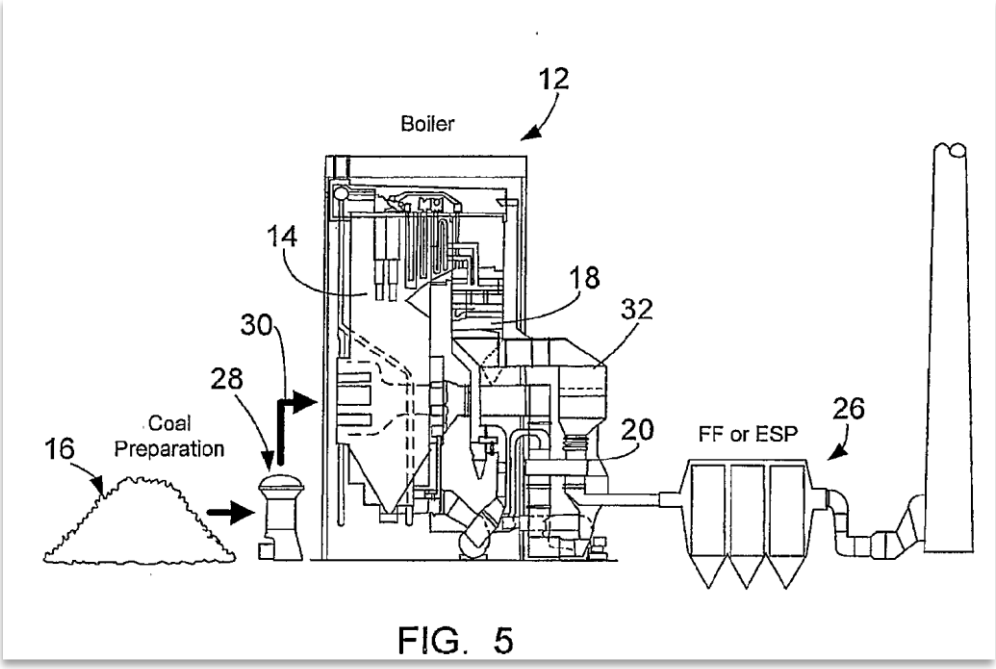


FIG. 5

3. Independent Claim 14

448. Claim 14 copies Claim 1, but modifies Element 1(a) slightly as shown in the redline below:

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

[759] EX1006 (Downs-Boiler) Figures 2, 4-6; see also EX1007 (Downs-Boiler-Provisional) Figures 2, 4-6.

~~1~~14. A method for treating a mercury-containing gas, the method comprising:

combusting coal in a ~~mixture~~combustor comprising ~~coal,~~ pyrolysis char~~,~~ and an additive comprising HBr, a bromide compound, or a combination thereof, to form the mercury-containing~~,~~ gas; and

adding a particulate sorbent material comprising activated carbon into the mercury-containing gas.

I discuss these differences below.

a. Claim 14: Preamble—"A method for treating a mercury-containing gas, the method comprising:"

449. The language of the preamble of Claim 14 is identical to the preamble of Claim 1. This limitation is disclosed for the same reasons as stated above for Claim 1.

b. Claim 14: Element 14(a)—"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; and"

450. The language of Claim Element 14(a) is nearly 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 14(a). As discussed above for Claim Element 1(a), Downs-Boiler discloses that the mixture is combusted in a boiler/furnace (i.e., "a combustor").

c. Claim 14: Element 14(b)—"adding a particulate sorbent material comprising activated carbon into the mercury-containing gas"

451. The language of Claim Element 14(b) 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 14(a).

4. Claims Depending from Claim 14

a. Claim 15: "The method of claim 14, wherein the pyrolysis char is a promoted pyrolysis char."

452. Claim 15 is obvious for the same reasons discussed above for Claim 2.

5. Independent Claim 17

453. Claim 17 copies Claim 1, but modifies Element 1(b) to remove "particulate" as shown in the redline below:

~~1~~17. A method for treating a mercury-containing gas, the method comprising:

combusting a mixture comprising coal, pyrolysis char, and an additive comprising HBr, a bromide compound, or a combination thereof, to form the mercury-containing~~,~~ gas; and

adding a ~~particulate~~ sorbent material comprising activated carbon into the mercury-containing gas.

Accordingly, the explanation I provide above for Claim 1 applies equally to Claim 17.

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]

454. It is my opinion that Claims 1, 2, 5-8, 14-15, 17-20, and 22-29 would have been obvious over the combination of Downs-Boiler and Starns (Ground A4). Claims 1, 2, 5-9, 11-12, 14-15, 17-20, and 22-29 would also have been obvious over the combination of Downs-Boiler and Mass-EPA (Ground 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

455. 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.

456. 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)."[760] 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 furnace.[761] Downs-Boiler also discloses that the mercury-sorbent composition would be removed by an electrostatic precipitator (ESP) or fabric filter.[762]

457. 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,[763] 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).

[760] EX1006 (Downs-Boiler) ¶[0025].

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

[762] EX1006 (Downs-Boiler) Figure 6; see also EX1006 (Downs-Boiler) Figures 4-5; EX1007 (Downs-Boiler-Provisional) Figures 4-6.

[763] Technology Background and State of the Art ("Sorbents/Activated Carbon"), §IX.C.

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).

1. Ground A4 (Combination of Downs-Boiler with Starns)

458. 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."[764] 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.[765]

459. Starns provides details as to how to supply activated carbon to the system and processes of Downs-Boiler:

[764] EX1008 (Starns) at 1.

[765] EX1008 (Starns) at 2.

- **Injection of the activated carbon:** "injection equipment" that includes a "bulk-storage silo and twin blower/feeder trains ...."[766] 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."[767] One of the "[p]rimary variables" to control how much mercury is removed is "injection concentration" of the sorbent.[768]

[766] EX1008 (Starns) at 7; *see also* EX1008 (Starns) at Fig. 2.

[767] EX1008 (Starns) at 7; *see also* EX1008 (Starns) at Fig. 2.

[768] 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 …."[769]

460. Starns provides the details of ACI—what Starns describes as the "most mature retrofit technology available today"[770]—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.

461. 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."[771] Downs-Boiler also discloses that this injected sorbent is powdered activated carbon.[772] 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

[769] EX1008 (Starns) at 9.

[770] EX1008 (Starns) at 2.

[771] EX1006 (Downs-Boiler) ¶[0025]

[772] EX1006 (Downs-Boiler) ¶[0025]

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 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.

462. 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."[773] The particle control equipment in Starns is an electrostatic precipitator (ESP), and Starns recommends "using activated carbon injection upstream of an ESP."[774] 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.[775] The mercury-sorbent composition is

[773] EX1008 (Starns) at 2.

[774] EX1008 (Starns) at 20. Starns also discloses that a fabric filter can be used. EX1008 (Starns) at 19 (Fig. 8).

[775] EX1006 (Downs-Boiler) Figure 6 (annotated; see also EX1006 (Downs-Boiler) Figures 4-5; EX1007 (Downs-Boiler-Provisional) Figures 4-6.

eventually removed by standard and well-known particulate control devices, such as the electrostatic precipitators (ESPs) in Downs-Boiler and in Starns.

2. Ground A5 (Combination of Downs-Boiler with Mass-EPA)

463. 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."[776] 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).[777]
>
> 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.[778]

[776] EX1008 (Starns) at 1.

[777] EX1009 (Mass-EPA) at 31 (section entitled, "Mercury-Specific Control Technologies").

[778] EX1009 (Mass-EPA) at 32 (subsection entitled, "Sorbent Injection").

464. 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.[779]
>
> 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. [780]

Mass-EPA discloses "activated carbon injection" in numerous other places.[781]

465. Mass-EPA concludes that the "estimated costs for powdered activated carbon injection-based technology, which most likely will reach commercialization for mercury control before other technologies, is within the current control costs for NOx."[782] 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.

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

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

[781] EX1009 (Mass-EPA) at 31, 35, 36, 49, 52, 56.

[782] EX1009 (Mass-EPA) at 58.

466. 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"[783] 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.

467. 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

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

removal in the near future."[784] 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."[785] Mass-EPA concludes that the "estimated costs for powdered activated carbon injection-based technology, which most likely will reach commercialization for mercury control before other technologies, is within the current control costs for NOx."[786]

468. 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."[787] 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.

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

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

[786] EX1009 (Mass-EPA) at 56.

[787] EX1009 (Mass-EPA) at 39.

B. DISCLOSURE AND TEACHINGS OF THE COMBINATIONS

469. 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. Claims 1, 14, and 17 require the presence of "pyrolysis char" in the combustion chamber. To the extent the pyrolysis char is not inherent, it would have been obvious for the combustion chamber to contain pyrolysis char and for the pyrolysis char to be mixed with coal and bromine-containing ingredients. A POSITA would have known that inside the combustion chamber, pyrolysis char would be formed as part of the mixture of coal and bromine-containing ingredients, for the reasons described above for this claim in Ground 3.

1. Independent Claim 1

470. As I discuss above in Ground A3, Claim 1 is anticipated by Downs-Boiler. I understand that anticipation is the epitome of obviousness, and that therefore this claim would have also been obvious over Downs-Boiler.

a. Claim 1: Element 1(b)—"adding a particulate sorbent material comprising activated carbon into the mercury-containing gas."

471. In addition to the reasons stated in Ground A3, Claim Element 1(b) would have been obvious over Downs-Boiler. As described above for Ground A3, Downs-Boiler discloses that "PAC injection removes both oxidized and elemental

mercury species."[788] Downs-Boiler further discloses that the injected sorbent adsorbs vapor-phase mercury and that "the sorbent, and its burden of adsorbed mercury" are separated from the flue gas.[789] Downs-Boiler additionally provides for the formation of the mercury-laden sorbent, referring to "the higher reactivity of oxidized mercury with PAC."[790] 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-laden sorbent that also includes Br. As such, it would have been at least obvious to a POSITA that the particulate sorbent material would be added into the mercury-containing gas.

472. 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 contacts the sorbent and attaches to its surface."[791] A "powdered" sorbent is in particulate form.

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[788] EX1006 (Downs-Boiler) ¶[0004]; EX1007 (Downs-Boiler-Provisional) ¶[005].

[789] EX1006 (Downs-Boiler) ¶[0004]; EX1007 (Downs-Boiler-Provisional) ¶[005].

[790] EX1006 (Downs-Boiler) ¶[0016]; EX1007 (Downs-Boiler-Provisional) ¶[0019].

[791] EX1008 (Starns) at 2.

473. Regarding Ground A5, Mass-EPA further verifies that through activated-carbon injection, the "sorbent particles … contact the Hg in the flue gas."[792]

2. Claims Depending from Claim 1

a. Claim 2: "The method of claim 1, wherein the pyrolysis char is a promoted pyrolysis char."

474. This claim would have been obvious for the reasons described above in Ground A3.

b. Claim 5: "The method of claim 1, further comprising using a particle separation device to remove mercury from the flue gas and comprising collecting greater than 70 wt % of the mercury in the mercury-containing gas to produce a cleaned gas."

475. Claim 5 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).

476. 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 utilize at least an electrostatic precipitator as a particle separation device. As discussed for Ground A3, and as shown by representative Figure 6 reproduced below as annotated,

[792] EX1009 (Mass-EPA) at 21 n.25. Page 33 also refers to "time available for the mercury to contact the AC [activated carbon] particle."

Downs-Boiler describes a coal-combustion facility that can have a number of downstream pollution control devices including particle separation devices (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).[793]

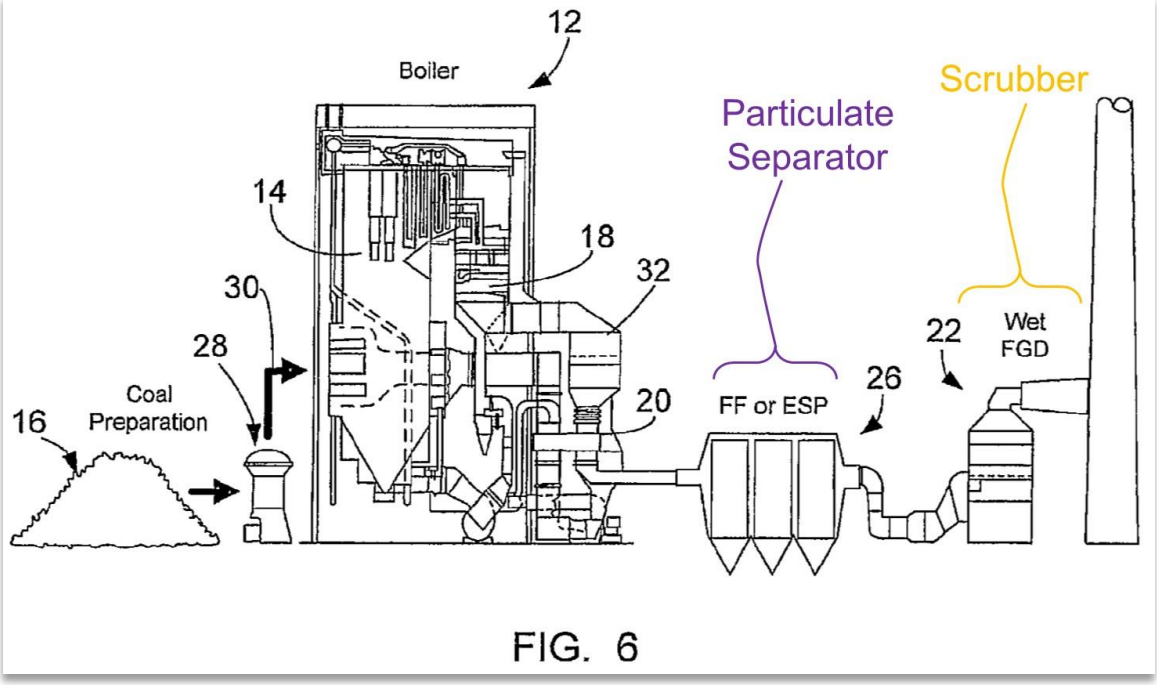


FIG. 6

477. The use of the bromine-containing reagent as disclosed by Downs-Boiler "thereby enhance[es] the overall removal of mercury in downstream pollution control devices."[794] Specifically, Downs-Boiler explains that a particular advantage

[793] EX1006 (Downs-Boiler) Figure 6 (annotated; see also EX1006 (Downs-Boiler) Figures 4-5; EX1007 (Downs-Boiler-Provisional) Figures 4-6.

[794] EX1006 (Downs-Boiler) ¶[0007]; see also EX1007 (Downs-Boiler-Provisional) ¶[009].

of the disclosed invention is that it "enhances removal of mercury across particulate collectors 26 such as fabric filters (FF) and electrostatic precipitators (ESP)."[795] 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 the flue gases in a downstream particulate collector."[796] The activated-carbon sorbent would be injected upstream of the ESP, so that it, and any adsorbed mercury, could be "subsequently removed" by that ESP. A particulate collector is a particle separation device.

478. 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 Grounds A1-A2, each of Starns and Mass-EPA also discloses an electrostatic precipitator (ESP). An ESP is an example of a particle separation device.

479. With respect to Ground A4, Starns states that the activated-carbon sorbent is carried "from the feeders to distribution manifolds located on the ESP inlet duct, feeding the injection probes"[797] further demonstrating that the injection of

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

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

[797] EX1008 (Starns) at 7.

sorbent into the mercury-containing gas occurs upstream of a particle separation device that removes mercury from flue gas.

480. With respect to Ground A5, Mass-EPA refers to the "injection of a sorbent into the exhaust system and subsequent collection of the particulates in a PM [particulate matter] control device."[798] This again demonstrates that the sorbent injection into the mercury-containing gas occurs upstream of a particle separation device that removes mercury from flue gas.

481. Additionally, each of the three references achieve greater than 70 wt% mercury collection, and the combinations would as well. According to Figure 3, reproduced below as annotated, Downs-Boiler indicates that the disclosed method for collecting 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).[799]

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

[799] EX1006 (Downs-Boiler) Figure 3 (annotated); see also EX1007 (Downs-Boiler-Provisional) Figure 3.

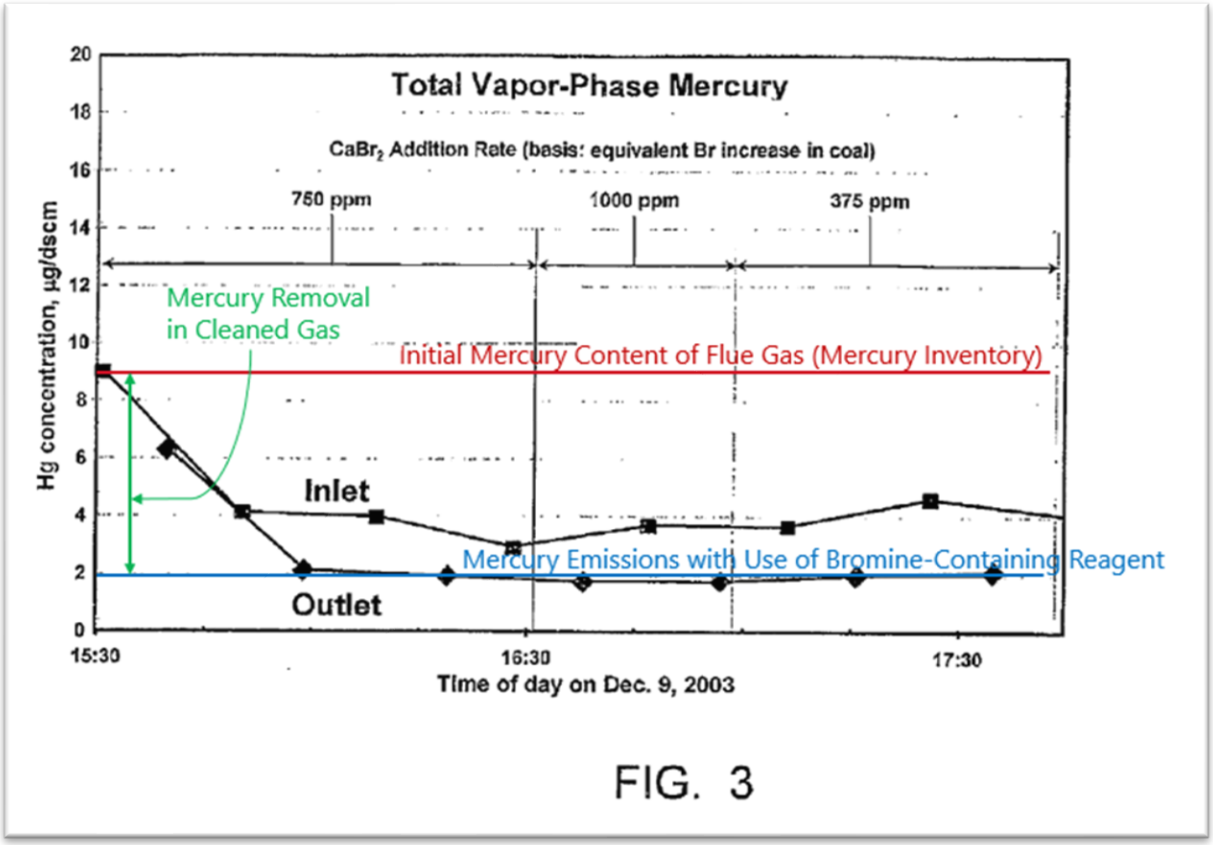


FIG. 3

Therefore, the use of the method disclosed by Downs-Boiler resulted in a system mercury collection of approximately 7 µg/dscm (green). This collection 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 removed by the particle separation device (e.g., ESP).

482. 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.[800] When combined with the improved oxidation through the halogenation of Downs-Boiler, the removal would be even greater than the 70%. In addition, the activated carbon injection in Starns takes place with solely a dry emissions system, and the activated carbon injection is particularly suited as "mercury control technology for coal-fired utility plants that do not have scrubbers for SO_2 control."[801]

483. 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.[802] When combined with the improved oxidation through the halogenation of Downs-Boiler, the removing would be even greater than the 70%. 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.[803] One of these plants, Brayton Point, was the site for field tests whose results, "indicate that the

[800] EX1008 (Starns) at 20.

[801] EX1008 (Starns) p. 2 (Abstract).

[802] EX1009 (Mass-EPA) at 11-12 (Chart 2 and accompanying discussion).

[803] EX1009 (Mass-EPA) at 70-71.

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."[804] The entire range of removals (i.e., collection) with the highest ACI concentration are greater than 70%.

484. Furthermore, a POSITA would understand that that the mercury collection on the sorbent (which is then removed by the particle separation device) 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" (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."[805] 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,[806] 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

[804] EX1009 (Mass-EPA) at 74.

[805] EX1006 (Downs-Boiler), ¶¶[0007], [0015]; EX1007 (Downs-Boiler-Provisional) ¶¶[009], [0018].

[806] *See* Technology Background and State of the Art, § IX.B.1.

content."[807] Such a plant would require the sorbent in a dry-emission system to remove the mercury.

485. 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.[808] Specifically, Downs-Boiler discloses that power stations burning western lignite coals, which produce a lower "percentage of oxidized mercury" and "have low chloride content" would benefit from the disclosed Hg control methods.[809] 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. Consequently, adding bromine-containing species to the furnace of coal-fired utility plants burning lignite and other low-rank

[807] EX1006 (Downs-Boiler) ¶¶[0005], [0020]; see also EX1007 (Downs-Boiler-Provisional) ¶¶[006], [0023].

[808] EX1006 (Downs-Boiler) ¶[0005]; EX1007 (Downs-Boiler-Provisional) ¶[006].

[809] EX1006 (Downs-Boiler) ¶[0005]; see also EX1007 (Downs-Boiler-Provisional) ¶[006].

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 modify the bromine addition level to achieve highly efficient Hg removal, including greater than 70% collection.

486. In addition to the mercury-removal percentages disclosed by Downs-Boiler, Starns, and Mass-EPA, Claim 5 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,[810] 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 (CAMR). Downs-Boiler further teaches compliance with EPA standards regulating mercury emissions from coal-fired plants.[811] 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

[810] *See* Technology Background and State of the Art, § IX.D – § IX.F.

[811] EX1006 (Downs-Boiler) ¶[0001]; see also EX1007 (Downs-Boiler-Provisional) ¶[002].

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.

c. Claim 6: "The method of claim 5, further comprising: measuring the mercury content of the mercury-containing gas; and modifying, in response to the measured mercury content: an injection rate of injecting the sorbent into the mercury-containing gas, an amount of the additive in the mixture, or a combination thereof."

487. This claim would have been obvious over Downs-Boiler. The mercury content is measured, as depicted by the Y-axis of Figure 3 (i.e., the "Hg concentration" in μg/dscm).[812] 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 mercury-containing gas (Y-Axis) and modifying the injection rate of the bromide compound ($CaBr_2$) of up to 1000 ppm:[813]

[812] EX1006 (Downs-Boiler) Figure 3 (annotated); see also EX1007 (Downs-Boiler-Provisional) Figure 3.

[813] EX1006 (Downs-Boiler) Figure 3 (annotated); see also EX1007 (Downs-Boiler-Provisional) Figure 3.

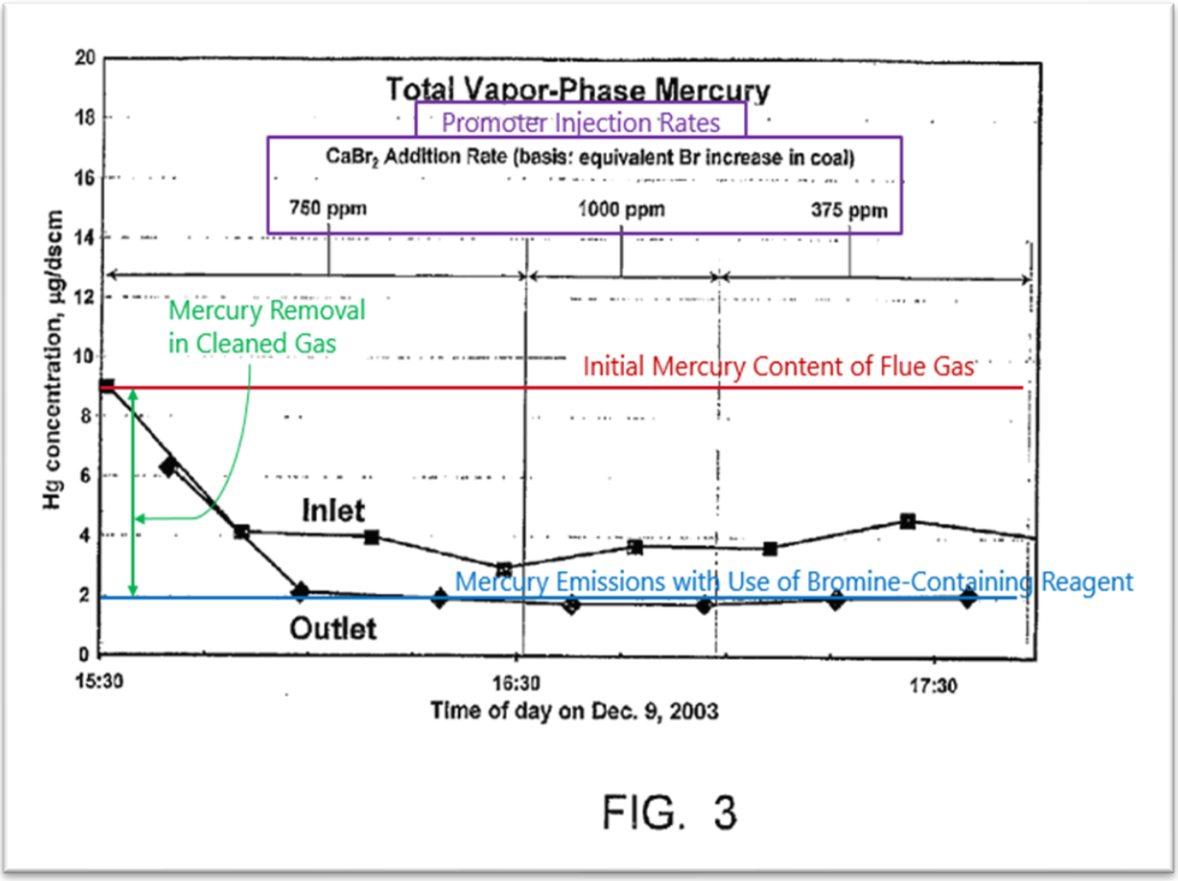


FIG. 3

In particular, Figure 3 shows that the mercury content of the mercury-containing gas (the data set provided by diamond symbols for the outlet of the particulate collector) is measured for a period of over two hours.[814] The associated description of Figure 3 of Downs-Boiler discloses modifying the amount of the additive in the mixture (e.g., "aqueous solution of calcium bromide ($CaBr_2$) [] injected into the combustion

[814] EX1006 (Downs-Boiler) Figure 3; see also EX1007 (Downs-Boiler-Provisional) Figure 3.

chamber") (purple) to between 375 to 1000 parts per million of a bromine-containing reagent ($CaBr_2$).[815]

488. Downs-Boiler draws a direct correlation between the injection rate of the bromide compound and the measured mercury content of the mercury-containing gas:

> 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.[816]

A POSITA reviewing the data as presented by Figure 3 of Downs-Boiler would have understood that the measured mercury content at the outlet of the particulate collector could be used to modify the amount of the bromine-containing reagent. It is further obvious over Downs-Boiler that the bromide addition rate is in response to the mercury content of the mercury-containing gas. A POSITA reviewing the data of the tests, as presented by Figure 3 of Downs-Boiler, would have understood that the measured mercury content is the information that would be used to modify

[815] EX1006 (Downs-Boiler) ¶[0018], Figure 3 (annotated); see also EX1007 (Downs-Boiler-Provisional) ¶[0021], Figure 3.

[816] EX1006 (Downs-Boiler) ¶¶[0011], [0018]; see also EX1007 (Downs-Boiler-Provisional) ¶¶[0013], [0021].

a rate amount of the bromine-containing reagent (e.g., one of the four levels provided: 0, 375, 750, and 1000 ppm) by selecting a given level or by interpolating an intermediate value in response to the measured mercury content of the mercury-containing gas. Downs-Boiler further teaches compliance with EPA standards regulating mercury emissions from coal-fired plants.[817] 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 amount of bromine-containing species (the additive) and/or activated carbon (sorbent) injection rate to meet and exceed (for purposes of safety margin) the EPA's proposed rules requiring a 70% removal of mercury. 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)

489. 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.,

[817] EX1006 (Downs-Boiler) ¶[0001]; see also EX1007 (Downs-Boiler-Provisional) ¶[002].

sorbent injection rate) based on the measured output (mercury content of the mercury-containing gas). Starns discloses a control scheme interoperable with that of Downs-Boiler, which is modifying the sorbent concentration in the flue gas based on continuous mercury-content 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., modify both sorbent injection rate and halogen amount in response to mercury-content measurements).

490. Starns discloses measuring "vapor phase mercury concentrations" in the flue gas using a "Semi-Continuous Emissions Monitor (S-CEM)," which was "operate[d] continuously."[818] The S-CEM was used to adjust sorbent concentration (activated carbon injection) and determine its effects on mercury removal:

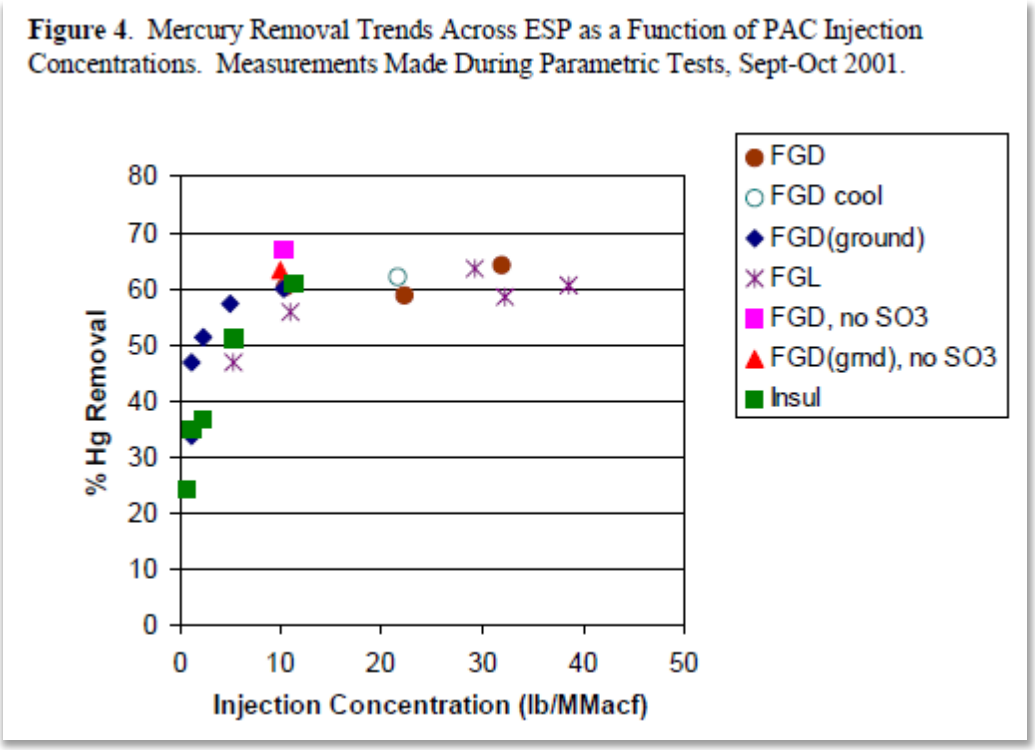
> Mercury removal was monitored as a function of the sorbent injection concentration. In addition, the impact of sorbent injection on the performance of the ESP was monitored. An example of the data from the S-CEMs during the first week of parametric testing is presented in Figure 3…. Reduction and recovery of outlet mercury concentration can be seen to correlate with periods of sorbent injection.[819]

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

[818] EX1008 (Starns) at 8.

[819] EX1008 (Starns) at 11.

million actual cubic feet of flue gas), both for the parametric testing and the long-term testing in Figures 3-6.[820] Exemplary Figure 4 is shown below, which shows the direct connection between mercury emissions and sorbent concentration:[821]



Thus, Starns discloses continuously measuring the mercury content of the gas in response to the measured sorbent concentration. Modifying of the rate of addition of the sorbent in response to the mercury content of the mercury-containing gas is also obvious over Starns. A POSITA reviewing the data of the tests, as presented by Figures 3-6 of Starns, would have understood that the continuously measured

[820] EX1008 (Starns) at Figs. 3-6.

[821] EX1008 (Starns) at 13.

mercury content (dependent variable in the graphs) is the information that would be used to modify a rate of 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 measured mercury content of the mercury-containing 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 modify an injection concentration of the sorbent into the mercury-containing gas, in response to the measured 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."[822]

491. 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.[823] The

[822] EX1008 (Starns) at 7.

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

normal desire of a POSITA to improve on a given process would have been to modify 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,[824] it would have been obvious that some amount of modification 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)

492. 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 modifying the input (e.g., sorbent injection rate) based on the continuously measured output (mercury content of the mercury-containing gas). Mass-EPA discloses a control scheme interoperable to that of Downs-Boiler, modifying the sorbent concentration in the

[824] See Technology Background and State of the Art, IX.B.1.

flue gas based on mercury-content 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., modify both sorbent injection rate and halogen addition rate in response to mercury-content measurements).

493. 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."[825] Mass-EPA recognized that a reason to continuously measure mercury was to understand the sorbent injection rate to use:

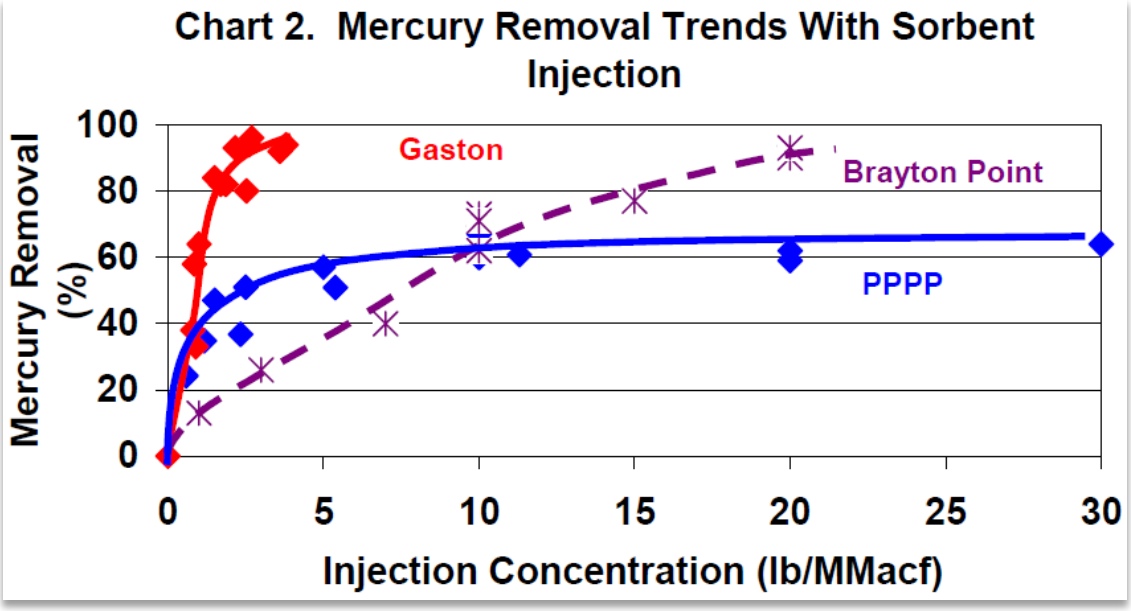
> [A] fraction of a pound increase in carbon injection rate increase[es] mercury removal from the gas by [as] much as 30%.[826]
>
> With respect to both the removal trend and the sorbent costs, preliminary results for Brayton Point indicate that the higher the amount of sorbent injected, the more mercury 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

[825] EX1009 (Mass-EPA) at 60.

[826] 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").

> reductions over the range of sorbent injection levels tested, with an approximately linear trend. [827]

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:[828]



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."[829]

[827] EX1009 (Mass-EPA) at 11.

[828] EX1009 (Mass-EPA) at 12

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

494. 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 injection by selecting a carbon injection rate above which additional amounts of carbon injection would achieve limited additional mercury control."[830] In other words, measure mercury content and, based on that measurement, modify the rate of injecting the sorbent into the mercury-containing gas.

495. Accordingly, a person of skill in the art would have been motivated to continuously modify an injection rate of the sorbent into the mercury-containing gas, in response to the measured mercury content of that gas, to provide the desired amount of sorbent needed to remove a targeted amount of mercury. A POSITA reviewing the data of the tests, as presented by Chart 2 of Mass-EPA, would have understood that the measured mercury content is the information that would be used to modify a rate of addition of the sorbent by either selecting a given rate or by

[830] EX1009 (Mass-EPA) at 13.

interpolating an intermediate value in response to the measured mercury content of the mercury-containing 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.

496. 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.[831] The normal desire of a POSITA to improve on a given process would have been to modify 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,[832] it would have been obvious that some amount of modification to

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

[832] See Technology Background and State of the Art, §IX.B.1, §IX.C.5.

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.

d. Claim 7: "The method of claim 1, wherein the additive further comprises Br_2."

497. This claim would have been obvious for the reasons described above in Ground A3.

e. Claim 8: "The method of claim 1, wherein the sorbent material is chosen from powdered activated carbon, granular activated carbon, carbon black, carbon fiber, aerogel carbon, pyrolysis char, and combinations thereof."

498. This limitation is disclosed by Downs-Boiler (Ground A4 and Ground A5). 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."[833]

499. For Ground A4, the activated carbon injected by Starns is "powdered activated carbon," which is also abbreviated as "PAC": "The most mature, retrofit

[833] EX1006 (Downs-Boiler) ¶[0025]; see also EX1007 (Downs-Boiler-Provisional) ¶[0028].

technology available today is the injection of sorbents such as powdered activated carbon (PAC) into the flue gas upstream of the particle control equipment."[834]

500. 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."[835]

f. Claim 9: "The method of claim 1, further comprising adding an alkaline component to the mercury-containing gas, the alkaline component chosen from alkali elements, alkaline earth elements, alkali salts, alkaline earth salts, and combinations thereof."

501. Claim 9 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-addition of not only activated carbon sorbents, but also alkaline components:

> 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.[836]

[834] EX1008 (Starns) at 2.

[835] EX1009 (Mass-EPA) at 22; *see also* p. 32 ("Powdered Activated Carbon … has been the most extensively studied sorbent for mercury adsorption.").

[836] EX1009 (Mass-EPA) at 37.

> 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. [837]
>
> 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.[838]

The "sodium carbonate" and "lime" are examples of an alkali salt and an alkaline earth salt, respectively. Such sorbents 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.

g. Claim 11: "The method of claim 1, further comprising contacting the sorbent material with a secondary component chosen from halogens, hydrogen halides, Group V halides, Group VI halides, and combinations thereof."

502. Claim 11 would have been obvious over the combination of Downs-Boiler in view of Mass-EPA (Ground A5). Mass-EPA discloses injecting "[m]odified activated carbons (i.e., doped with sulfur, iron, chlorine, and iodine)."[839]

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

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

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

The modified activated carbons "doped with" chlorine and iodine describes a sorbent material that has been contacted with chlorine and iodine (i.e., halogens).

a. Claim 12: "The method of claim 11, wherein the secondary component is chosen from halogens, halide salts, HI, HBr, HCl, and combinations thereof."

503. Claim 12 is obvious for the same reasons discussed above for Claim 11. The secondary components of chlorine and iodine (halogens, disclosed by Mass-EPA) each satisfy this claim.

b. Claim 18: "The method of claim 1, further comprising modifying, in response to a measured mercury content, an injection rate of injecting the sorbent into the mercury-containing gas, an amount of the additive in the mixture, or a combination thereof."

504. Claim 18 is obvious for the reasons discussed for Claim 6.

c. Claim 19: "The method of claim 1, wherein the coal comprises added sorbent enhancement additive that comprises the bromide compound."

505. This claim would have been obvious for the reasons described above in Ground A3.

d. Claim 20: "The method of claim 1, wherein the coal is combusted in a combustion chamber at a coal-combustion facility, wherein the HBr, bromide compound, or combination thereof, is added to the coal before the coal enters the combustion chamber, wherein the addition of the HBr, bromide compound, or combination thereof, to the coal is performed at the coal-combustion facility."

506. This claim would have been obvious for the reasons described above in Ground A3.

e. Claim 22: "The method of claim 1, wherein the sorbent is contacted with a halogen or halide promoter prior to the addition of the sorbent to the mercury-containing gas."

507. Claim 22 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 by contacting the base sorbent with the promoter prior to adding it into the mercury-containing flue gas. For example, it was well-known in the art since the 1930s to remove mercury vapors by adding pre-halogenated sorbents into a mercury-containing flue gas.[840]

[840] Technology Background and State of the Art, §§IX.C, IX.G (including EX1029 (Stock)).

508. Claim 22 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)."[841] Mass-EPA explains that exemplary forms of the impregnated activated carbon are "chlorine-impregnated activated carbon."[842] 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."[843] Chlorine and iodine are each types of halogens, and the activated carbons with these halogens are promoted[844]

509. 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

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

[842] EX1009 (Mass-EPA) at 34 & n.44.

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

[844] Technology Background and State of the Art, §IX.C.3.

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."[845] 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.

f. Claim 23: "The method of claim 1, wherein the sorbent is free of contact with a halogen or halide promoter prior to the addition of the sorbent to the mercury-containing gas."

510. Claim 23 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 conventional PAC injection process" is well known and understood in the industry but concedes that that use of these systems is "very expensive" when

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

not used in combination with the disclosed invention.[846] These "conventional" PAC injection processes referred to by Downs-Boiler are the addition of a powdered activated carbon (PAC) sorbent that is untreated (i.e., substantially free of halogen or halide promotion) prior to addition of the sorbent to the mercury-containing gas. 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)."[847] Further, because Downs-Boiler does not characterize the sorbent as having been pre-brominated or otherwise impregnated with a halogen promoter prior to addition of the sorbent to the mercury-containing gas, 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.

511. 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),

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

[847] 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.[848]

512. For Ground A5, the same activated carbon was used: "Norit FGD," specifically "Norit America's 'Darco FGD.'"[849] A POSITA would have recognized that the Norit Darco FGD is substantially free of halogen and halide promotion prior to addition of the sorbent to the mercury-containing gas. Articles dating back to at least 1998 confirm that the chemical composition of "Norit Darco FGD" does not have halogens.[850]

g. Claim 24: "The method of claim 6, wherein the measurement of the mercury content of the mercury-containing gas comprises continuous measurement."

513. Claim 24 would have been obvious for the reasons discussed above in Claim 6. The measuring of the mercury content of the mercury-containing gas is performed substantially "continuously."

h. Claim 25: "The method of claim 1, wherein the coal comprises subbituminous coal."

514. This claim would have been obvious over Downs-Boiler (Ground A4 and Ground A5), for the reasons described above in Ground A3.

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[848] EX1008 (Starns) at 3.

[849] EX1009 (Mass-EPA) at 73, 74.

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

515. With respect to Ground A4, this claim would have been further obvious over Downs-Boiler in view of Starns. Starns discloses that the mercury removal occurred for units that "fire a variety of Powder River Basin (PRB) low sulfur, sub-bituminous coals."[851]

516. With respect to Ground A5, this claim would have been further obvious over Downs-Boiler in view of Mass-EPA. Mass-EPA discusses throughout the document about the need to remove mercury from "subbituminous" coal (also referred to as "powder river basin" coal).[852]

i. Claim 26: "The method of claim 1, wherein the coal comprises lignite coal."

517. This claim would have been obvious over Downs-Boiler (Ground A4 and Ground A5), for the reasons described above in Ground A3.

518. With respect to Ground A5, this claim would have been further obvious over Downs-Boiler in view of Mass-EPA. Mass-EPA discusses that the need for mercury remediation is particularly acute with lignite coal, in view of its relatively low native halogen concentration.[853]

[851] EX1008 (Starns) at 4.

[852] EX1009 (Mass-EPA) at 77; see also pages 24, 29 (similar discussion).

[853] EX1009 (Mass-EPA) at 24.

j. Claim 27: "The method of claim 1, wherein the mixture is combusted in a combustion chamber of a coal-combustion facility upstream of a scrubber, a particulate control system, or a combination thereof, wherein the particulate sorbent is added to the mercury-containing gas before the mercury-containing gas encounters the scrubber, the particulate control system, or the combination thereof."

519. Downs-Boiler discloses this limitation. As discussed for Ground A3, the mixture is combusted in a combustion chamber of a coal-combustion facility. As also discussed for Ground A3, and as shown by representative Figure 6 reproduced below as annotated, Downs-Boiler describes a coal-combustion facility that can have a number of downstream pollution control devices including particulate control 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).[854]

[854] EX1006 (Downs-Boiler) Figure 6 (annotated; see also EX1006 (Downs-Boiler) Figures 4-5; EX1007 (Downs-Boiler-Provisional) Figures 4-6.

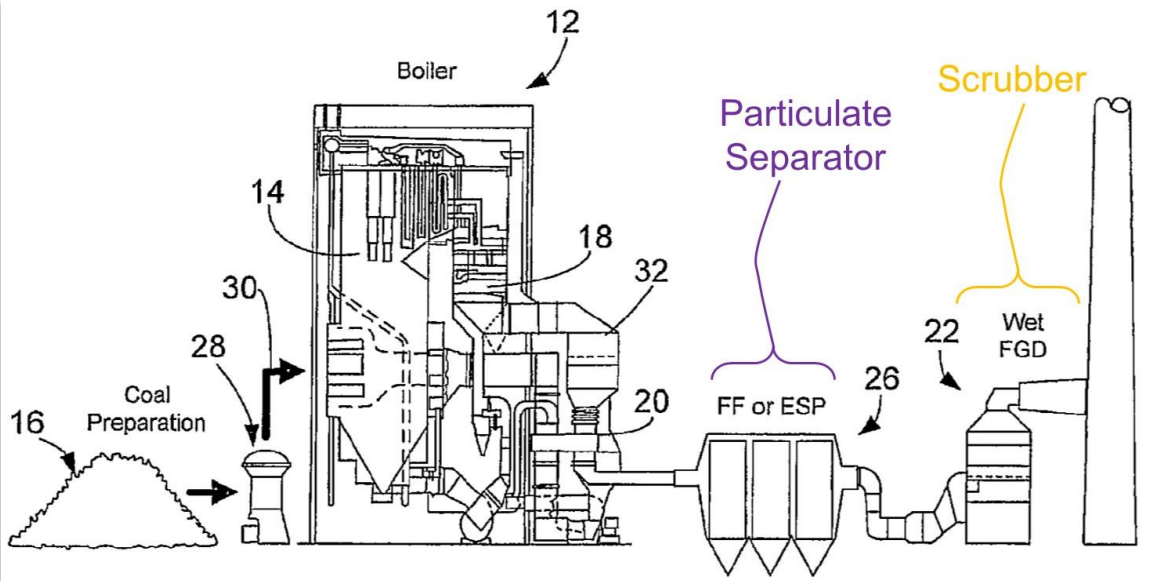


FIG. 6

520. The use of the bromine-containing reagent as disclosed by Downs-Boiler "thereby enhance[es] the overall removal of mercury in downstream pollution control devices."[855] Specifically, Downs-Boiler explains that a particular advantage of the disclosed invention is that it "enhances removal of mercury across particulate collectors 26 such as fabric filters (FF) and electrostatic precipitators (ESP)."[856] 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

[855] EX1006 (Downs-Boiler) ¶[0007]; see also EX1007 (Downs-Boiler-Provisional) ¶[009].

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

the flue gases in a downstream particulate collector."[857] The activated-carbon sorbent would be injected upstream of the ESP, so that it could be "subsequently removed" by that ESP.

521. 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 Grounds A1-A2, each of Starns and Mass-EPA also discloses an electrostatic precipitator (ESP), and they specify that the activated carbon sorbent is injected upstream of the ESP. An ESP is an example of a particulate control system.

522. With respect to Ground A4, Starns states that the activated-carbon sorbent is carried "from the feeders to distribution manifolds located on the ESP inlet duct, feeding the injection probes"[858] further demonstrating that the injection of sorbent into the mercury-containing gas occurs upstream of a particulate control system.

523. With respect to Ground A5, Mass-EPA refers to the "injection of a sorbent into the exhaust system and subsequent collection of the particulates in a PM [particulate matter] control device."[859] This again demonstrates that the sorbent

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

[858] EX1008 (Starns) at 7.

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

injection into the mercury-containing gas occurs upstream of a particulate control system.

k. Claim 28: "The method of claim 26, wherein the particulate control system comprises an electrostatic precipitator, a baghouse, a fabric filter, or a combination thereof."

524. This claim is disclosed by the combinations of Downs-Boiler with Starns (Ground A4) and Downs-Boiler with Mass-EPA (Ground A5). As described for Claim 27, 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 utilizes at least an electrostatic precipitator as a particulate control system.

l. Claim 29: "The method of claim 19, wherein the combustion chamber is a coal combustion furnace."

525. This claim would have been obvious for the reasons described above in Ground A3.

3. Independent Claim 14

526. Claim 14 copies Claim 1, but modifies Element 1(a) slightly as shown in the redline below:

~~1~~14. A method for treating a mercury-containing gas, the method comprising:

combusting coal in a ~~mixture~~combustor comprising ~~coal,~~ pyrolysis char~~,~~ and an additive comprising HBr, a bromide compound, or a combination thereof, to form the mercury-containing~~,~~ gas; and

adding a particulate sorbent material comprising activated carbon into the mercury-containing gas.

I discuss these differences below.

a. Claim 14: Preamble—"A method for treating a mercury-containing gas, the method comprising:"

527. The language of the preamble of Claim 14 is identical to the preamble of Claim 1. This limitation is disclosed for the same reasons as stated above for Claim 1.

b. Claim 14: Element 14(a)—"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; and"

528. The language of Claim Element 14(a) is nearly 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 14(a). As discussed above for Ground A3, Downs-Boiler discloses that the mixture is combusted in a boiler/furnace (i.e., "a combustor").

c. Claim 14: Element 14(b)—"adding a particulate sorbent material comprising activated carbon into the mercury-containing gas"

529. The language of Claim Element 14(b) 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 14(a).

4. Claims Depending from Claim 14

a. Claim 15: "The method of claim 14, wherein the pyrolysis char is a promoted pyrolysis char."

530. Claim 15 is obvious for the same reasons discussed above for Claim 2.

5. Independent Claim 17

531. Claim 17 copies Claim 1, but modifies Element 1(b) to remove "particulate" as shown in the redline below:

~~1~~17. A method for treating a mercury-containing gas, the method comprising:

combusting a mixture comprising coal, pyrolysis char, and an additive comprising HBr, a bromide compound, or a combination thereof, to form the mercury-containing~~,~~ gas; and

adding a ~~particulate~~ sorbent material comprising activated carbon into the mercury-containing gas.

Accordingly, the explanation I provide above for Claim 1 applies equally to Claim 17.

XVI. GROUND B1: OBVIOUSNESS OVER SJOSTROM IN VIEW OF ECKBERG

532. It is my opinion that Claims 1-2, 5-8, 10-12, 14-15, 17-20, and 22-29 would have been obvious over the combination of Sjostrom and Eckberg (Ground B1). In the subsections below, I discuss the reasons to combine Sjostrom with Eckberg, followed by the disclosure of Sjostrom and Eckberg.

A. REASONS TO COMBINE

533. 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."[860] Sjostrom provides an overall process schematic showing activated-carbon sorbents for mercury removal in coal-fired flue gas.[861] Sjostrom discusses that activated carbon was a well-known sorbent for mercury control and discloses suitable ranges for

[860] EX1010 (Sjostrom) at 1.

[861] EX1010 (Sjostrom) at 4.

sorbent injection rate.[862] Sjostrom teaches adding halogen-containing reagents (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.[863]

534. 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."[864] Eckberg includes a similar process schematic as Sjostrom that shows injection of halogens into a coal-fired boiler for mercury removal.[865] 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).[866]

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[862] EX1010 (Sjostrom) at 10, 11, 16.

[863] EX1010 (Sjostrom) at 4.

[864] EX1011 (Eckberg) at 1.

[865] EX1011 (Eckberg) at 5.

[866] EX1011 (Eckberg) at 3, 9, 14, 15.

535. A POSITA would be further motivated to combine the references, and have a reasonable expectation of success, because both references were presented at the 2005 EUEC.[867] 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.[868] Namely, Sjostrom was presented in the A3b slot and Eckberg was presented in the A3c slot.[869] Further, both presentations included a common author—Dr. Ramsay Chang, Ph.D.—and shared a common partner, namely EPRI.[870] 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.

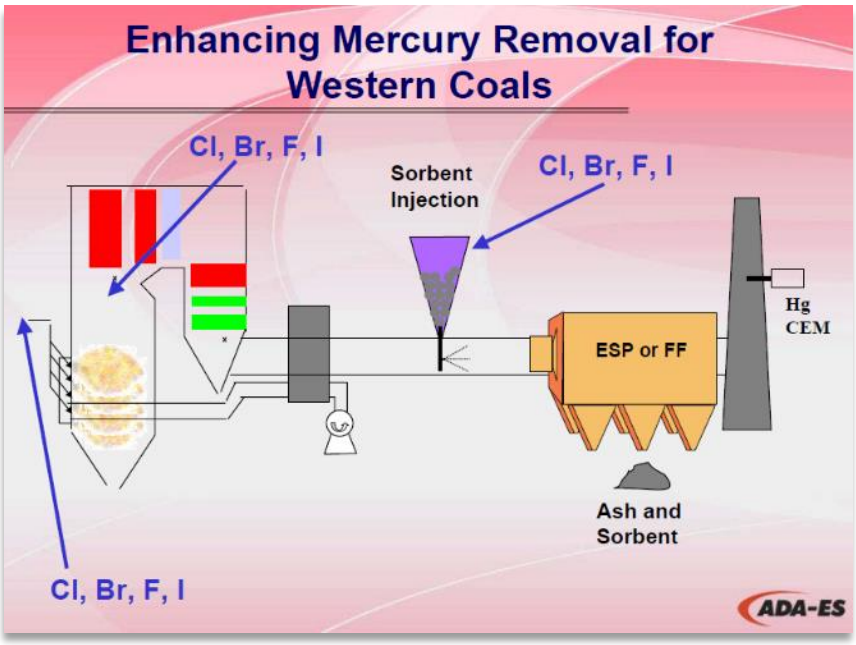
[867] EX1030 (EUEC Handout) at 23.

[868] EX1030 (EUEC Handout) at 23.

[869] EX1030 (EUEC Handout) at 23.

[870] EX1030 (EUEC Handout) at 23.

536. 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.[871]



Sjostrom demonstrates that activated-carbon sorbent injection was a well-known way of treating mercury emissions in flue gas.[872] Sjostrom also teaches that halogens (e.g., "Cl, Br, F, I") may be injected within the process in multiple locations.[873] 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

[871] EX1010 (Sjostrom) at 4.

[872] EX1010 (Sjostrom) at 10-11.

[873] EX1010 (Sjostrom) at 4.

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 (%)" achieved throughout the testing performed on coal flue gas.[874] 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.[875]

537. 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

[874] EX1010 (Sjostrom) at 8, 15-17, 20, and 21.

[875] EX1010 (Sjostrom) at 16.

system. Specifically, Eckberg teaches injection of "$CaCl_2$ (25 wt%)" or "$CaBr_2$ (52 wt%)" into the combustion chamber.[876] As a result of this injection, the bromine is 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.[877]

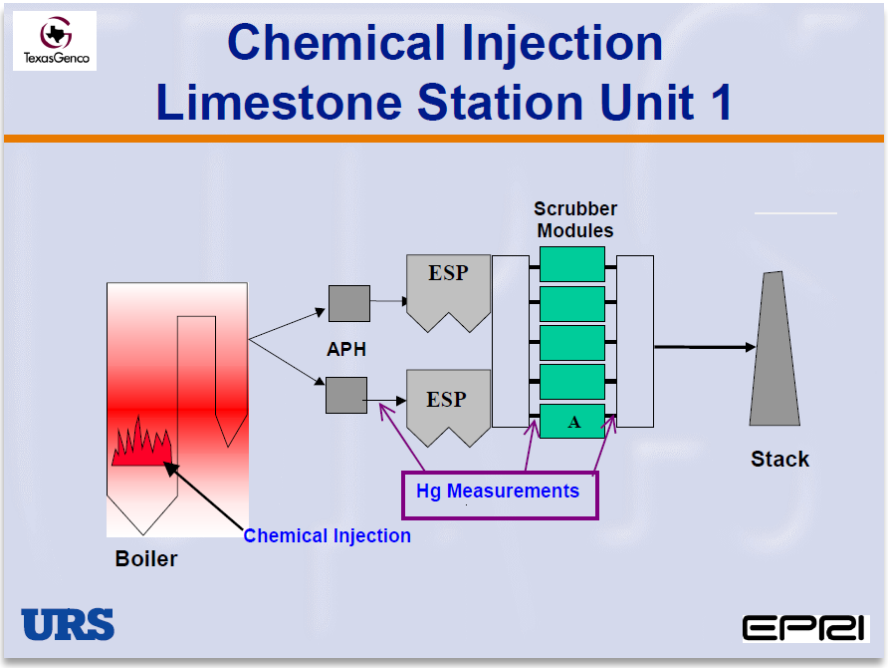
538. Like Sjostrom, Eckberg also teaches enhancing mercury removal through halogen injection into a boiler. Eckberg describes several testing objectives including "[i]ncreas[ing] mercury oxidation in flue gas derived from Texas lignite" and "[e]nhanc[ing] mercury removal across wet scrubbers."[878] As 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.[879]

[876] EX1011 (Eckberg) at 9.

[877] EX1011 (Eckberg) at 9.

[878] EX1011 (Eckberg) at 3.

[879] EX1011 (Eckberg) at 5.

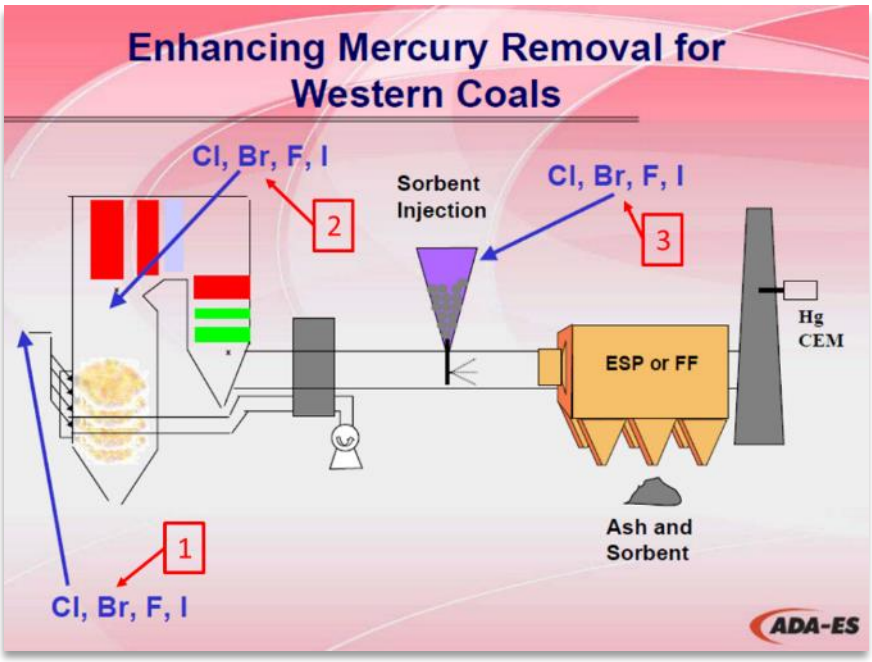


As discussed below, a POSITA would have been motivated to apply the teachings of Eckberg to Sjostrom because it would have provided well-known chemical substances that could be used as the "Br" identified in the figures of Sjostrom.

539. 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.[880] Specifically, the annotated figure below shows that Sjostrom teaches adding halogens in at least three locations.[881]

[880] EX1010 (Sjostrom) at 4.

[881] EX1010 (Sjostrom) at 4 (annotations in red).



Location 2 of Sjostrom teaches Br into the boiler,[882] the same location as in Eckberg.

540. 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

[882] EX1010 (Sjostrom) at 4 (annotations in red).

referred to as western subbituminous) and Texas Lignite.[883] Thus, a POSITA would have had a reasonable expectation of success in using the salt solutions of Eckberg in the system of Sjostrom.

541. 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 addition to coal-plants to remove mercury from flue gas.[884] Both references include similar surrounding equipment, such as boilers, air pre-heaters, and an ESP or other particulate matter control devices.[885]

542. 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

[883] EX1010 (Sjostrom) at 3-8; EX1011 (Eckberg) at 2, 6.

[884] EX1010 (Sjostrom) at 4; EX1011 (Eckberg) at 2, 9.

[885] EX1010 (Sjostrom) at 4; EX1011 (Eckberg) at 5.

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. DISCLOSURE AND TEACHINGS OF THE COMBINATIONS

543. It is my opinion that the combination of Sjostrom in view of Eckberg (Ground B1) renders obvious the claims below of the Challenged Patent.

1. Independent Claim 1

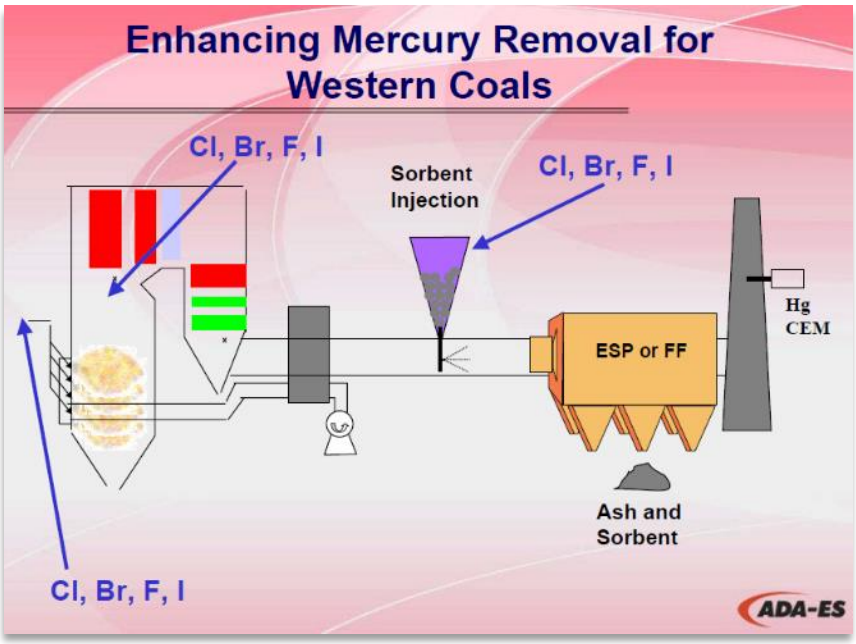
a. Claim 1: Preamble—"A method for treating a mercury-containing gas, the method comprising:"

544. The preamble is disclosed by Sjostrom. Sjostrom teaches treating a mercury-containing gas by separating mercury from the mercury-containing gas. The title of Sjostrom is "Full Scale Evaluations of Mercury Control Technologies with PRB Coals."[886] Specifically, Sjostrom described various mercury control tests conducted at several coal-fired power plants.[887] Sjostrom described testing mercury removal from flue gas of coal-fired power plants involving sorbent injection and halogen addition, as detailed below.[888]

[886] EX1010 (Sjostrom) at 1.

[887] EX1010 (Sjostrom) at 12, 18.

[888] EX1010 (Sjostrom) at 4.



Sjostrom includes numerous charts detailing the "Hg Removal (%)" and "Hg Removal Efficiency (%)" achieved throughout the testing performed on coal flue gas in order to reduce mercury emissions.[889] 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.[890] The pile removed from the ESP or FF is labeled "Ash and Sorbent," which also contains mercury that was removed from the flue gas.

[889] EX1010 (Sjostrom) at 8, 15-17, 20, and 21.

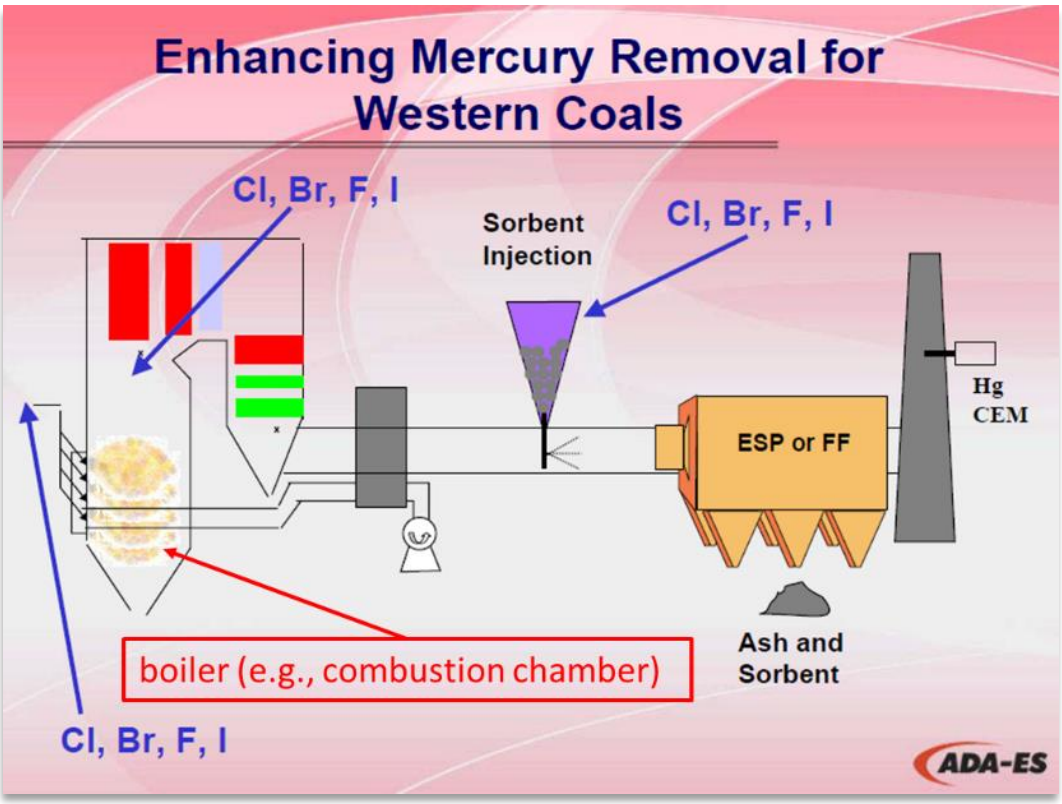
[890] *See* Technology Background and State of the Art, § IX.B.5.a.

b. Claim 1: Element 1(a)—"combusting a mixture comprising coal, pyrolysis char, and an additive comprising HBr, a bromide compound, or a combination thereof, to form the mercury-containing, gas; and"

545. 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.[891] These plants combust coal in a coal-fired boiler, also referred to as a coal-fired furnace (e.g., combustion chamber) as shown in the annotated figure below.[892]

[891] EX1010 (Sjostrom) at 12, 18.

[892] EX1010 (Sjostrom) at 4 (annotations in red).



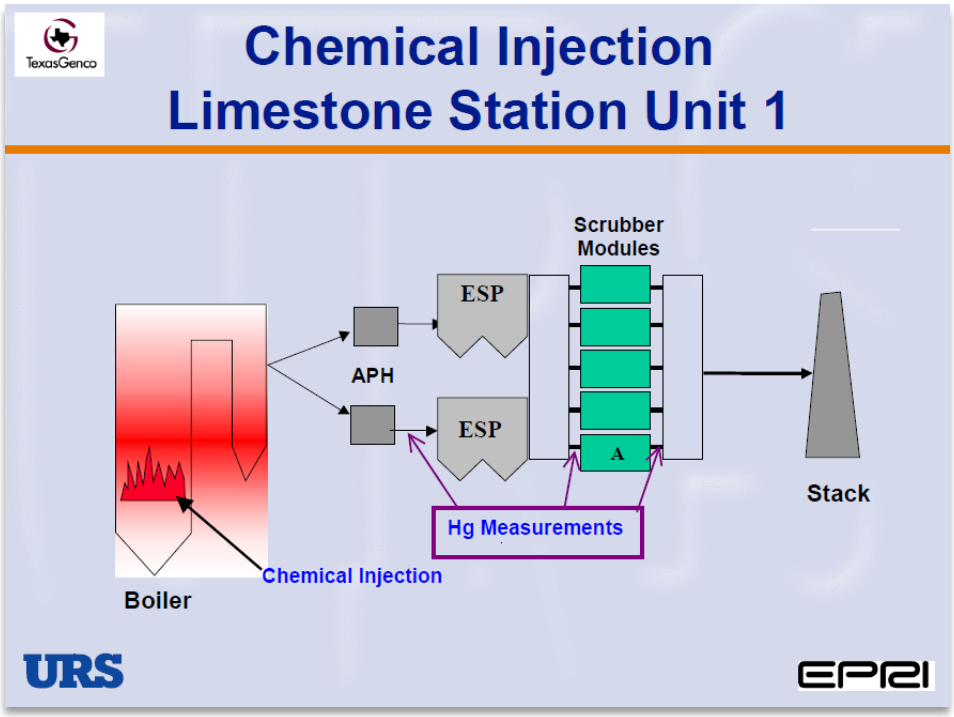
A POSITA would have understood that this unit was a boiler/furnace based on the image used to represent the unit in the drawing, which was a common and routine way to represent a coal-combustion chamber (boiler/furnace). Sjostrom explains that at the time of testing, two of the coal-fired power plants combusted PRB (Powder River Basin) coal having a mercury content of "0.04 – 0.1 ppm-dry."[893] Relying only on existing equipment at these plants, Sjostrom shows that the outlet mercury content of the flue gas was 11.2 µg/dncm.[894] Thus, Sjostrom discloses

[893] EX1010 (Sjostrom) at 12, 18.

[894] EX1010 (Sjostrom) at 3.

combusting coal in a combustion chamber (e.g., boiler/furnace) to form a mercury containing flue gas stream.

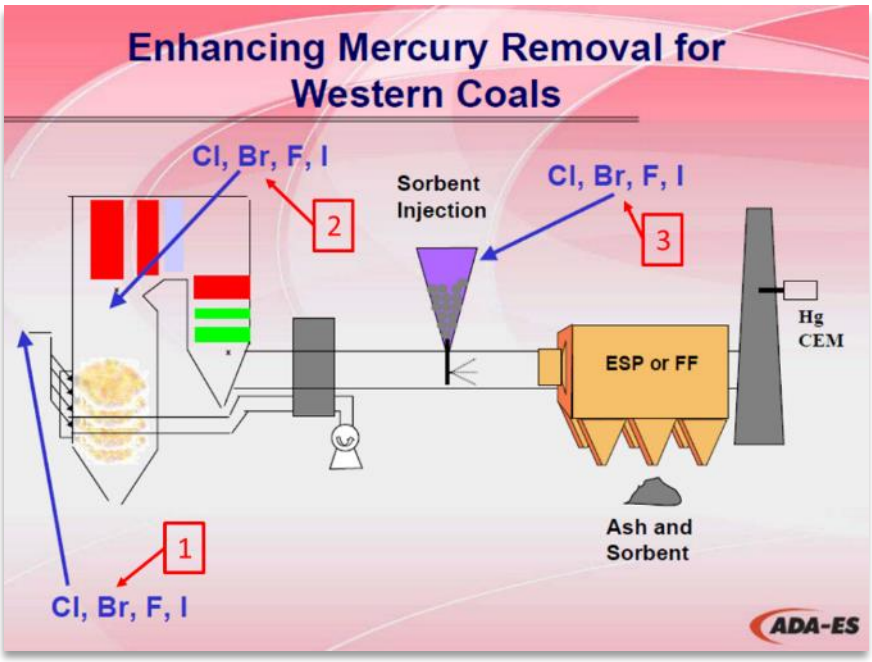
546. Combusting coal in a combustion chamber to produce a mercury-containing gas is further obvious over Eckberg. As shown in the figure below, Eckberg explicitly describes combusting coal in a boiler.[895]



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/furnace) to form a mercury containing flue gas stream.

[895] EX1011 (Eckberg) at 5.

547. Sjostrom, as the annotated figure below shows, teaches injection of bromine-containing ingredients in at least three locations throughout the coal-combustion process.[896]



Location 1 of Sjostrom renders obvious injecting bromine-containing ingredients upstream of the combustion chamber, such as by adding it to the coal before the coal enters the combustion chamber.[897] Though there are multiple places upstream of a combustion chamber, 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

[896] EX1010 (Sjostrom) at 4 (annotations in red).

[897] EX1010 (Sjostrom) at 4 (annotations in red).

additives."[898] Location 2 of Sjostrom discloses injecting bromine-containing ingredients directly into the combustion chamber.[899] With injection of bromine-containing ingredients at either Location 1 or 2, a mixture of coal and "Br" additive is combusted in the combustion chamber to form a mercury-containing gas. Location 3 of Sjostrom discloses adding halogens ("Cl, Br, F, I") to the activated-carbon sorbent that is injected into the flue gas.[900] At least Location 1 and Location 2 satisfy the claim limitation.

548. A POSITA would have found it obvious that the "Br" of Sjostrom would be a widely available bromine-containing material such as aqueous solutions of widely-available bromide compounds, such as $CaBr_2$. Further, Sjostrom teaches the addition of "KNX (Alstom Power)."[901] KNX was a known aqueous solution of a bromide salt additive developed for enhanced mercury control. As discussed above, Locations 1 and 2 of Sjostrom render obvious adding bromine-containing species upstream of the combustion chamber, such as by adding it to the coal

[898] EX1010 (Sjostrom) at 23, 25; see also EX1094 (O'Keefe) at 246:21-247:6, 249:6-252:9 (describing Locations 1-3 of Sjostrom).

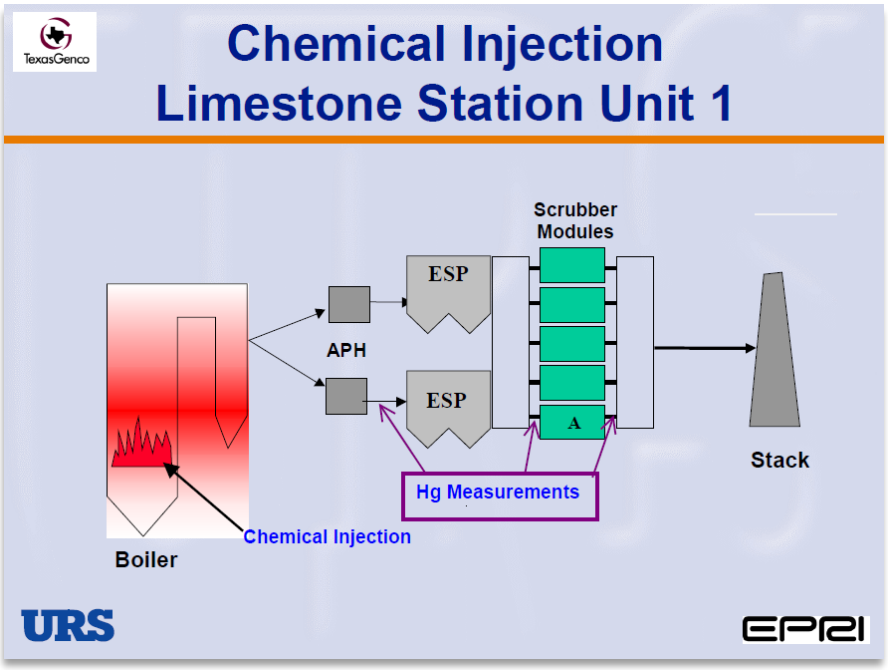
[899] EX1010 (Sjostrom) at 4 (annotations in red).

[900] EX1010 (Sjostrom) at 4 (annotations in red).

[901] EX1010 (Sjostrom) at 23.

entering the boiler, and directly to the combustion chamber.[902] Thus, Sjostrom renders obvious combusting a mixture comprising coal and an additive comprising HBr, a bromide compound, or a combination thereof, to form the mercury-containing gas.

549. 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.[903]



[902] EX1010 (Sjostrom) at 4 (annotations in red).

[903] EX1011 (Eckberg) at 5.

Specifically, Eckberg teaches injection of "$CaBr_2$ (52 wt%)" into the boiler.[904] A POSITA would have understood that calcium bromide was an example of a "bromide compound."

550. 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 system 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.

551. It would have been inherent, or at least obvious, for the mixture being combusted to comprise not only coal and Br-containing ingredients, but also comprise pyrolysis char. It was known long before the earliest priority date of the '225 Patent that pyrolysis char necessarily forms during the combustion of coal, including even under the most favorable conditions.[905] Thus, at least some quantity of the mixture of coal and bromine-containing ingredients (introduced into the combustion chamber) is further mixed with the pyrolysis char formed in the

[904] EX1011 (Eckberg) at 9; see also EX1011 (Eckberg) at 8.

[905] Technology Background and State of the Art, §IX.H; EX1100 (Coal Chemsitry) p. 673.

chamber. This mixture of coal, pyrolysis char, and bromine-containing ingredients entrains air and, since the flame temperatures inside the combustion chamber are several hundred degrees hotter than the ignition temperatures for both coal and pyrolysis char, the mixture spontaneously burns as it is contacted by oxygen in the air.

552. Patent Owner's expert in the Delaware Litigation, Mr. O'Keefe, further confirmed—in both his expert report and his deposition concerning the '225 Patent—the inherency of pyrolysis char in the bromine-coal mixture being combusted:

> Q. Just continuing on, on '225, claim 1. How would a person of skill in the art know whether there is any pyrolysis char in the mixture that was being combusted?
>
> A. Whenever you combust coal you create pyrolysis char.
>
> Q. It's always there whenever you combust coal?
>
> A. Right. It depends, you know, whether it's completely turned into ash or not, you know, by the combustion process.
>
> Q. … Pyrolysis char is an inherent result from the combustion of coal; is that correct?
>
> A. Correct. Correct.
>
> Q. Now, does claim 1 require any particular amount of pyrolysis char?
>
> A. No.

> Q. How would a person with skill in the art know if there was enough pyrolysis char to accomplish the goals of claim 1?
>
> A. Well, during combustion there's always pyrolysis char. You know, the question is whether it's entirely burned off or not during the combustion process. …
>
> Q. And looking at claim 1, is it important to know whether the pyrolysis char was all combusted or not?
>
> A. No.[906]

In his infringement report, Mr. O'Keefe further stated that "when coal is combusted, it produces some amount of pyrolysis char."[907]

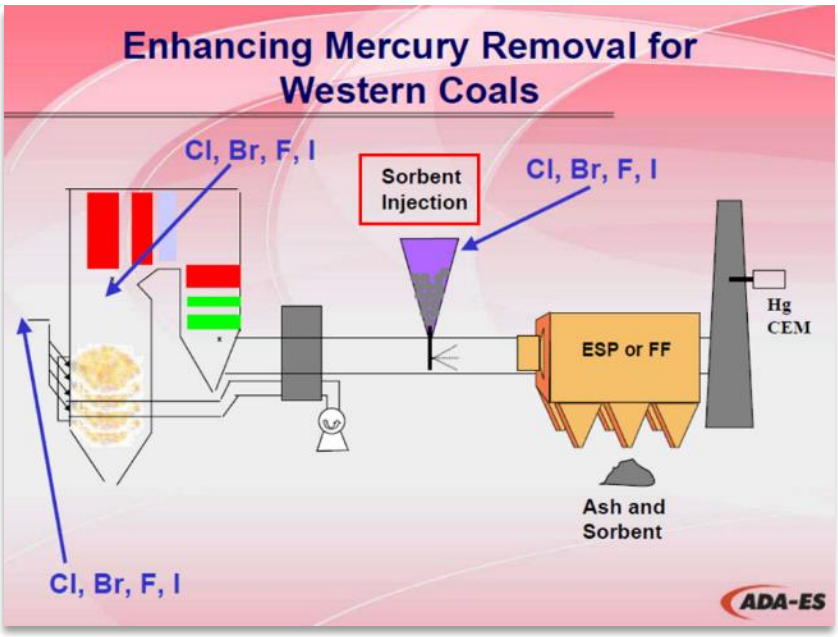
c. Claim 1: Element 1(b)—"adding a particulate sorbent material comprising activated carbon into the mercury-containing gas."

553. This limitation is disclosed by Sjostrom. As shown in the annotated figure below, Sjostrom described certain tests involving sorbent injection downstream of the boiler.[908]

[906] EX1094 (O'Keefe) at 233:33-235:9.

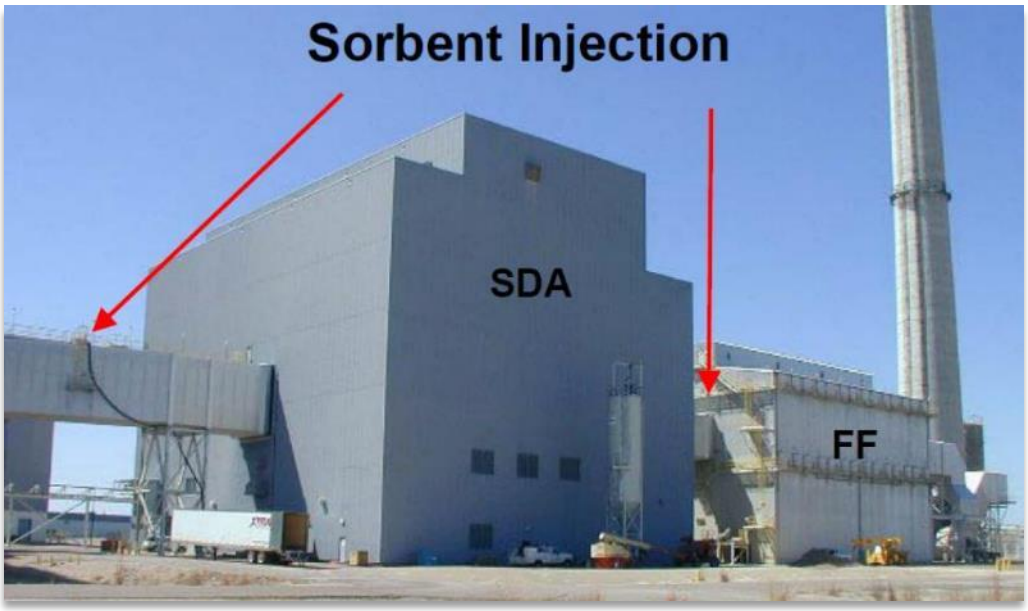
[907] EX1092 (O'Keefe Report) at 163 ('225 Patent Cl. 1b).

[908] EX1010 (Sjostrom) at 4 (annotations in red).

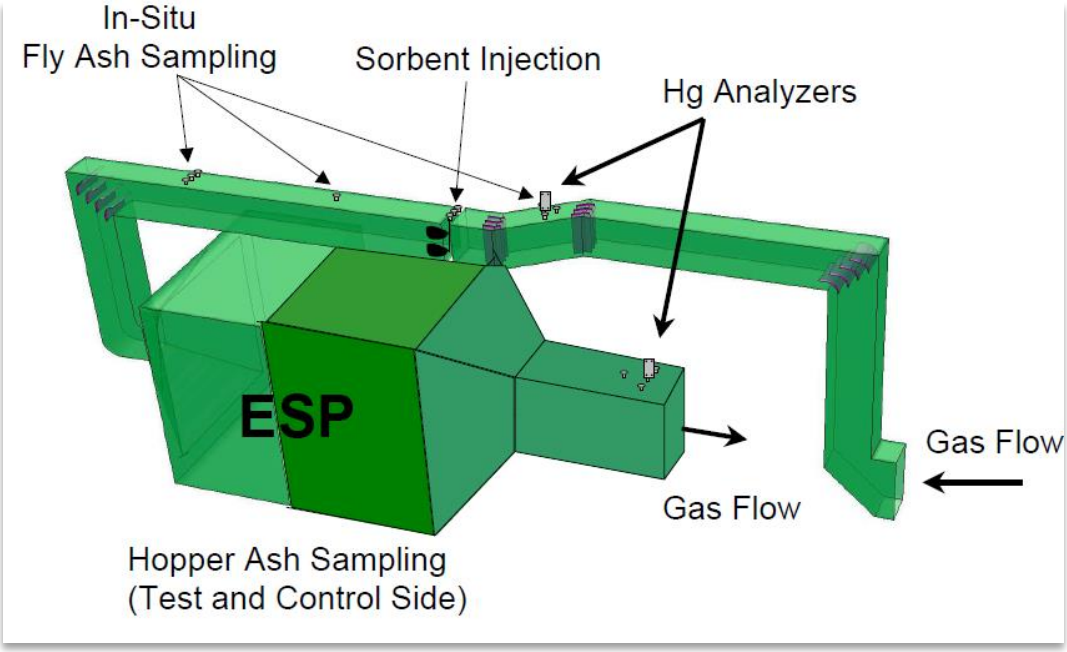


As shown in the above figure, the "Sorbent Injection" occurs downstream from a combustion chamber, and thus into the mercury-containing gas. Sjostrom refers to "Sorbent Injection Rate."[909] A photo of the sorbent injection is below (annotations in original):

[909] EX1010 (Sjostrom) at 32.



EX1010, 13. A schematic of "sorbent injection" into mercury-containing gas ("gas flow") is also provided:



EX1010, 19. Specifically, Sjostrom described that the type of particulate sorbent being injected into the mercury-containing flue gas is activated carbon ("activated

carbon injection to improve mercury control"),[910] which Sjostrom abbreviates as "ACI."[911] The specific brand of ACI is "DARCO FGD."[912] A POSITA would have understood that Norit DARCO FGD was a well-known type of activated carbon used for mercury capture.[913]

2. Claims Depending from Claim 1

a. Claim 2: "The method of claim 1, wherein the pyrolysis char is a promoted pyrolysis char."

554. According to Patent Owner's expert in the Delaware litigation, "pyrolysis char forms in the presence of bromine that has been added to the coal. Thus, it is promoted pyrolysis char."[914]

[910] EX1010 (Sjostrom) at 10.

[911] EX1010 (Sjostrom) at 11.

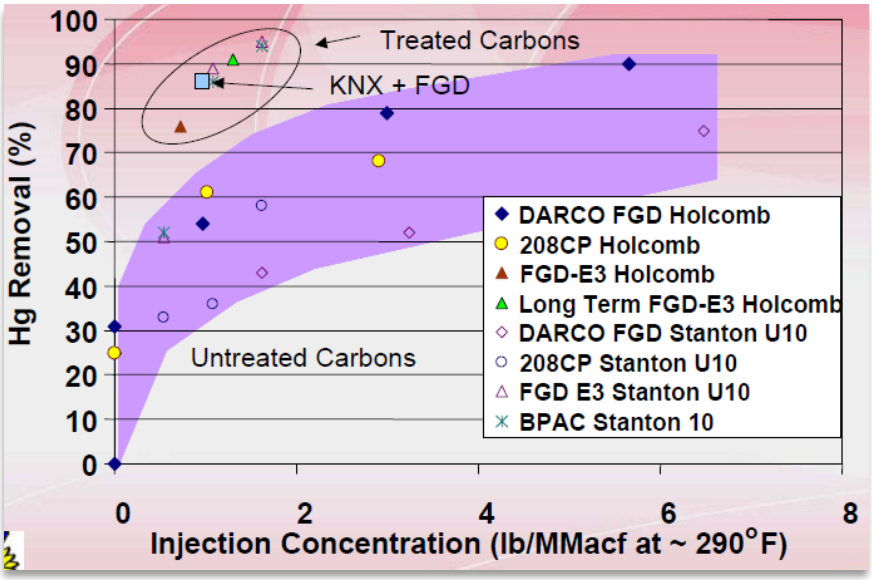
[912] EX1010 (Sjostrom) at 10, 11, 15-16.

[913] Technology Background and State of the Art, §IX.G.2.

[914] EX1092 (O'Keefe Report) at 163.

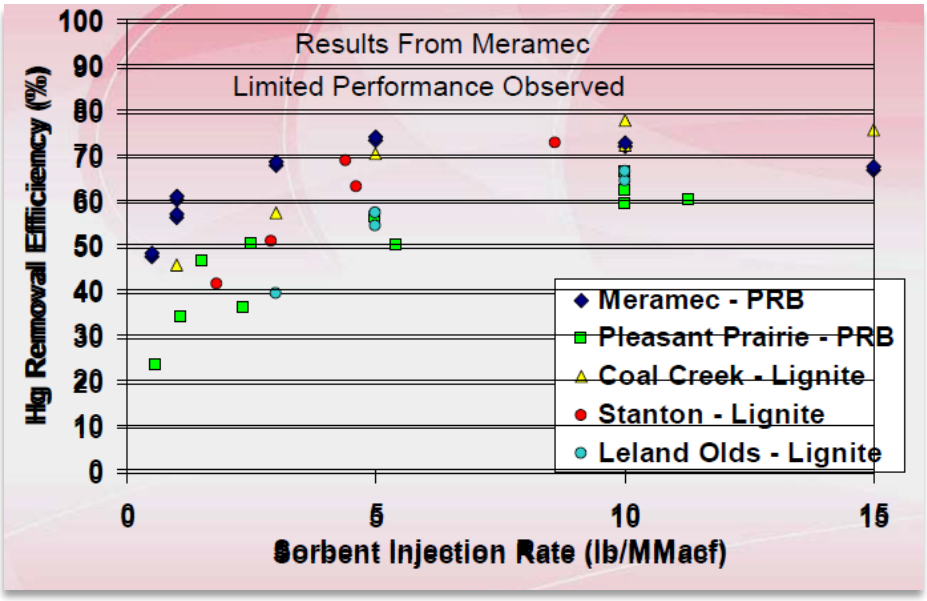
b. Claim 5: "The method of claim 1, further comprising using a particle separation device to remove mercury from the flue gas and comprising collecting greater than 70 wt % of the mercury in the mercury-containing gas to produce a cleaned gas."

555. This claim would have been obvious over Sjostrom. Sjostrom includes numerous charts showing greater than 70% by weight collection 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 collection (using treated carbons) and almost 90% Hg collection (using KNX + FGD) from the mercury-containing gas, thus producing a cleaned gas.[915]



[915] EX1010 (Sjostrom) at 16.

Similarly, the below chart shows the mercury collection from testing at plants using the system of Sjostrom.[916]

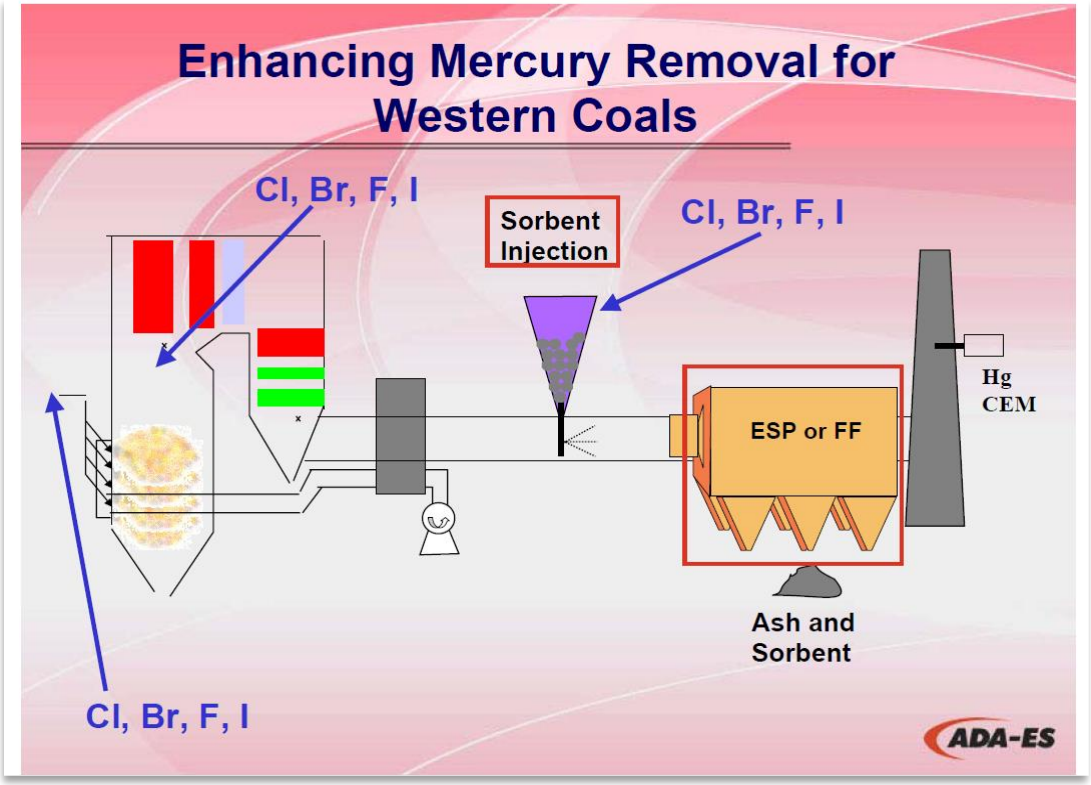


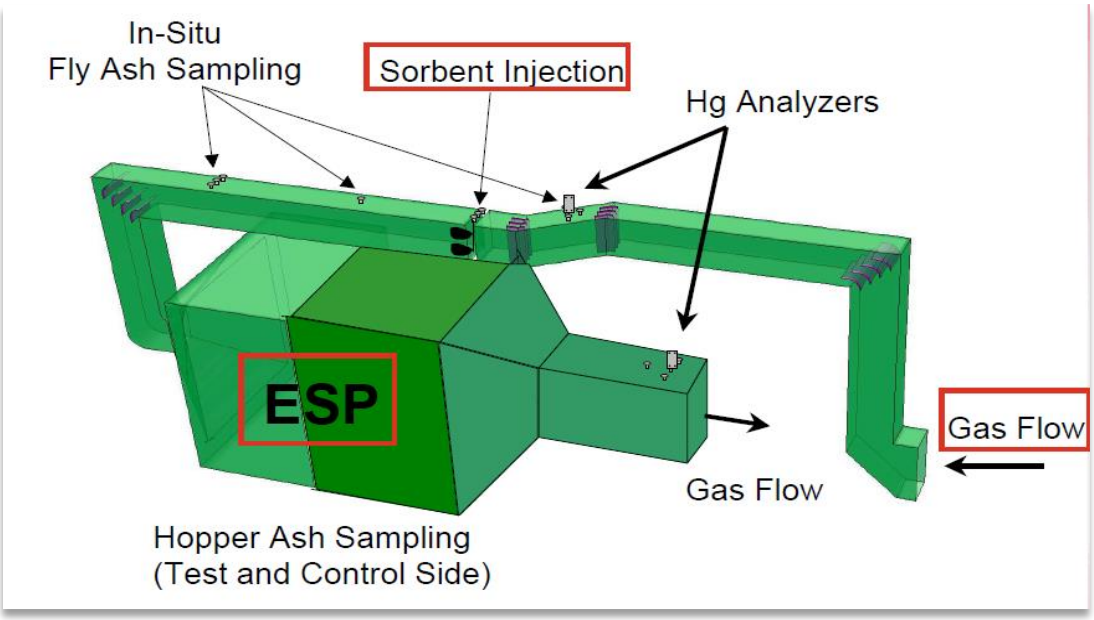
As can be seen in the above graphs, Sjostrom achieved greater than 70 % mercury collection.

556. In the plant setup for which the halogens are added to the coal, there is only dry emission-control equipment, such as the ESP or FF taught by Sjostrom.[917]

[916] EX1010 (Sjostrom) at 20.

[917] EX1010 (Sjostrom) at 4, 19.





Such plants with "solely" a dry emission control system, and without a scrubber, would be dependent on the activated carbon for mercury removal via a particle

separation device. The Hg collection on sorbents alone would meet or exceed the 70% collection threshold under the configurations disclosed by Sjostrom. A person of ordinary skill in the art would have understood that this mercury-laden sorbent is collected and removed from the flue gas by a particle separation device, such as an ESP as disclosed by Sjostrom.

557. In addition to the express disclosure of Sjostrom, a person of ordinary skill in the art would have understood that 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 halogenating 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.

558. As described in the State of the Art,[918] 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

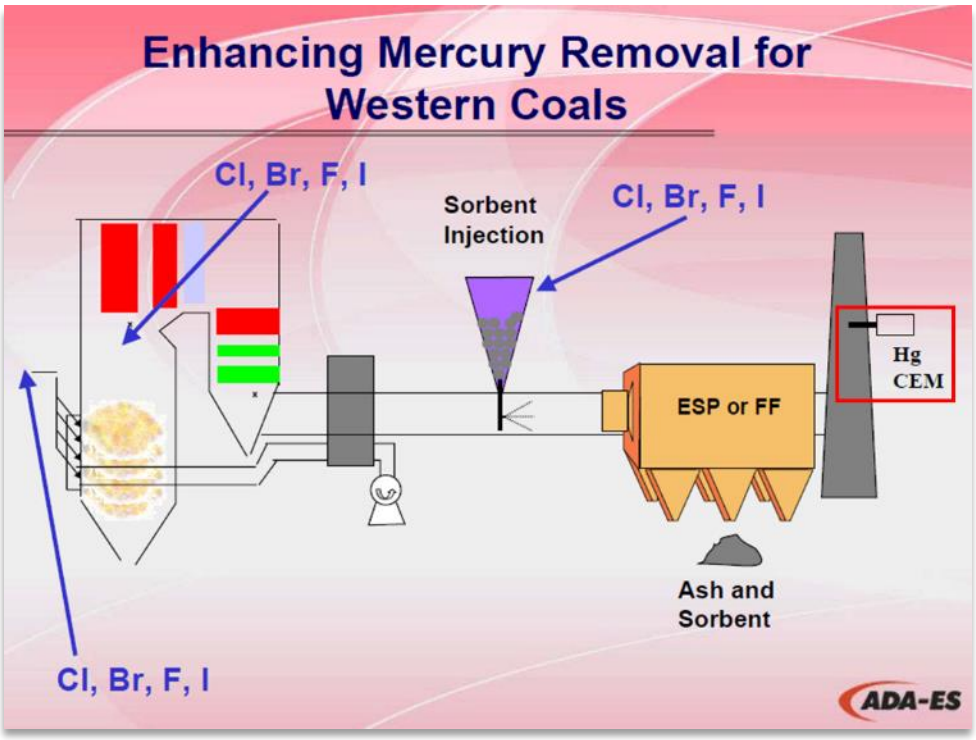
[918] Technology Background and State of the Art, §IX.D – §IX.F.

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 to meet and exceed (for purposes of safety margin) the EPA's proposed rules requiring a 70% removal of mercury.

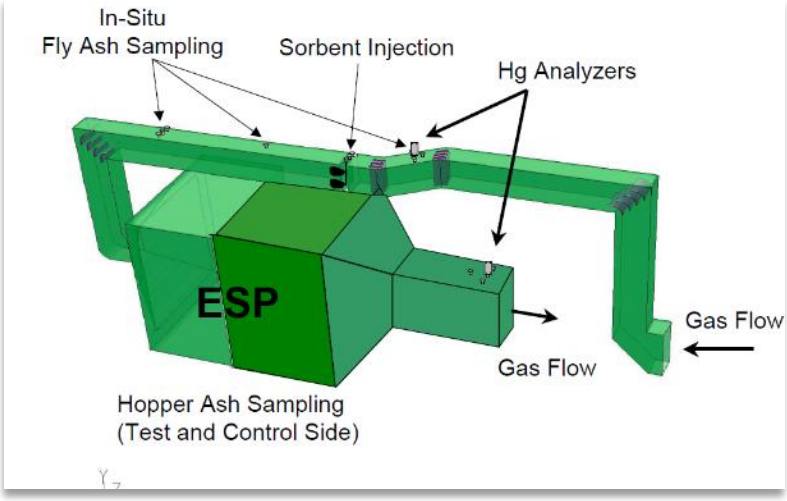
c. Claim 6: "The method of claim 5, further comprising: measuring the mercury content of the mercury-containing gas; and modifying, in response to the measured mercury content: an injection rate of injecting the sorbent into the mercury-containing gas, an amount of the additive in the mixture, or a combination thereof."

559. This claim is obvious over 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.[919] As shown in the figure below, sorbent injection is applied, and then the "ash and sorbent" (i.e., including the mercury-laden sorbent) is removed in the electrostatic precipitator (ESP) or fabric filter (FF). At this point, the mercury content of the mercury-containing gas is continuously measured downstream by the Hg CEM.

[919] EX1010 (Sjostrom) at 4 (annotations in red).

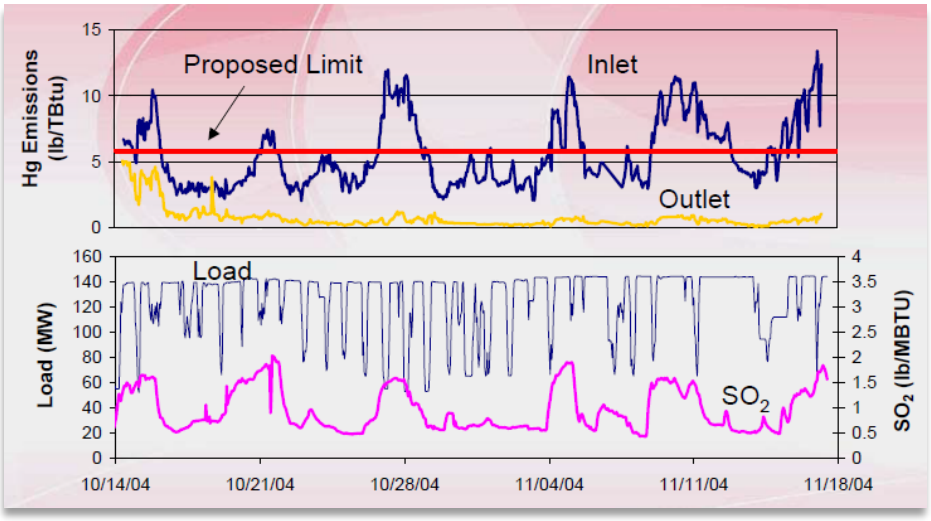


Further, Sjostrom discusses taking Hg measurements at both the inlet and outlet of the ESP as shown below (labeled "Hg Analyzers").[920]



[920] EX1010 (Sjostrom) at 19.

Sjostrom includes the chart below showing the Hg emissions as measured at the inlet and outlet of the ESP, as well as a "Proposed Limit" (red line):[921]

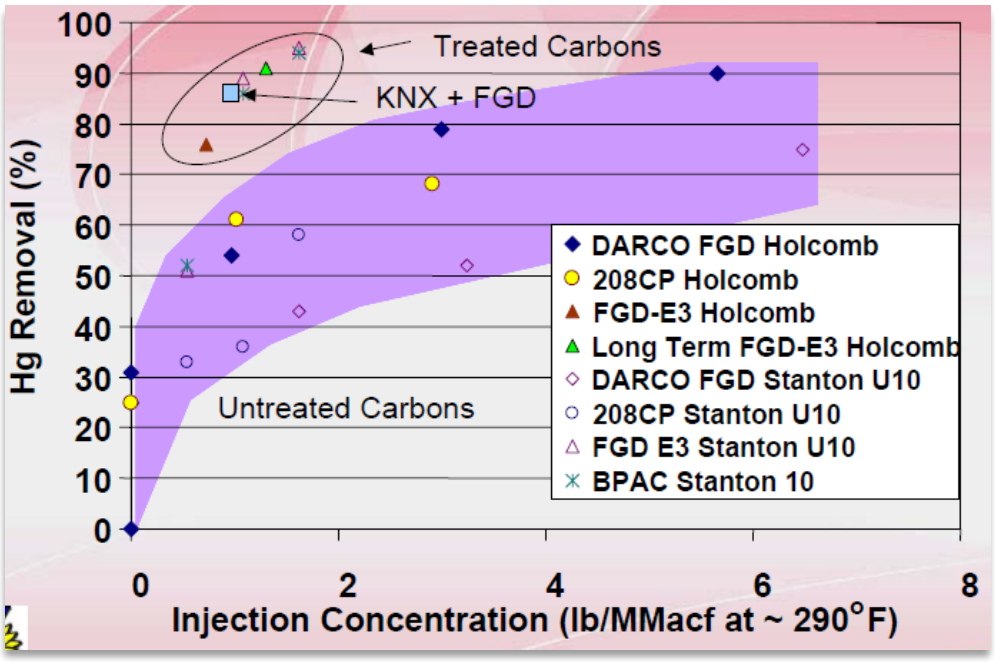


Thus, Sjostrom discloses measuring the mercury content of the mercury-containing gas.

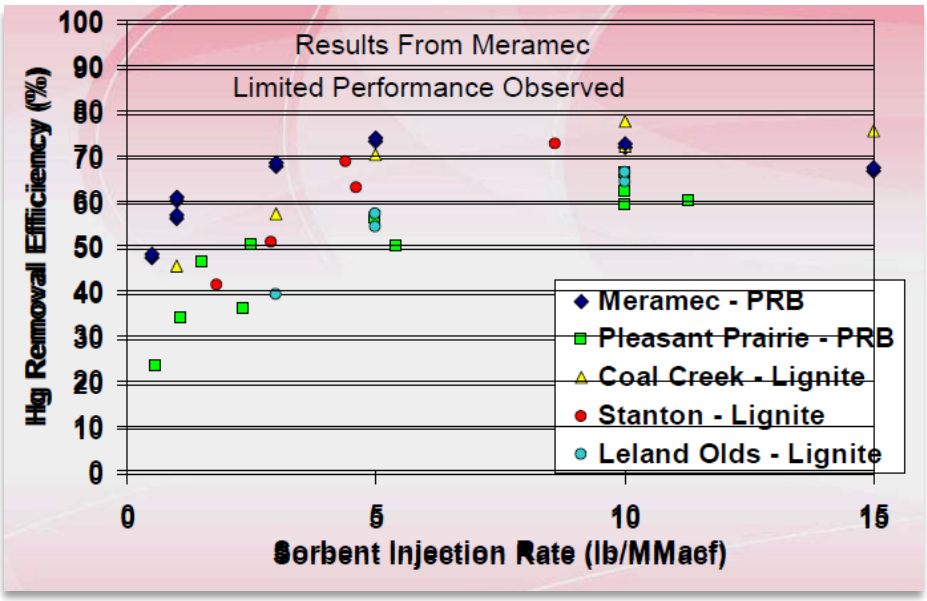
560. Sjostrom includes numerous charts of measured mercury removals (100% – outlet mercury content) for various injection rates of activated-carbon sorbents. For example, the below chart shows the effects of activated carbon injection rates for testing using the system of Sjostrom.[922]

[921] EX1010 (Sjostrom) at 22.

[922] EX1010 (Sjostrom) at 16.



Similarly, the below chart shows the effects of activated carbon injection rates for testing using the system of Sjostrom.[923]



[923] EX1010 (Sjostrom) at 20.

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 modified to result in a target mercury removal percentage. A POSITA would have further used the CEM (measured mercury content) and would have modified the sorbent-injection rate in response.

561. As discussed previously, a POSITA would have known that activated carbon was expensive, especially relative to costs of components such as "Br" in the form of an additive. 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 modify the sorbent injection rate in response to mercury measurements at a level that minimized costs while reaching mercury removal targets.

d. Claim 7: "The method of claim 1, wherein the additive further comprises Br_2."

562. As described for Element 1(a), Sjostrom discloses adding halogens to the system at multiple locations, including adding "Br" at Location 2 (directly into the combustion chamber). A POSITA would have been motivated to at least try molecular bromine (Br_2) as the "Br" source for Sjostrom, as it is a liquid at room temperature.[924] A POSITA would have used a liquid spray (e.g., as opposed to gas) to add halogens, such as molecular bromine, to a furnace because a liquid would achieve greater penetration into the furnace (and thus better mixing).

e. Claim 8: "The method of claim 1, wherein the sorbent material is chosen from powdered activated carbon, granular activated carbon, carbon black, carbon fiber, aerogel carbon, pyrolysis char, and combinations thereof."

563. This limitation is disclosed by Sjostrom. Sjostrom repeatedly discusses the use of activated carbon.[925] Further, Sjostrom includes test results of "Untreated PAC Injection into ESP" for "PRB and Lignite Coals."[926] A POSITA would have known that PAC stood for "powdered activated carbon." Sjostrom also discusses

[924] EX1036 (CRC Press: March 2005**)** at 4-53, 4-65.

[925] EX1010 (Sjostrom) at 10, 20, 34.

[926] EX1010 (Sjostrom) at 20.

testing done with the injection of "DARCO FGD" sorbent.[927] A POSITA would have known that DARCO FGD was a well-known type of powdered activated-carbon sorbent.[928] Articles dating back to at least 1998 confirm that the chemical composition of "Norit Darco FGD" does not have halogens.[929]

f. Claim 10: "The method of claim 1, further comprising contacting the sorbent material with a mercury-stabilizing reagent chosen from S, Se, H_2S, SO_2, H_2Se, SeO_2, CS_2, P_2S_5, and combinations thereof."

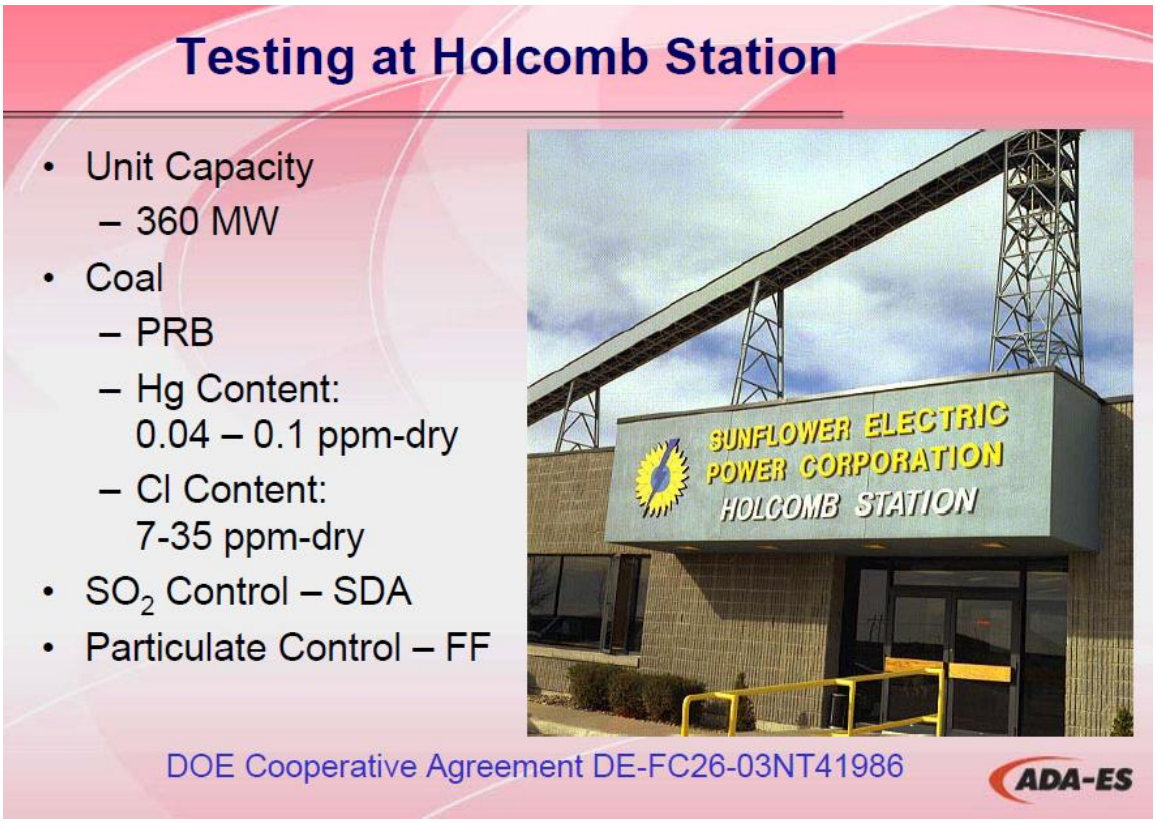
564. This limitation is disclosed by Sjostrom. Sjostrom discloses that SO_2 is present in the mercury-containing gas with the sorbent:[930]

[927] EX1010 (Sjostrom) at 15, 16.

[928] Technology Background and State of the Art, §IX.C.3, § IX.G.2.

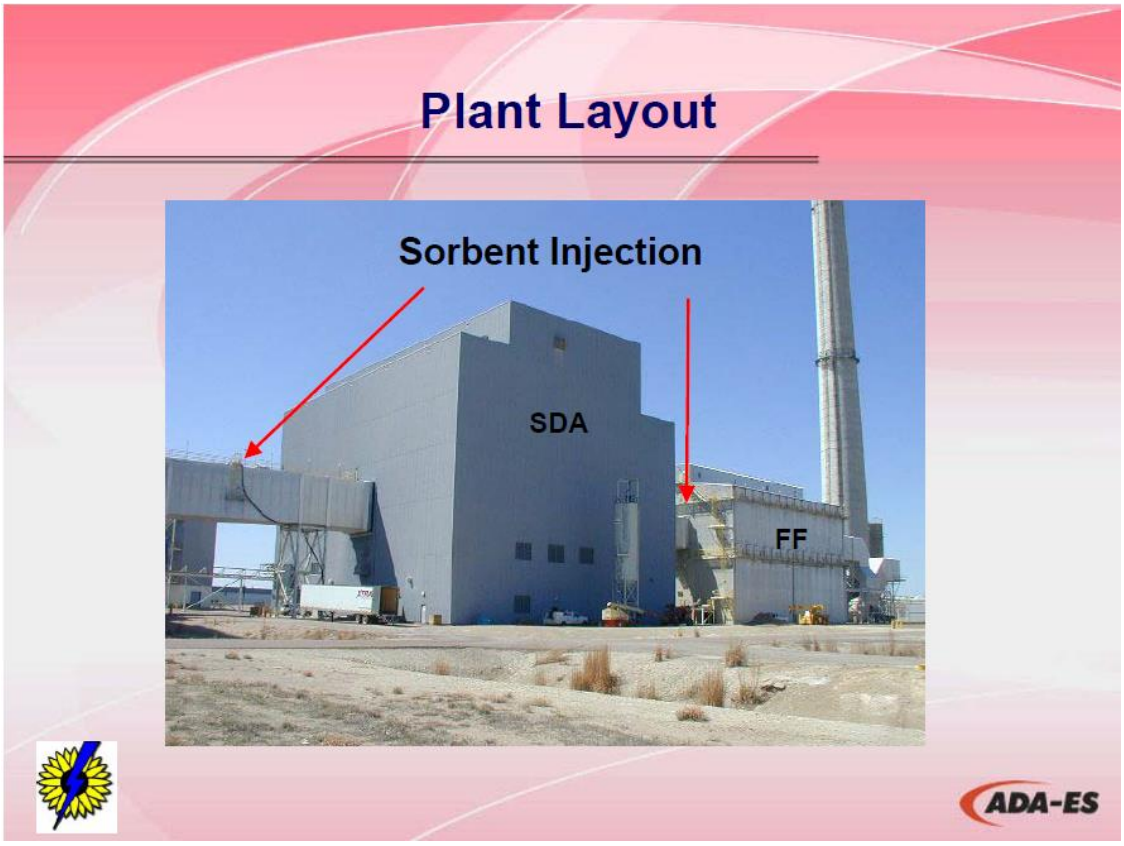
[929] EX1048 (Carey) at 1169 (Table 1, discussing chemical analysis of Norit FGD).

[930] EX1010 (Sjostrom) at 12 (describing "SO_2 Control – SDA").



The SO_2 is formed within the combustion chamber during coal combustion, and its concentration is greatest at the exit of the combustion chamber. Sjostrom confirms in the above graphic that the SO_2 is present, including in the spray dry adsorber (SDA). The contact with the activated-carbon sorbent (shown in graphic below) is inevitable, regardless of whether the sorbent is injected upstream or downstream of the SDA.[931]

[931] EX1010 (Sjostrom) at 13.



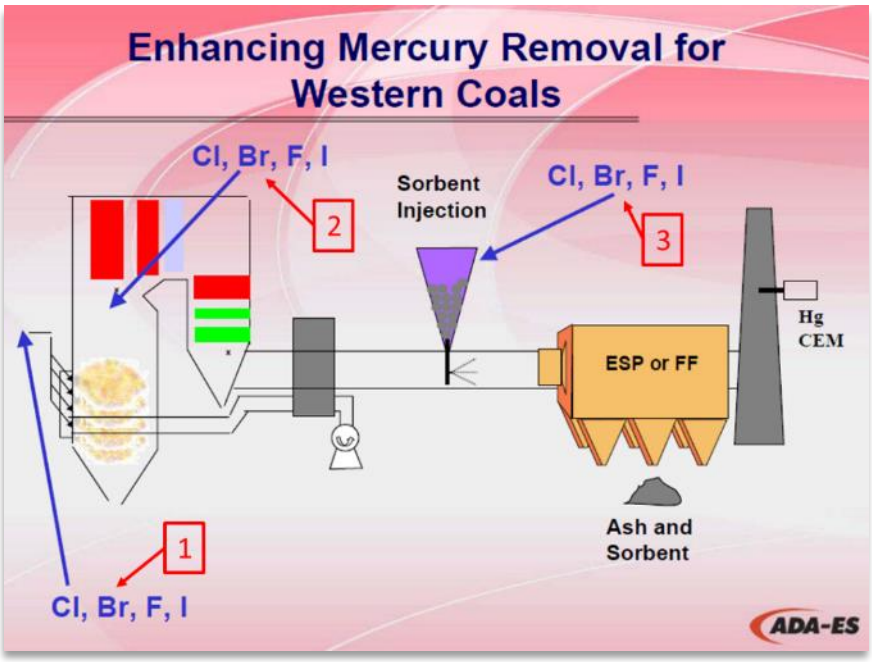
Thus, a POSITA would have understood that the SO_2 would contact the sorbent material in the mercury-containing gas.

g. Claim 11: "The method of claim 1, further comprising contacting the sorbent material with a secondary component chosen from halogens, hydrogen halides, Group V halides, Group VI halides, and combinations thereof."

565. 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.[932] Specifically,

[932] EX1010 (Sjostrom) at 4.

the annotated figure below shows that Sjostrom teaches injection of halogens, including "Cl, Br, F, I," in at least three locations throughout the coal-combustion process:[933]



Location 3 of Sjostrom teaches adding bromine or other halogens to the activated-carbon sorbent that is injected into the flue gas.[934] The bromine (or other halogens) added at Location 3 is a secondary component that is injected into the mercury-containing flue gas. Thus, the claimed "secondary component" found in this claim includes other halogens, such as Cl and I, which Sjostrom teaches may be injected at Location 3.

[933] EX1010 (Sjostrom) at 4 (annotations in red).

[934] EX1010 (Sjostrom) at 4 (annotations in red).

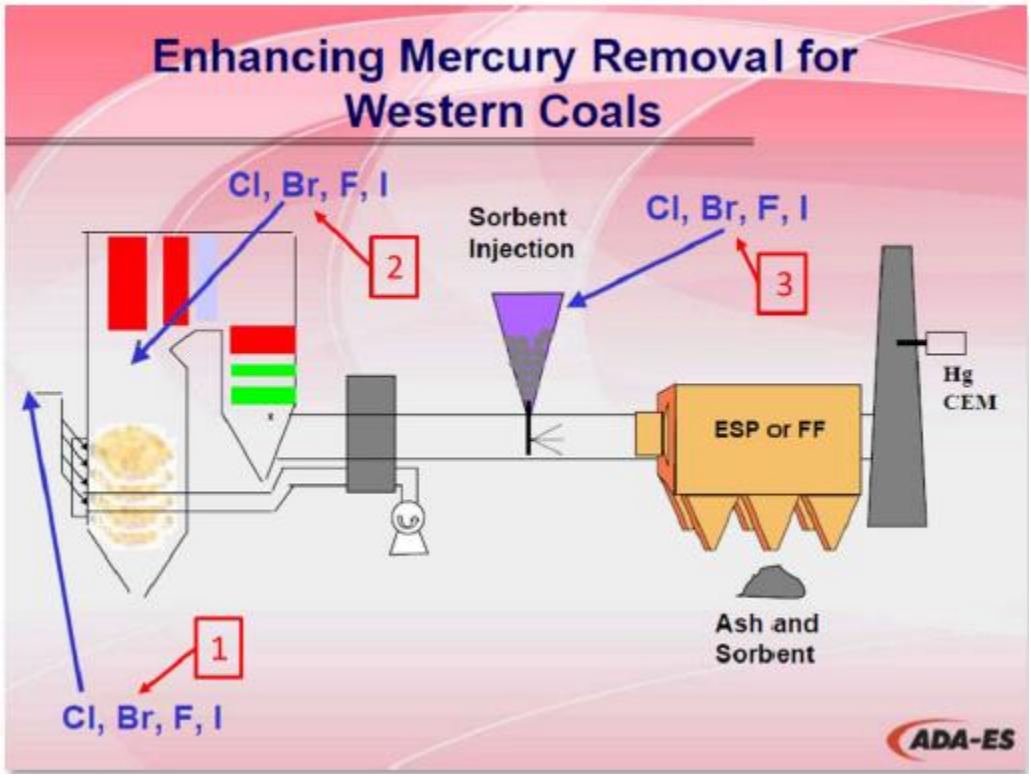
566. This limitation is also obvious over Sjostrom in view of Eckberg. For example, Eckberg provides additional details regarding the specific chemical compound and concentration to use as the injected "Cl" or "Br" secondary material. Specifically, Eckberg teaches injection of "$CaCl_2$ (25 wt%)" and "$CaBr_2$ (52 wt%)."[935] 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.

h. Claim 12: "The method of claim 11, wherein the secondary component is chosen from halogens, halide salts, HI, HBr, HCl, and combinations thereof."

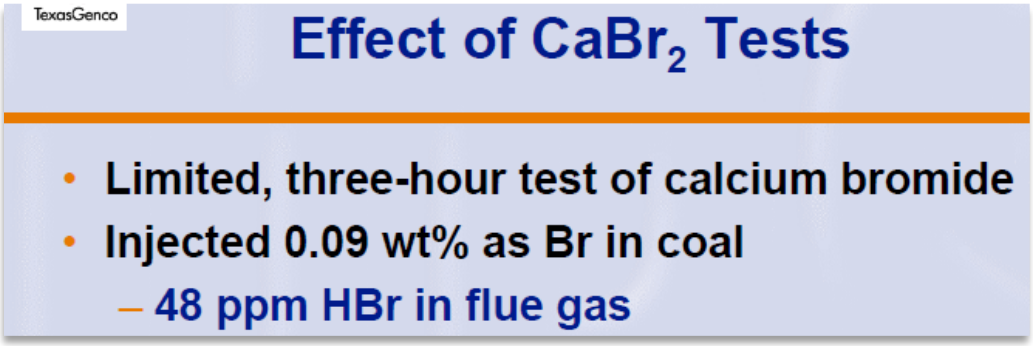
567. As discussed for Claim 11, Sjostrom discloses injecting halogens ("Cl, Br, F, I") as a secondary component at Location 3 downstream of the combustion chamber.[936]

[935] EX1011 (Eckberg) at 9.

[936] EX1010 (Sjostrom) at 4 (annotations in red).



568. Claim 12 would have been further obvious over Eckberg. Eckberg discloses injection of halide salts (e.g., $CaBr_2$, $CaCl_2$).[937] Eckberg teaches that, upon combustion, $CaBr_2$ forms HBr in the mercury-containing gas.



[937] EX1011 (Eckberg) at 9.

The HBr in the mercury-containing would contact the sorbent injected by Sjostrom to create a promoted sorbent.[938]

i. Claim 18: "The method of claim 1, further comprising modifying, in response to a measured mercury content, an injection rate of injecting the sorbent into the mercury-containing gas, an amount of the additive in the mixture, or a combination thereof."

569. Claim 18 is obvious for the reasons discussed for Claim 6.

j. Claim 19: "The method of claim 1, wherein the coal comprises added sorbent enhancement additive that comprises the bromide compound."

570. This claim would have been obvious over Sjostrom in view of Eckberg. As described above for Claim Element 1(a), Sjostrom renders obvious adding bromine to the coal in the form of a widely available bromine-containing material, such as an aqueous solution of a bromide compound (e.g., $CaBr_2$). The '225 Patent does not define "sorbent enhancement additive," but as evidenced by this claim a sorbent enhancement additive at least includes a bromide compound. Claim 19 is further obvious over Eckberg, which discloses addition of calcium bromide (i.e., a bromide compound) to the coal.[939]

[938] EX1095 (Olson), 231:3-9; see 98:23-100:3 (discussing "in-flight promotion").

[939] EX1011 (Eckberg) at 14.

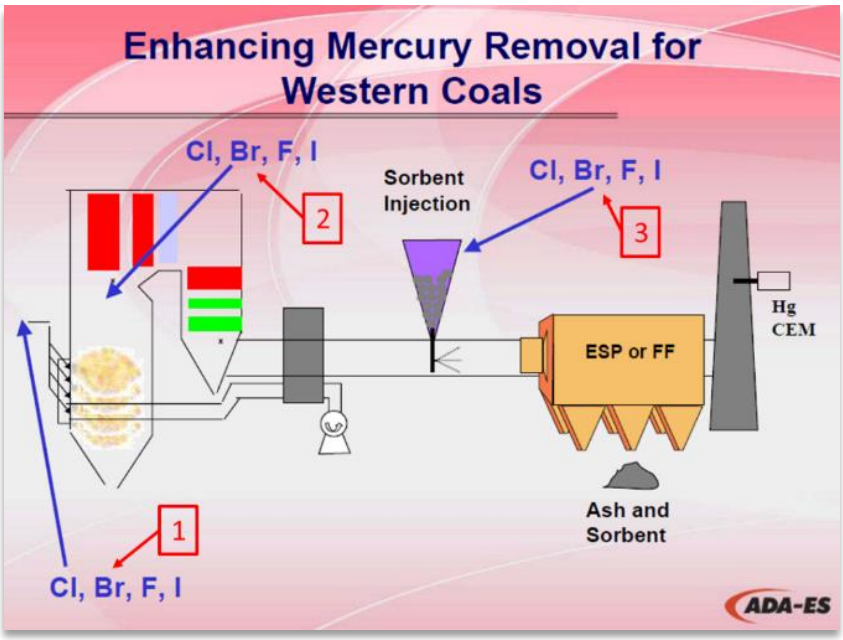
k. Claim 20: "The method of claim 1, wherein the coal is combusted in a combustion chamber at a coal-combustion facility, wherein the HBr, bromide compound, or combination thereof, is added to the coal before the coal enters the combustion chamber, wherein the addition of the HBr, bromide compound, or combination thereof, to the coal is performed at the coal-combustion facility."

571. This claim would have been obvious over Sjostrom in view of Eckberg. As discussed for Claim Element 1(a), the coal is combusted in a combustion chamber. The combustion chamber is located at a coal-combustion facility, such as the "Sunflower Electric Power Corporation Holcomb Station" and the "We Energies Presque Isle Power Plant," as disclosed by Sjostrom, or "Texas Genco's Limestone Electric Generating Station" as disclosed by Eckberg.[940] An electric utility plant with a coal-fired combustion chamber is an example of a coal-combustion facility. The bromide compound is added to the coal just before the combustion chamber at Location 1 of Sjostrom, as I describe above for Claim Element 1(a), which is at the coal-combustion facility.

[940] EX1010 (Sjostrom) at 3, 5, 8, 12, 29; EX1011 (Eckberg) at 4-5.

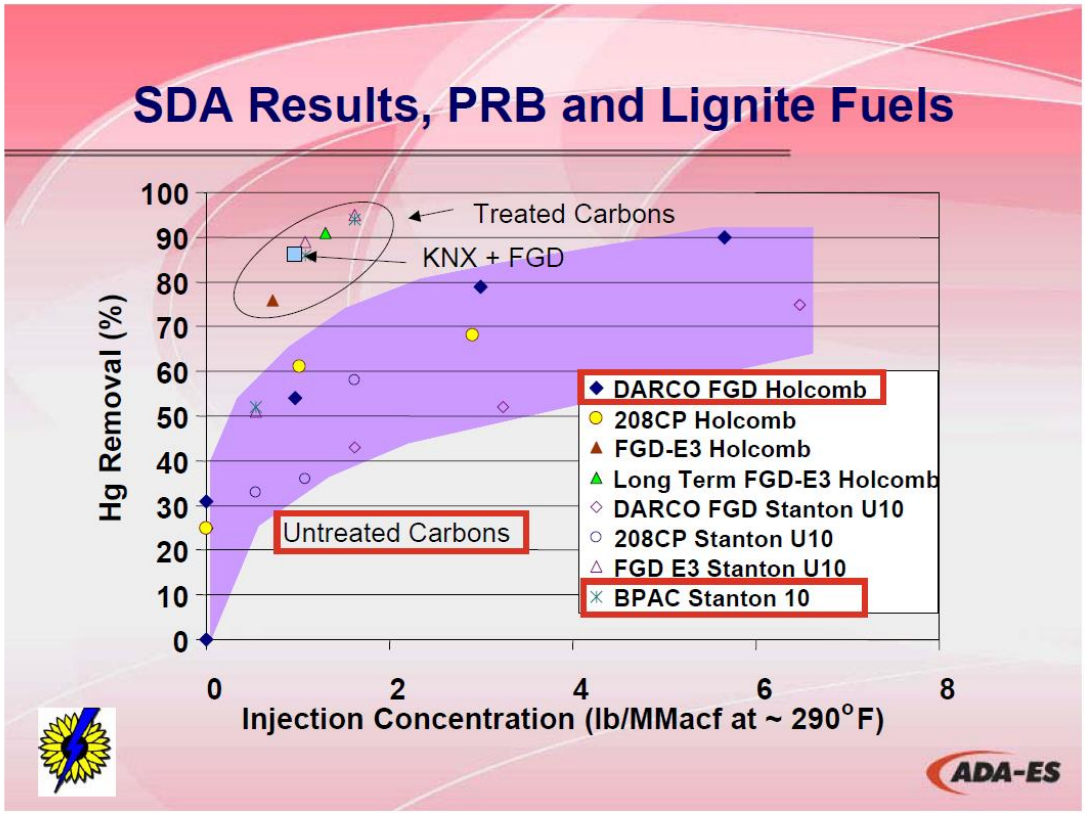
l. Claim 22: "The method of claim 1, wherein the sorbent is contacted with a halogen or halide promoter prior to the addition of the sorbent to the mercury-containing gas."

572. This limitation is disclosed by Sjostrom. At Location 3, Sjostrom teaches contacting a base sorbent with a halogen or halide promoter prior to addition of the sorbent into the mercury-containing flue gas.[941]



[941] EX1010 (Sjostrom) at 4 (annotations in red).

Sjostrom also teaches pre-brominating (or pre-chlorinating) the activated carbon at Location 3 (such as "BPAC," which stands for brominated-PAC).[942] One of the tests in Sjostrom used "BPAC" at the Stanton unit.[943]



573. A POSITA would have been motivated to try such a configuration—adding bromine at Locations 1 and/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)

[942] EX1010 (Sjostrom) at 4 (annotations in red).

[943] EX1010 (Sjostrom) at 16 (identifying "BPAC Stanton 10" in the legend).

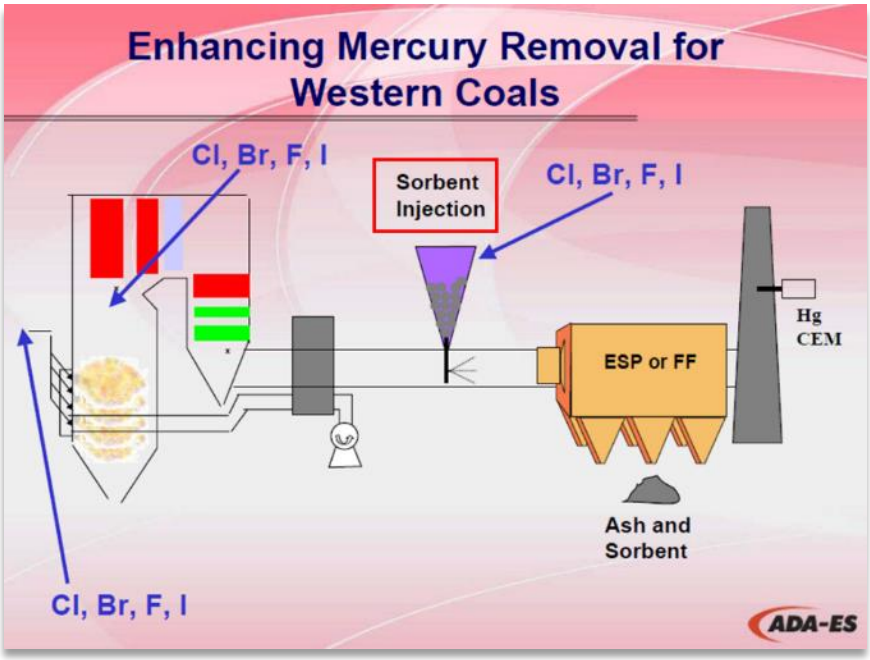
in order to further reduce total mercury emissions. In situations where additional mercury capture was required, a POSITA would have been motivated to inject, or at least try injecting, "Br" at Locations 1 and/or 2 while also adding a treated activated-carbon sorbent to the flue gas downstream of the boiler 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 prior to addition into the mercury-containing gas 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.[944]

m. Claim 23: "The method of claim 1, wherein the sorbent is free of contact with a halogen or halide promoter prior to the addition of the sorbent to the mercury-containing gas."

574. This limitation is disclosed by Sjostrom. As described for Claim Element 1(b), Sjostrom discloses adding sorbent into the mercury-containing gas. As shown in the annotated figure below, Sjostrom described certain tests involving

[944] Technology Background and State of the Art, §IX.C.3, § IX.G.2.

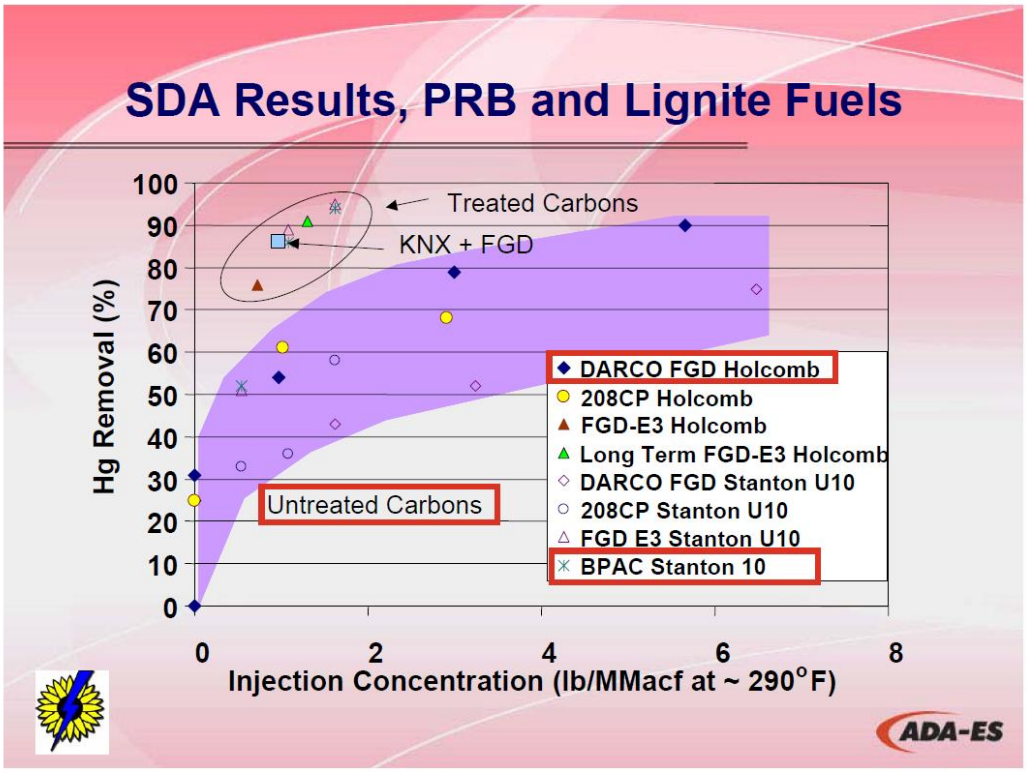
activated-carbon "sorbent injection" downstream of the boiler into the mercury-containing gas, at any of 3 locations.[945]



Among the sorbent added was "Untreated Carbons."[946]

[945] EX1010 (Sjostrom) at 4 (annotations in red).

[946] EX1010 (Sjostrom) at 16 (annotations in red).



A POSITA would have understood that "untreated carbons" are not pre-halogenated and are substantially free of halogen or halide promotion prior to addition into the mercury-containing gas. 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 prior to its addition into the mercury-containing gas.[947] Articles dating back to at least 1998 confirm that the chemical composition

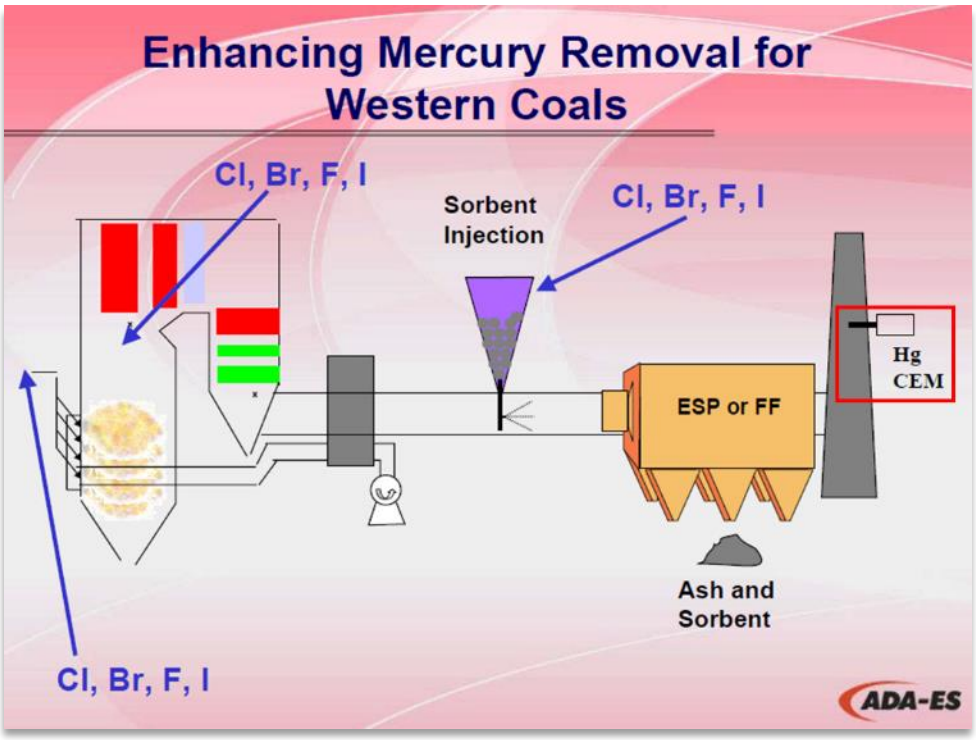
[947] Technology Background and State of the Art, §IX.C.3, §IX.G.2.

of "Norit Darco FGD" does not have halogens.[948] The untreated activated carbon (e.g., the Darco in solid blue diamonds) obtained more than 70% mercury removal. When adding KNX (an aqueous solution of bromide salt) (i.e., at Locations 1 and/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.

n. Claim 24: "The method of claim 6, wherein the measurement of the mercury content of the mercury-containing gas comprises continuous measurement."

575. As discussed above for Claim 6, Sjostrom expressly discloses measuring mercury content of the mercury-containing gas "continuously." Sjostrom discloses that the mercury-containing gas is measured downstream by the "Hg CEM" (which stands for Continuous Emissions Monitor).

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



Thus, a POSITA would have understood that Sjostrom's measurement of the mercury content of the mercury-containing gas "comprises continuous measurement," as required by Claim 24.

o. Claim 25: "The method of claim 1, wherein the coal comprises subbituminous coal."

576. This claim is disclosed by each of Sjostrom and Eckberg. Sjostrom is titled "Full Scale Evaluations of Mercury Control Technologies with PRB Coals."[949] Sjostrom further discloses use of "Subbituminous (PRB)" coal.[950] Eckberg also

[949] EX1010 (Sjostrom) at 1.

[950] EX1010 (Sjostrom) at 3; *see also* EX1010 (Sjostrom) at 20 (slide titled "Untreated PAC Injection into ESP PRB and Lignite Coals").

discloses use of "PRB coals."[951] As recognized by Sjostrom, "PRB" (Powder River Basin) coal is a subbituminous coal.

p. Claim 26: "The method of claim 1, wherein the coal comprises lignite coal."

577. This claim is disclosed by each of Sjostrom and Eckberg. Sjostrom discloses use of "Lignite Coals," such as "Coal Creek – Lignite," "Stanton – Lignite," "Leland Olds – Lignite," and "North Dakota Lignite."[952] Eckberg is titled "Mercury Control Evaluations of Halogen Injection into a Texas Lignite-Fired Boiler."[953] Eckberg also discloses use of "lignite" coals elsewhere in the reference.[954]

q. Claim 27: "The method of claim 1, wherein the mixture is combusted in a combustion chamber of a coal-combustion facility upstream of a scrubber, a particulate control system, or a combination thereof, wherein the particulate sorbent is added to the mercury-containing gas before the mercury-containing gas encounters the scrubber, the particulate control system, or the combination thereof."

578. This limitation is disclosed by Sjostrom. As discussed above for Claim Element 1(a) and Claim 20, Sjostrom discloses combusting the mixture in a

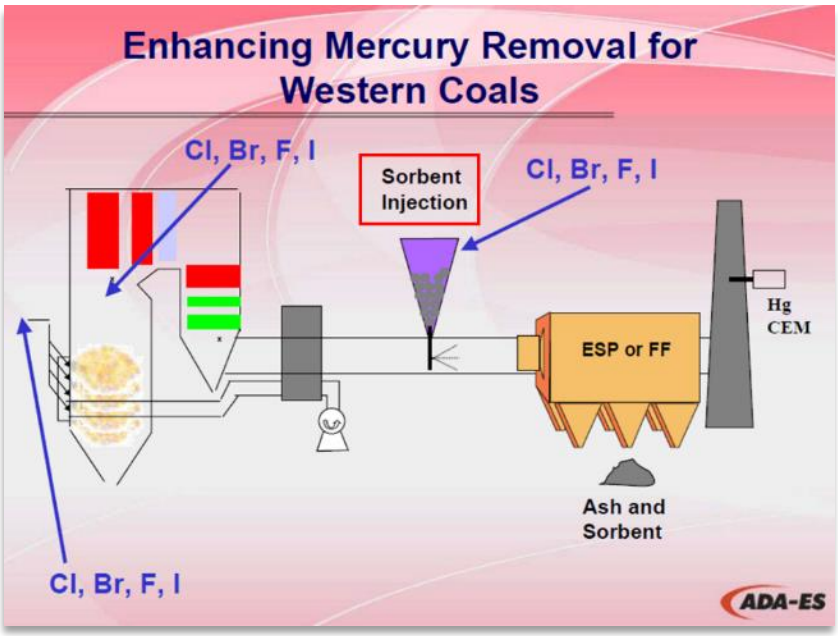
[951] EX1011 (Eckberg) at 2, 6.

[952] EX1010 (Sjostrom) at 20, 31, 32.

[953] EX1011 (Eckberg) at Title.

[954] EX1011 (Eckberg) at 2, 3, 6.

combustion chamber of a coal-combustion facility. As shown in the annotated figure below, Sjostrom described certain tests involving sorbent injection downstream of the boiler/furnace (i.e., combustion chamber).[955]

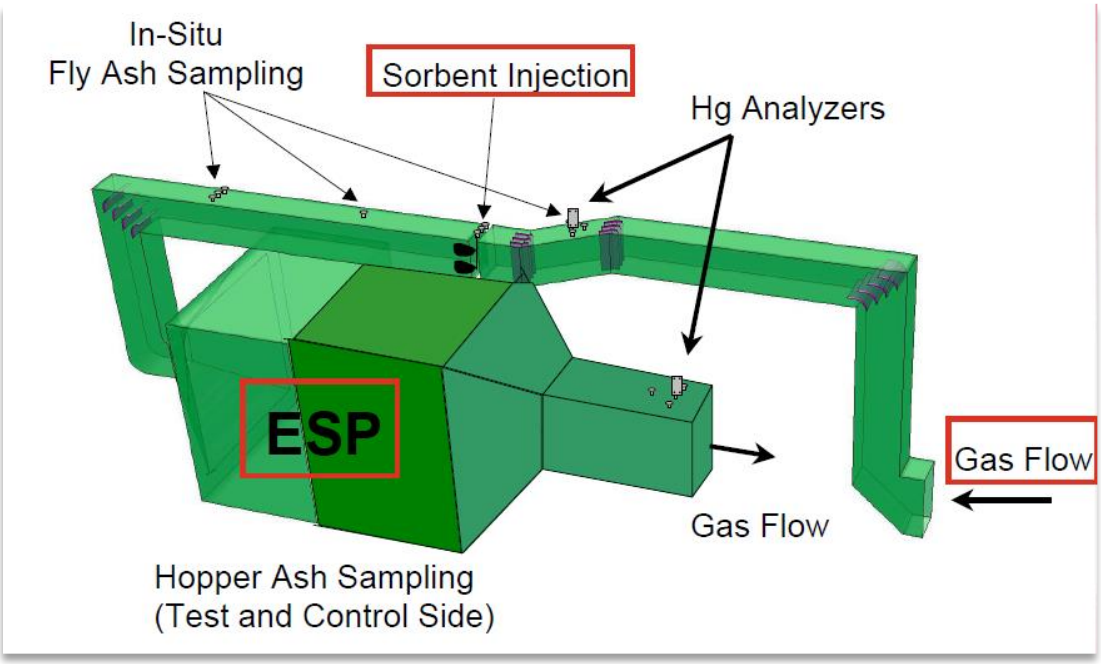


The sorbent injection system of Sjostrom is shown upstream of an ESP or FF.[956] The sorbent injection is also shown in another figure as being upstream of the ESP.[957]

[955] EX1010 (Sjostrom) at 4 (annotations in red).

[956] EX1010 (Sjostrom) at 4.

[957] EX1010 (Sjostrom) at 19 (annotated).



A POSITA would have understood that ESPs and FFs were well-known particulate control systems and would be used to collect the mercury-laden sorbent (and thus be downstream of where the mercury-laden sorbent is formed).[958]

r. Claim 28: "The method of claim 26, wherein the particulate control system comprises an electrostatic precipitator, a baghouse, a fabric filter, or a combination thereof."

579. As discussed above for Claim 27, Sjostrom expressly discloses wherein the particulate control system comprises an electrostatic precipitator or a fabric filter.

[958] Technology Background and State of the Art, IX.B.5.a

s. Claim 29: "The method of claim 19, wherein the combustion chamber is a coal combustion furnace."

580. Claim 29 would have been obvious for the reasons discussed above in Claim Element 1(a). The combustion chamber in the Sjostrom is a coal-combustion furnace. This limitation is further rendered obvious by Eckberg, which expressly references a furnace.[959]

3. Independent Claim 14

581. Claim 14 copies Claim 1, but modifies Element 1(a) slightly as shown in the redline below:

~~1~~14. A method for treating a mercury-containing gas, the method comprising:

combusting coal in a ~~mixture~~combustor comprising ~~coal,~~ pyrolysis char~~,~~ and an additive comprising HBr, a bromide compound, or a combination thereof, to form the mercury-containing~~,~~ gas; and

adding a particulate sorbent material comprising activated carbon into the mercury-containing gas.

I discuss these differences below.

[959] EX1011 (Eckberg) at 4.

a. Claim 14: Preamble—"A method for treating a mercury-containing gas, the method comprising:"

582. The language of the preamble of Claim 14 is identical to the preamble of Claim 1. This limitation is disclosed for the same reasons as stated above for Claim 1.

b. Claim 14: Element 14(a)—"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; and"

583. The language of Claim Element 14(a) is nearly 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 14(a). As discussed above for Claim Element 1(a), Sjostrom and Eckberg disclose that the mixture is combusted in a boiler/furnace (i.e., "a combustor").

c. Claim 14: Element 14(b)—"adding a particulate sorbent material comprising activated carbon into the mercury-containing gas"

584. The language of Claim Element 14(b) 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 14(a).

4. Claims Depending from Claim 14

a. Claim 15: "The method of claim 14, wherein the pyrolysis char is a promoted pyrolysis char."

585. Claim 15 is obvious for the same reasons discussed above for Claim 2.

5. Independent Claim 17

586. Claim 17 copies Claim 1, but modifies Element 1(b) to remove "particulate" as shown in the redline below:

~~1~~17. A method for treating a mercury-containing gas, the method comprising:

combusting a mixture comprising coal, pyrolysis char, and an additive comprising HBr, a bromide compound, or a combination thereof, to form the mercury-containing~~,~~ gas; and

adding a ~~particulate~~ sorbent material comprising activated carbon into the mercury-containing gas.

587. Accordingly, the explanation I provide above for Claim 1 applies equally to Claim 17.

XVII. GROUND B2: OBVIOUSNESS OVER SJOSTROM IN VIEW OF OLSON-646

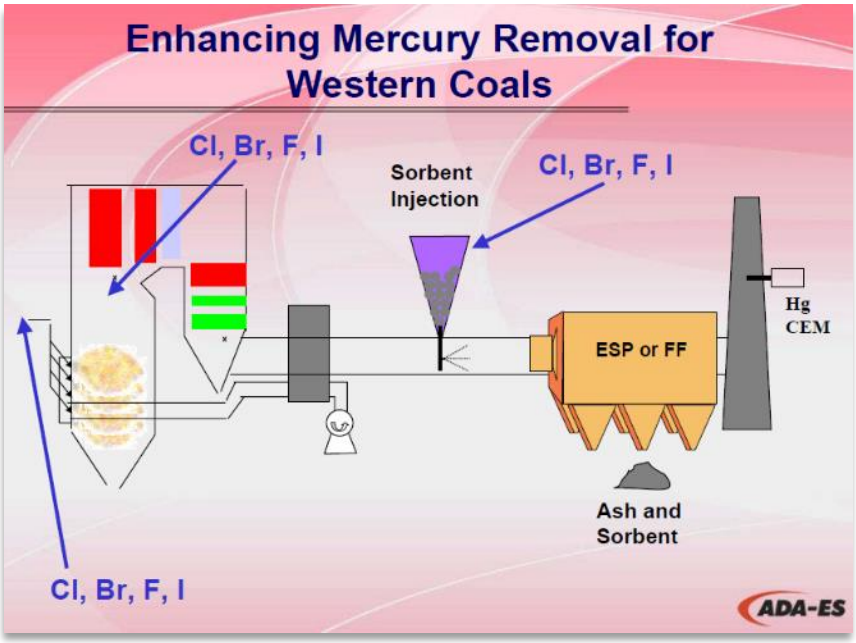
588. It is my opinion that Claims 1-2, 5-15, 17-20, 22-29 would have been obvious over the combination of Sjostrom and Olson-646 (Ground B2). In the subsections below, I discuss the reasons to combine Sjostrom with Olson-646, followed by the disclosure of Sjostrom and Olson-646.

A. REASONS TO COMBINE

589. 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."[960] Similarly, the title of Olson is "Sorbents for the Oxidation and Removal of Mercury."[961]

590. 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.[962]



[960] EX1010 (Sjostrom) at 1 (Title).

[961] EX1012 (Olson-646) at 1 (Title).

[962] EX1010 (Sjostrom) at 4.

Sjostrom demonstrates that activated-carbon sorbent injection was a well-known way of treating mercury emissions in flue gas.[963] Sjostrom also teaches that halogens (e.g., "Cl, Br, F, I") may be injected at multiple locations.[964] 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.[965]

591. 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 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.

592. 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

963 EX1010 (Sjostrom) at 10-11.

964 EX1010 (Sjostrom) at 4.

965 EX1010 (Sjostrom) at 16.

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."[966] 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.

593. 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."[967]

[966] EX1012 (Olson-646) ¶[0066].

[967] EX1012 (Olson-646) ¶[0054], Figure 2; *see also* ¶¶[0033], [0073].

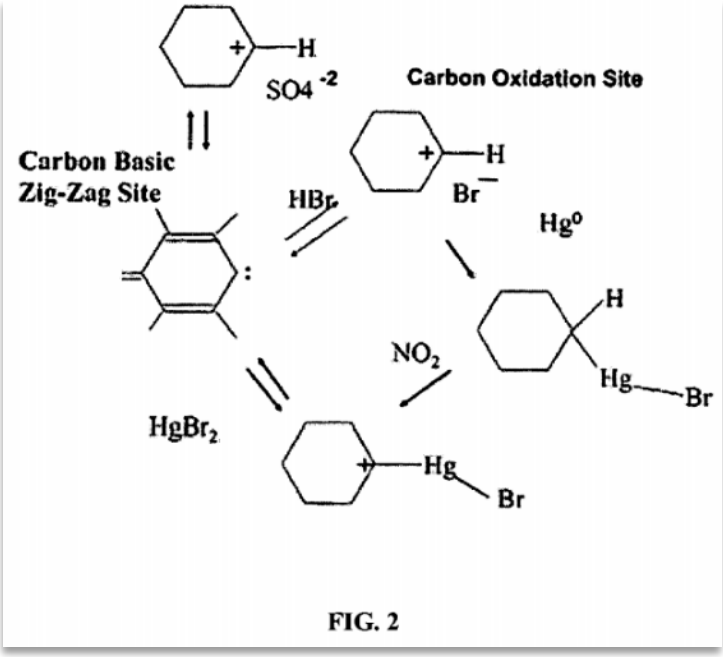


FIG. 2

Olson-646 explains that "hydrogen bromide reacts with the unsaturated structure of the activated carbon."[968] Olson-646 teaches that the reaction may take place at "a carbene species on the edge of the graphene sheet structures of the carbon."[969] 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."[970] 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

[968] EX1012 (Olson-646) ¶[0054].

[969] EX1012 (Olson-646) ¶[0054].

[970] EX1012 (Olson-646) ¶[0054].

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.

594. 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).[971] Sjostrom describes mercury removal testing performed using "DARCO FGD" sorbent.[972] Likewise, Olson-646 teaches the use of "powdered activated carbon" such as "NORIT Darco FGD."[973]

595. 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.

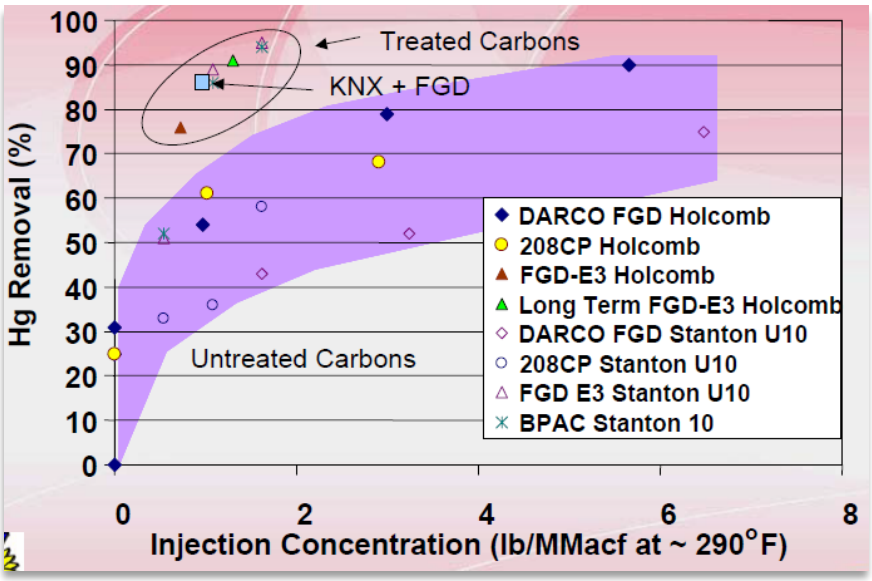
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[971] EX1010 (Sjostrom) at 15, 16; EX1012 (Olson-646) ¶¶[0035], [0036], [0039], [0040], [0095], [0100], [0126]

[972] EX1010 (Sjostrom) at 15, 16.

[973] EX1012 (Olson-646) ¶[0095].

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).[974]



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."[975]

596. Looking to the implementation details provided in the Olson-646 reference to understand the chemicals and reactions taking place in Sjostrom, would

[974] EX1010 (Sjostrom) at 16.

[975] EX1012 (Olson-646) ¶[0022].

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. DISCLOSURE AND TEACHINGS OF THE COMBINATIONS

597. It is my opinion that the combination of Sjostrom in view of Olson-646 (Ground B2) renders obvious the claims below of the Challenged Patent.

1. Independent Claim 1

a. Claim 1: Preamble—"A method for treating a mercury-containing gas, the method comprising:"

598. 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.

b. Claim 1: Element 1(a)—"combusting a mixture comprising coal, pyrolysis char, and an additive comprising HBr, a bromide compound, or a combination thereof, to form the mercury-containing, gas; and"

599. 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.

600. In addition, Olson-646 states that the "combustion and gasification of fossil fuel such as coal generates flue gas that contains mercury . . . ."[976] 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 mercury-sorbent surface reactions, at very short contact times of seconds or less."[977] Olson-646 teaches embodiments "wherein the halogen/halide promoter is in gaseous or vapor form" that comprises "gaseous HBr or Br_2."[978] A POSITA would have been motivated, with a reasonable expectation of success, to add HBr into the combustion chamber of Sjostrom (e.g., Location 2), because it would have been a simple

[976] EX1012 (Olson-646) ¶[0006].

[977] EX1012 (Olson-646) ¶[0043].

[978] EX1012 (Olson-646) ¶[0066].

substitution of one known element (e.g., the "Br" in Sjostrom at the location specified by Sjostrom) for another known element (e.g., 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).[979]

c. Claim 1: Element 1(b)—"adding a particulate sorbent material comprising activated carbon into the mercury-containing gas."

601. 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.

602. This limitation is further obvious over Sjostrom in view of Olson-646. Olson-646 describes "[a] promoted activated-carbon sorbent . . . that is highly effective for the removal of mercury from flue gas streams."[980] Olson-646 explains that a "promoted carbon sorbent and/or an optional alkali component is injected into

[979] EX1095 (Olson), 98:23-100:3, 231:3-9 (discussing in-flight promotion).

[980] EX1012 (Olson-646) at Abstract.

contaminated flue gas stream 15,"[981] where it adsorbs mercury: sorbent "that capture[s] mercury via mercury-sorbent surface reactions."[982] The "contaminated flue gas stream" refers to a stream of mercury-containing gas. Figure 2 of Olson-646 shown below depicts a mercury-laden sorbent:[983]

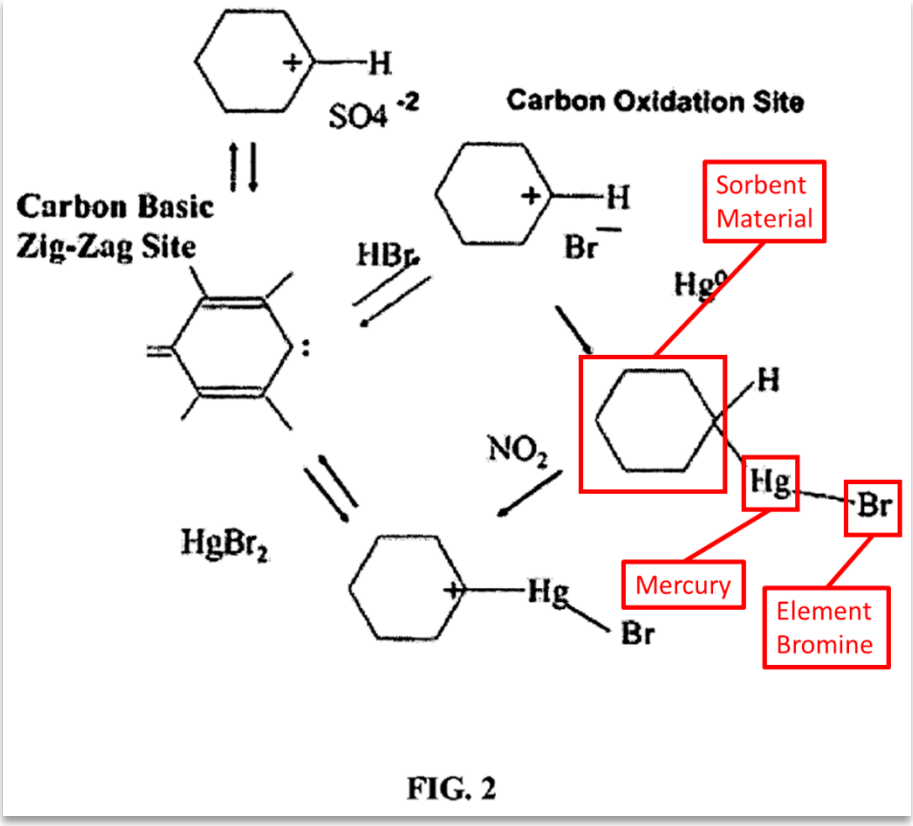


FIG. 2

[981] EX1012 (Olson-646) ¶[0061].

[982] EX1012 (Olson-646) ¶[0043].

[983] EX1012 (Olson-646) Fig. 2 (annotated).

Olson-646 describes "AC mercury binding sites," where mercury contacts sorbent and forms a mercury-laden sorbent.[984]

2. Claims Depending from Claim 1

a. Claim 2: "The method of claim 1, wherein the pyrolysis char is a promoted pyrolysis char."

603. According to Patent Owner's expert in the Delaware litigation, "pyrolysis char forms in the presence of bromine that has been added to the coal. Thus, it is promoted pyrolysis char."[985]

b. Claim 5: "The method of claim 1, further comprising using a particle separation device to remove mercury from the flue gas and comprising collecting greater than 70 wt % of the mercury in the mercury-containing gas to produce a cleaned gas."

604. As discussed in Ground B1 above, Sjostrom discloses Claim 5. My analysis with regards to the disclosure of Sjostrom regarding Claim 5 for Ground B1 applies equally here.

605. In addition, Claim 5 is 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

[984] EX1012 (Olson-646) ¶[0128].

[985] EX1092 (O'Keefe Report) at 163.

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."[986] Claim 30 of Olson-646 also discloses "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."[987]

606. A person of skill in the art would have looked to the Olson-646 reference to further understand the mechanisms for the mercury-collection disclosed by Sjostrom. Specifically, a POSITA would have understood that the activated carbon of Sjostrom collected "greater than 70 wt % of the mercury in the mercury-containing gas," as discussed in Ground B1 above. It would have been obvious over Olson-646 that the mercury is collected on the sorbent, which is then recovered from the mercury-containing gas by particle separation devices, such as an ESP. For instance, Olson-646 teaches that, "[w]hen 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."[988]

[986] EX1012 (Olson-646) ¶[0022].

[987] EX1012 (Olson-646) at Claim 30.

[988] EX1012 (Olson-646) ¶[0007].

This description instructs positioning activated-carbon sorbent upstream of the particle separation device (e.g., ESP), so that the mercury-laden sorbent can be collected.

c. Claim 6: "The method of claim 5, further comprising: measuring the mercury content of the mercury-containing gas; and modifying, in response to the measured mercury content: an injection rate of injecting the sorbent into the mercury-containing gas, an amount of the additive in the mixture, or a combination thereof."

607. As discussed for Claim 6 in Ground B1 above, this claim is obvious over Sjostrom. It is also obvious in view of Olson-646. My analysis with regards to the disclosure of Sjostrom regarding this claim 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… and using the monitored mercury content … to control the rate of injection of the sorbent."[989] Olson-646 discloses a "Continuous Emission Monitor" (CEM) as the tool for measuring mercury content of the mercury-containing gas.[990]

608. After separation, Olson-646 explains that "[t]he reduced mercury 'clean' flue gas stream 142 is then monitored for mercury content by an optional

[989] EX1012 (Olson-646) ¶[0022].

[990] EX1012 (Olson-646) ¶[0060].

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."[991] Even Olson-646 recognizes the corresponding control algorithms were "well known in the art" to keep the mercury content of the mercury-containing gas "within desired limits."[992]

609. Olson-646 explains that "mercury CEM 205 and flow controllers 201, 202, 203, 208, and 209 are electrically connected via optional lines 207 (or 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."[993] 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.[994]

[991] EX1012 (Olson-646) ¶[0061].

[992] EX1012 (Olson-646) ¶[0061].

[993] EX1012 (Olson-646) ¶[0060], Figure 3.

[994] EX1012 (Olson-646) ¶¶[0056, 60-61].

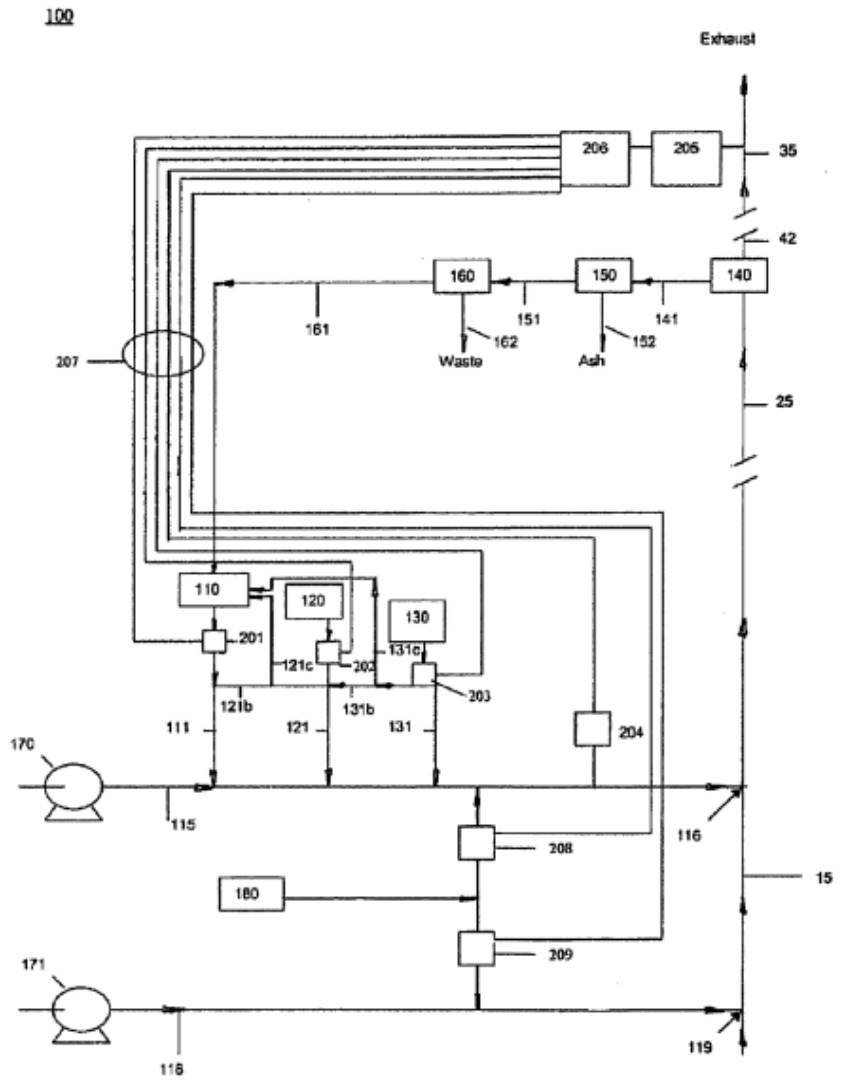


FIG. 3

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 mercury-containing gas based on feedback signals from mercury-content measurements, including by modifying the sorbent injection rate.

610. As discussed in Ground B1 for this claim, 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 modify 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.

d. Claim 7: "The method of claim 1, wherein the additive further comprises Br_2."

611. As discussed in Ground B1 above, this limitation would have been obvious over Sjostrom. This claim would have been further obvious over Olson-646. Olson-646 discloses that "the promoter is selected from the group consisting of

molecular halogens," which includes Br_2.[995] Olson-646 further discloses "molecular bromine" (i.e., Br_2) as the promoter for activated-carbon sorbent.[996]

e. Claim 8: "The method of claim 1, wherein the sorbent material is chosen from powdered activated carbon, granular activated carbon, carbon black, carbon fiber, aerogel carbon, pyrolysis char, and combinations thereof."

612. 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.[997]

f. Claim 9: "The method of claim 1, further comprising adding an alkaline component to the mercury-containing gas, the alkaline component chosen from alkali elements, alkaline earth elements, alkali salts, alkaline earth salts, and combinations thereof."

613. This limitation is obvious over Sjostrom in view of Olson-646. Olson-646 teaches "adding an optional alkali component."[998] Olson-646 further discloses "co-injecting an optional alkaline material" into the mercury-containing gas,

[995] EX1012 (Olson-646) ¶¶[0013], [0019], [0023], [0027].

[996] EX1012 (Olson-646) ¶¶[0054], [0073], [0121].

[997] EX1012 (Olson-646) at cl. 2.

[998] EX1012 (Olson-646) ¶[0017].

"including without limitation alkaline and alkaline earth components."[999] Claims 31 and 40 of Olson-646 further disclose "co-injecting an optional alkaline component into the mercury containing flue gas stream."[1000] Olson-646 teaches that the alkaline component is used "to improve the efficiency of mercury capture by capturing oxidized mercury and/or capturing gaseous components that might otherwise reduce sorbent capacity."[1001] Thus, Olson-646 discloses "adding an alkaline component to the mercury-containing gas." A person of skill in the art would have been motivated to use co-addition of an alkaline component as taught by Olson-646 in combination with Sjostrom as Olson-646 teaches that its use "improve[s] the efficiency of mercury capture."[1002]

614. Olson-646 further teaches that the alkaline component can "includ[e] without limitation alkaline and alkaline earth components," including "lime."[1003] Olson-646 further discloses that "the optional alkaline material may preferably

[999] EX1012 (Olson-646) ¶[0026].

[1000] EX1012 (Olson-646) at claims 31, 40.

[1001] EX1012 (Olson-646) ¶[0026].

[1002] EX1012 (Olson-646) ¶¶[0026], [0127].

[1003] EX1012 (Olson-646) ¶ [0026].

comprise calcium oxide, sodium carbonate, and the like, as are known in the art."[1004] The examples provided in Olson-646 of "sodium carbonate" (Na_2CO_3) "calcium oxide" (CaO), and "lime" (which itself contains calcium oxide) are examples of an alkali salt (Na_2CO_3) and alkaline earth salts (lime, calcium oxide). Thus, Olson-646 discloses "the alkaline component chosen from alkali elements, alkaline earth elements, alkali salts, alkaline earth salts, and combinations thereof."

g. Claim 10: "The method of claim 1, further comprising contacting the sorbent material with a mercury-stabilizing reagent chosen from S, Se, H_2S, SO_2, H_2Se, SeO_2, CS_2, P_2S_5, and combinations thereof."

615. 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.

616. In addition, this limitation is also obvious over Sjostrom in view of Olson-646. Olson-646 discloses this limitation almost verbatim: "adding a mercury-stabilizing reagent selected from the group consisting of S, Se, H_2S, SO_2, H_2Se, SeO_2, CS_2, P_2S_5, and combinations thereof."[1005] A POSITA would have been

[1004] EX1012 (Olson-646) ¶ [0026].

[1005] EX1012 (Olson-646) ¶[0017]; see also ¶¶[0021], [0025], cls. 12, 14, 28-29, 44.

motivated to add these components "to stabilize" the mercury binding to activated carbon.[1006]

h. Claim 11: "The method of claim 1, further comprising contacting the sorbent material with a secondary component chosen from halogens, hydrogen halides, Group V halides, Group VI halides, and combinations thereof."

617. 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.

618. In addition, this limitation is also obvious over Sjostrom in view of Olson-646. Olson-646 repeatedly refers to a "secondary component."[1007] Olson-646 provides more detail of injecting a secondary component into flue gas in Figure 3, reproduced below.[1008]

[1006] EX1012 (Olson-646) ¶[0074].

[1007] EX1012 (Olson-646) ¶¶[0011], [0014], [0015], [0017], cls. 4-8, 11, 24-27, 38-43.

[1008] EX1012 (Olson-646) ¶[0056], Figure 3.

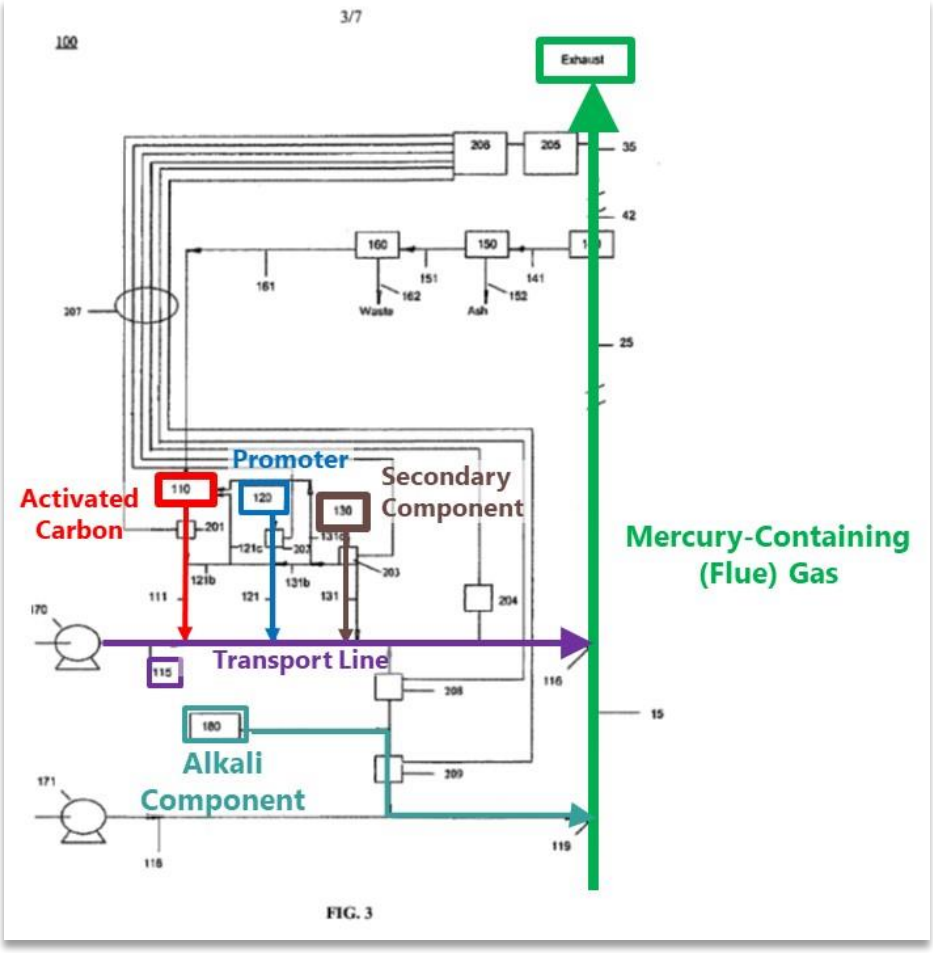


Figure 3 of Olson-646 shows a schematic of "mercury control system 100 comprising preparation of promoted carbon sorbents," which includes "an optional secondary component reservoir 130, and an optional akali [*sic*] component reservoir 180."[1009] Specifically, Olson-646 teaches that "the optional secondary component may be contacted and react directly in transport line 115 via line 131, or optionally

[1009] EX1012 (Olson-646) ¶[0056].

as described above with respect to the halogen/halide, via lines 131b and 131c."[1010] As shown in Figure 3, transport line 115 leads into flue gas stream 15. The secondary 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.[1011]

619. Olson-646 teaches that in certain embodiments, the "optional secondary component compris[es] a halogen or a hydrohalide."[1012] Olson-646 explains that these secondary components are added "such that the reactivity and mercury capacity of the sorbent are enhanced."[1013] A POSITA would have desired

[1010] EX1012 (Olson-646) ¶[0063].

[1011] EX1012 (Olson-646) ¶[0128].

[1012] EX1012 (Olson-646) ¶[0014]; *see also* EX1012 (Olson-646) at Claim 4.

[1013] 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."[1014]

620. As previously discussed, Sjostrom teaches injection of halogens, such as bromine, in one or more of at least three locations throughout the coal-combustion process.[1015] 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.[1016] 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.

621. In addition, Olson discloses embodiments wherein "the optional secondary component is selected from the group consisting of Group V halides,

[1014] EX1012 (Olson-646) ¶[0011].

[1015] EX1010 (Sjostrom) at 4.

[1016] EX1010 (Sjostrom) at 4.

Group VI halides, HI, HBr, HCl, and combinations thereof."[1017] 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."[1018]

i. Claim 12: "The method of claim 11, wherein the secondary component is chosen from halogens, halide salts, HI, HBr, HCl, and combinations thereof."

622. 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.

623. Claim 12 is further obvious in view of Olson-646, which discloses wherein the secondary component is "selected from the group consisting of Group V halides, Group VI halides, HI, HBr, HCl, and combinations thereof."[1019]

j. Claim 13: "The method of claim 11, wherein the secondary component is chosen from I_2, HI, and combinations thereof."

624. As discussed for Claim 11, Sjostrom discloses injecting a secondary component comprising halogens ("Cl, Br, F, I") downstream of the combustion

[1017] EX1012 (Olson-646) ¶[0017]; *see also* EX1012 (Olson-646) at Claim 7.

[1018] EX1012 (Olson-646) ¶[0025]; *see also* EX1012 (Olson-646) at Claim 39.

[1019] EX1012 (Olson-646) ¶[0017]; *see also* EX1012 (Olson-646) at Claim 7.

chamber at Location 3.[1020] It would have been obvious to a POSITA to inject "HI" as the iodine agent ("I") taught by Sjostrom. Olson-646 discloses the "secondary component is selected from the group consisting of … HI."[1021]

k. Claim 18: "The method of claim 1, further comprising modifying, in response to a measured mercury content, an injection rate of injecting the sorbent into the mercury-containing gas, an amount of the additive in the mixture, or a combination thereof."

625. Claim 18 is obvious for the reasons discussed for Claim 6.

l. Claim 19: "The method of claim 1, wherein the coal comprises added sorbent enhancement additive that comprises the bromide compound."

626. As discussed in Ground B1 above, this claim is rendered obvious by Sjostrom. My analysis with regards to these claims for Ground B1 applies equally here.

627. 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 addition of HBr) to the system of Sjostrom, as discussed in the Reasons to Combine section. Olson-646 describes that its invention "provides a cost-effective

[1020] EX1010 (Sjostrom) at 4.

[1021] EX1012 (Olson-646) ¶[0017]; *see also* ¶¶[0067], [0074] (similar).

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."[1022] Olson-646 teaches embodiments "wherein the halogen/halide promoter is in gaseous or vapor form" that comprises "gaseous HBr or Br_2."[1023] Olson-646 explains that the "invention provides for cost-effective removal of pollutants including mercury, using sorbent enhancement additives."[1024] Thus, a POSITA would have understood that Olson-646 referred to the HBr or Br_2 as sorbent enhancement additives. A POSITA would have also understood that HBr is one type of bromide compound. A POSITA would have been motivated, and expected a reasonable chance of success, to use a "Br" in Sjostrom (at the Location 1 specified by Sjostrom) that upon combustion would yield HBr or Br_2 (which Olson-646 identifies as effective gas-phase promoters). While Olson-646 does not expressly disclose adding HBr to the coal, it does identify the effectiveness of gas-phase HBr promoting activated carbon in the mercury-containing gas.

[1022] EX1012 (Olson-646) ¶[0043].

[1023] EX1012 (Olson-646) ¶[0066].

[1024] EX1012 (Olson-646) ¶[0009].

m. Claim 20: "The method of claim 1, wherein the coal is combusted in a combustion chamber at a coal-combustion facility, wherein the HBr, bromide compound, or combination thereof, is added to the coal before the coal enters the combustion chamber, wherein the addition of the HBr, bromide compound, or combination thereof, to the coal is performed at the coal-combustion facility."

628. This claim would have been obvious over Sjostrom in view of Olson-646. As discussed for Claim Element 1(a), the coal is combusted in a combustion chamber. The combustion chamber is located at a coal-combustion facility, such as the "Sunflower Electric Power Corporation Holcomb Station" and the "We Energies Presque Isle Power Plant."[1025] An electric utility plant with a coal-fired combustion chamber is an example of a coal-combustion facility. The bromide compound is added to the coal upstream of the combustion chamber, as I describe above for Claim Element 1(a), which is at the coal-combustion facility.

[1025] EX1010 (Sjostrom) at 3, 5, 8, 12, 29.

n. Claim 22: "The method of claim 1, wherein the sorbent is contacted with a halogen or halide promoter prior to the addition of the sorbent to the mercury-containing gas."

629. 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.

630. In addition, this limitation is also obvious over Sjostrom in view of Olson-646. Sjostrom and Olson-646 use the same brand name of commercial product—Norit Darco FGD sorbent.[1026] And, similar to Location 3 of Sjostrom, Olson-646 teaches first promoting a base activated carbon (item 10) with a bromine promoter (items 20, 40), and then adding the "promoted carbon sorbent" into the mercury-containing flue gas (item 50).[1027]

[1026] EX1010 (Sjostrom) at 15, 16; EX1012 (Olson-646) ¶[0095].

[1027] EX1012 (Olson-646) at Figure 1, ¶¶[0045]-[0048].

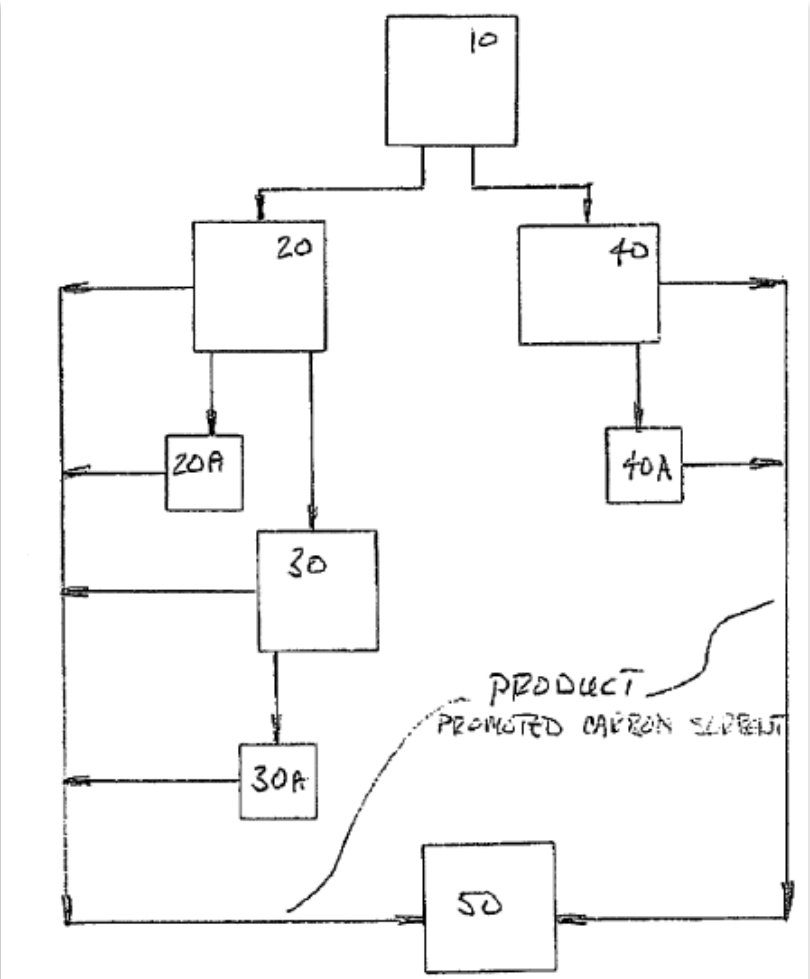


FIG. 1

631. A POSITA would have been motivated to try adding bromine at Locations 1 and/or 2, as taught by Sjostrom, and also adding bromine to the sorbent before injecting at Location 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

Locations 1 and/or 2 while adding a treated activated-carbon sorbent to the flue gas downstream of the boiler/furnace (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 Locations 1 and/or 2.

o. Claim 23: "The method of claim 1, wherein the sorbent is free of contact with a halogen or halide promoter prior to the addition of the sorbent to the mercury-containing gas."

632. 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.

p. Claim 24: "The method of claim 6, wherein the measurement of the mercury content of the mercury-containing gas comprises continuous measurement."

633. As discussed above for Claim 6, each of Sjostrom and Olson-646 expressly discloses measuring mercury content of the mercury-containing gas "continuously." Olson-646 also discloses a "Continuous Emission Monitor" to measure mercury content.[1028]

[1028] EX1012 (Olson-646) ¶ [0060].

q. Claim 25: "The method of claim 1, wherein the coal comprises subbituminous coal."

634. This claim is disclosed by each of Sjostrom and Olson-646. Sjostrom is titled "Full Scale Evaluations of Mercury Control Technologies with PRB Coals."[1029] Sjostrom further discloses use of "Subbituminous (PRB)" coal.[1030] Olson-646 also discloses an example wherein "[t]ests were conducted on a pilot-scale combustor while firing a subbituminous coal, to evaluate mercury control by injecting larger-than-normal sized treated activated carbon."[1031]

r. Claim 26: "The method of claim 1, wherein the coal comprises lignite coal."

635. This claim is disclosed by each of Sjostrom and Olson-646. Sjostrom discloses use of "Lignite Coals," such as "Coal Creek – Lignite," "Stanton – Lignite," "Leland Olds – Lignite," and "North Dakota Lignite."[1032] Olson-646 also discloses an example wherein "[t]ests were conducted on the pilot-scale PTC combustor described above with reference to Example 6 while firing a Texas lignite

[1029] EX1010 (Sjostrom) at 1.

[1030] EX1010 (Sjostrom) at 3; *see also* EX1010 (Sjostrom) at 20 (slide titled "Untreated PAC Injection into ESP PRB and Lignite Coals").

[1031] EX1012 (Olson-646) ¶ [0106].

[1032] EX1010 (Sjostrom) at 20, 31, 32.

to evaluate mercury control by co-injecting a standard activated carbon (also referred to herein as 'AC') and an alkali material upstream of a fabric filter."[1033]

s. Claim 27: "The method of claim 1, wherein the mixture is combusted in a combustion chamber of a coal-combustion facility upstream of a scrubber, a particulate control system, or a combination thereof, wherein the particulate sorbent is added to the mercury-containing gas before the mercury-containing gas encounters the scrubber, the particulate control system, or the combination thereof."

636. 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."[1034] A POSITA would recognize this description as an instruction to position sorbent injection upstream of a particulate control system to allow the mercury-laden sorbent to be collected.

[1033] EX1012 (Olson-646) ¶ [0127]; *see also* EX1012 (Olson-646) ¶ [0124] ("In one exemplary test conducted at a facility fired with lignite coal . . . .").

[1034] EX1012 (Olson-646) ¶[0007].

t. Claim 28: "The method of claim 26, wherein the particulate control system comprises an electrostatic precipitator, a baghouse, a fabric filter, or a combination thereof."

637. As discussed above for Claim 27, Sjostrom and Olson-646 expressly discloses wherein the particulate control system comprises an electrostatic precipitator (both), a fabric filter (Sjostrom), and a baghouse (Olson-646).[1035]

u. Claim 29: "The method of claim 19, wherein the combustion chamber is a coal combustion furnace."

638. Claim 29 would have been obvious for the reasons discussed above for Claim Element 1(a) and Ground B1. The combustion chamber in Sjostrom is a coal-combustion furnace. This limitation is further rendered obvious by Olson-646, which expressly references a furnace.[1036]

3. Independent Claim 14

639. Claim 14 copies Claim 1, but modifies Element 1(a) slightly as shown in the redline below:

[1035] EX1012 (Olson-646) ¶[0007].

[1036] EX1012 (Olson-646) ¶[0113].

~~1~~14. A method for treating a mercury-containing gas, the method comprising:

combusting coal in a ~~mixture~~combustor comprising ~~coal,~~ pyrolysis char~~,~~ and an additive comprising HBr, a bromide compound, or a combination thereof, to form the mercury-containing~~,~~ gas; and

adding a particulate sorbent material comprising activated carbon into the mercury-containing gas.

I discuss these differences below.

a. Claim 14: Preamble—"A method for treating a mercury-containing gas, the method comprising:"

640. The language of the preamble of Claim 14 is identical to the preamble of Claim 1. This limitation is disclosed for the same reasons as stated above for Claim 1.

b. Claim 14: Element 14(a)—"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; and"

641. The language of Claim Element 14(a) is nearly 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 14(a). As discussed above for Claim Element 1(a), Sjostrom discloses that the mixture is combusted in a boiler/furnace (i.e., "a combustor").

c. Claim 14: Element 14(b)—"adding a particulate sorbent material comprising activated carbon into the mercury-containing gas"

642. The language of Claim Element 14(b) 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 14(a).

4. Claims Depending from Claim 14

a. Claim 15: "The method of claim 14, wherein the pyrolysis char is a promoted pyrolysis char."

643. Claim 15 is obvious for the same reasons discussed above for Claim 2.

5. Independent Claim 17

644. Claim 17 copies Claim 1, but modifies Element 1(b) to remove "particulate" as shown in the redline below:

~~1~~17. A method for treating a mercury-containing gas, the method comprising:

combusting a mixture comprising coal, pyrolysis char, and an additive comprising HBr, a bromide compound, or a combination thereof, to form the mercury-containing~~,~~ gas; and

adding a ~~particulate~~ sorbent material comprising activated carbon into the mercury-containing gas.

645. Accordingly, the explanation I provide above for Claim 1 applies equally to Claim 17.

XVIII. GROUND B3: ANTICIPATION BY OLSON-235

646. Because the priority date of the '225 Patent is no earlier than May 2015, Olson-235 qualifies as a prior art anticipatory reference. It is my opinion that Claims 1-2, 5-15, 17-18, 22-24, and 27-29 of the '225 Patent are anticipated by Olson-235.

1. Independent Claim 1

a. Claim 1: Preamble—"A method for treating a mercury-containing gas, the method comprising:"

647. Olson-235 discloses the claim language nearly verbatim: "A method for separating mercury from a mercury-containing gas."[1037] A POSITA would have understood that "separating mercury from a mercury-containing gas" constitutes "treating a mercury-containing gas."

[1037] EX1018 (Olson-235) at 21:59-60.

b. Claim 1: Element 1(a)—"combusting a mixture comprising coal, pyrolysis char, and an additive comprising HBr, a bromide compound, or a combination thereof, to form the mercury-containing, gas; and"

648. Olson-235 discloses "a combustion chamber that produces a mercury-containing gas."[1038] The "combustion chamber 301" combusts coal to provide the mercury-containing gas.[1039]

649. Olson-235 discloses that the "halogen or halide promoter is introduced … into a combustion chamber that produces a mercury-containing gas."[1040] Olson-235 refers to the "halide/halogen gas, for example, gaseous HBr or Br_2."[1041]

650. As discussed for Element 1(a) of Grounds B1-B2 above, the mixture inherently comprises pyrolysis char as a result of the combustion of the coal.

c. Claim 1: Element 1(b)—"adding a particulate sorbent material comprising activated carbon into the mercury-containing gas."

651. Olson-235 discloses the claim language near-verbatim:

[1038] EX1018 (Olson-235) at 22:39-42.

[1039] EX1018 (Olson-235) at 17:60-18:25 & Figs. 5A-5B.

[1040] EX1018 (Olson-235) at 22:39-42.

[1041] EX1018 (Olson-235) at 15:34-35; see also EX1018 (Olson-235) at 15:60-61.

- "providing a base sorbent, either by injection or in situ creation, into a mercury-containing flue gas stream"[1042]
- "carbon base sorbent may include powdered activated carbon."[1043]

2. Claims Depending from Claim 1

a. Claim 2: "The method of claim 1, wherein the pyrolysis char is a promoted pyrolysis char."

652. According to Patent Owner's expert in the Delaware litigation, "pyrolysis char forms in the presence of bromine that has been added to the coal. Thus, it is promoted pyrolysis char."[1044]

b. Claim 5: "The method of claim 1, further comprising using a particle separation device to remove mercury from the flue gas and comprising collecting greater than 70 wt % of the mercury in the mercury-containing gas to produce a cleaned gas."

653. 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."[1045] Olson-235 discloses that the "base sorbent…is

[1042] EX1018 (Olson-235) at 5:31-33.

[1043] EX1018 (Olson-235) at 10:53-55.

[1044] EX1092 (O'Keefe Report) at 163.

[1045] EX1018 (Olson-235) at 5:33-35.

introduced at location 402 upstream of air heater 302."[1046] "Downstream from injection point 116 and 119 [for the sorbent] is provided particulate separator 140…[which] may comprise one or more fabric filters, [or] one or more ESPs…."[1047] Fabric filters and ESPs are examples of particle separation devices. The "collecting" the mercury in the flue gas involves "removing" that mercury from the flue gas by using a particle separation device to collect the mercury-laden sorbent.

c. Claim 6: "The method of claim 5, further comprising: measuring the mercury content of the mercury-containing gas; and modifying, in response to the measured mercury content: an injection rate of injecting the sorbent into the mercury-containing gas, an amount of the additive in the mixture, or a combination thereof."

654. Olson-235 discloses the claim language nearly verbatim: "continuous measurement of mercury emissions as feedback to assist in control of the sorbent injection rate."[1048] A POSITA would have understood that "monitoring" as described by Olson-235 meant "measuring" the mercury content of the mercury-containing gas.

[1046] EX1018 (Olson-235) at 18:33-35.

[1047] EX1018 (Olson-235) at 14:4-8.

[1048] EX1018 (Olson-235) at 20:1-5; *see also* EX1018 (Olson-235) at 6:55-57, 7:8-20.

655. Olson-235 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."[1049] The "rate at which the carbon base sorbent is introduced" refers to an injection rate of injecting the sorbent into the mercury-containing gas.

d. Claim 7: "The method of claim 1, wherein the additive further comprises Br_2."

656. Olson-235 discloses Claim 7. As discussed above for Element 1(a), the additive further comprises Br_2. Olson-235 discloses that "the promoter is selected from the group consisting of Br_2 …."[1050]

e. Claim 8: "The method of claim 1, wherein the sorbent material is chosen from powdered activated carbon, granular activated carbon, carbon black, carbon fiber, aerogel carbon, pyrolysis char, and combinations thereof."

657. Olson-235 includes language almost identical to the claim language.[1051]

[1049] EX1018 (Olson-235) at 6:64-67, 7:17-20.

[1050] EX1018 (Olson-235) at 5:9-11.

[1051] EX1018 (Olson-235) at 10:53-55.

f. Claim 9: "The method of claim 1, further comprising adding an alkaline component to the mercury-containing gas, the alkaline component chosen from alkali elements, alkaline earth elements, alkali salts, alkaline earth salts, and combinations thereof."

658. Olson-235 teaches "coinjecting an optional alkaline material, including without limitation alkaline and alkaline-earth components," such as "calcium oxide [and] sodium carbonate" "to improve the efficiency of mercury capture by capturing oxidized mercury and/or capturing gaseous components that might otherwise reduce promoted sorbent capacity."[1052] The examples provided in Olson-646 of "sodium carbonate" (Na_2CO_3) and "calcium oxide" (CaO) are examples of an alkali salt (Na_2CO_3) and alkaline earth salt (calcium oxide). A POSITA would have been motivated to co-inject alkaline components, such as sodium carbonate and calcium oxide, to "improve the efficiency of mercury capture" as taught by Olson-235.

g. Claim 10: "The method of claim 1, further comprising contacting the sorbent material with a mercury-stabilizing reagent chosen from S, Se, H_2S, SO_2, H_2Se, SeO_2, CS_2, P_2S_5, and combinations thereof."

659. Olson-235 discloses this limitation nearly verbatim:

> In another embodiment, the promoter and optional secondary component are combined with the base sorbent substantially simultaneously. Another embodiment further comprises adding a mercury-stabilizing reagent selected from the group consisting

[1052] EX1018 (Olson-235) at 6:5-13; *see also* 4:36-38, 51-52, cls. 26-27.

of S, Se, H_2S, SO_2, H_2Se, SeO_2, CS_2, P_2S_5, and combinations thereof.[1053]

h. Claim 11: "The method of claim 1, further comprising contacting the sorbent material with a secondary component chosen from halogens, hydrogen halides, Group V halides, Group VI halides, and combinations thereof."

660. Olson-235 discloses co-injecting a "secondary component to enhance the reactivity and capacity of the promoted sorbent" downstream of the combustion chamber.[1054] Olson-235 further discloses "the optional secondary component is selected from the group consisting of Group V halides, Group VI halides, HI, HBr, HCl, and combinations thereof."[1055]

i. Claim 12: "The method of claim 11, wherein the secondary component is chosen from halogens, halide salts, HI, HBr, HCl, and combinations thereof."

661. As discussed for Claim 11, Olson-235 discloses the secondary component can be "halogens, …, HI, HBr, HCl, and combinations thereof."[1056]

[1053] EX1018 (Olson-235) at 4:48-51; *see also* 5:16-21, 6:1-4, 15:56-63.

[1054] EX1018 (Olson-235) at 5:56-62, 13:10-42, Fig. 3.

[1055] EX1018 (Olson-235) at 4:39-41, cl. 21.

[1056] EX1018 (Olson-235) at 4:39-41, cl. 21.

j. Claim 13: "The method of claim 11, wherein the secondary component is chosen from I_2, HI, and combinations thereof."

662. As discussed for Claim 11, Olson-235 discloses the secondary component can be "HI."[1057]

k. Claim 18: "The method of claim 1, further comprising modifying, in response to a measured mercury content, an injection rate of injecting the sorbent into the mercury-containing gas, an amount of the additive in the mixture, or a combination thereof."

663. Claim 18 is disclosed for the reasons discussed for Claim 6.

l. Claim 22: "The method of claim 1, wherein the sorbent is contacted with a halogen or halide promoter prior to the addition of the sorbent to the mercury-containing gas."

664. 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."[1058]
>
> [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.[1059]

[1057] EX1018 (Olson-235) at 4:39-41, cl. 21.

[1058] EX1018 (Olson-235) at 22:15-20.

[1059] EX1018 (Olson-235) at 14:30-34.

m. Claim 23: "The method of claim 1, wherein the sorbent is free of contact with a halogen or halide promoter prior to the addition of the sorbent to the mercury-containing gas."

665. Olson-235 discloses injecting sorbent into the mercury-containing gas that is free of contact with a halogen or halide promoter prior to injection of the sorbent into the mercury-containing gas:

> Referring still to FIG. 1, another preferred embodiment of the process of the present invention is illustrated by path 10-50 in combination with path 20-50. In this embodiment, 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. Thus the base sorbent and promoter react at block 50 to produce a product promoted sorbent.[1060]

n. Claim 24: "The method of claim 6, wherein the measurement of the mercury content of the mercury-containing gas comprises continuous measurement."

666. As discussed above for Claim 6, Olson-235 expressly discloses measuring mercury content of the mercury-containing gas "continuously."

[1060] EX1018 (Olson-235) at 10:29-37; *see also* EX1018 (Olson-235) at Fig. 1, Fig. 3.

o. Claim 27: "The method of claim 1, wherein the mixture is combusted in a combustion chamber of a coal-combustion facility upstream of a scrubber, a particulate control system, or a combination thereof, wherein the particulate sorbent is added to the mercury-containing gas before the mercury-containing gas encounters the scrubber, the particulate control system, or the combination thereof."

667. Olson-235 discloses a coal-combustion facility, including "a combustion chamber that produces a mercury-containing gas."[1061] "[C]ombustion chamber 301" combusts coal to provide the mercury-containing gas.[1062] Olson-235 discloses "providing a base sorbent, either by injection or in situ creation, into a mercury-containing flue gas stream"[1063] It further discloses that "[d]ownstream from injection point 116 and 119 [for the sorbent] is provided particulate separator 140."[1064] A POSITA would have understood that "particulate separator 140" is a particulate control system.

[1061] EX1018 (Olson-235) at 22:39-42.

[1062] EX1018 (Olson-235) at 17:60-18:25, Figs. 5A-5B.

[1063] EX1018 (Olson-235) at 5:31-33; see also EX1018 (Olson-235) at 18:33-35.

[1064] EX1018 (Olson-235) at 14:4-5.

p. Claim 28: "The method of claim 26, wherein the particulate control system comprises an electrostatic precipitator, a baghouse, a fabric filter, or a combination thereof."

668. Olson-235 discloses that "particulate separator 140 may comprise one or more fabric filters, [or] one or more ESPs, or other particulate removal devices as are known in the art."[1065]

q. Claim 29: "The method of claim 19, wherein the combustion chamber is a coal combustion furnace."

669. Claim 29 is disclosed by Olson-235 for the reasons discussed above in Claim Element 1(a). Olson-235 further states:

> As shown, chamber 301 is a boiler, however, one skilled in the art will appreciate that chamber 301 can also be the combustion chamber or any other chamber in which mercury containing gas is either generated or passed through.[1066]

3. Independent Claim 14

670. Claim 14 copies Claim 1, but modifies Element 1(a) slightly as shown in the redline below:

[1065] EX1018 (Olson-235) at 14:4-8.

[1066] EX1018 (Olson-235) at 18:17-22.

~~1~~14. A method for treating a mercury-containing gas, the method comprising:

combusting coal in a ~~mixture~~combustor comprising ~~coal,~~ pyrolysis char~~,~~ and an additive comprising HBr, a bromide compound, or a combination thereof, to form the mercury-containing~~,~~ gas; and

adding a particulate sorbent material comprising activated carbon into the mercury-containing gas.

I discuss these differences below.

a. Claim 14: Preamble—"A method for treating a mercury-containing gas, the method comprising:"

671. The language of the preamble of Claim 14 is identical to the preamble of Claim 1. This limitation is disclosed for the same reasons as stated above for Claim 1.

b. Claim 14: Element 14(a)—"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; and"

672. The language of Claim Element 14(a) is nearly 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 14(a). As discussed above for Claim Element 1(a), Olson-235 discloses that the mixture is combusted in "a combustion chamber" (i.e., "a combustor").

c. Claim 14: Element 14(b)—"adding a particulate sorbent material comprising activated carbon into the mercury-containing gas"

673. The language of Claim Element 14(b) 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 14(a).

4. Claims Depending from Claim 14

a. Claim 15: "The method of claim 14, wherein the pyrolysis char is a promoted pyrolysis char."

674. Claim 15 is inherent for the same reasons discussed above for Claim 2.

5. Independent Claim 17

675. Claim 17 copies Claim 1, but modifies Element 1(b) to remove "particulate" as shown in the redline below:

~~1~~17. A method for treating a mercury-containing gas, the method comprising:

combusting a mixture comprising coal, pyrolysis char, and an additive comprising HBr, a bromide compound, or a combination thereof, to form the mercury-containing~~,~~ gas; and

adding a ~~particulate~~ sorbent material comprising activated carbon into the mercury-containing gas.

676. Accordingly, the explanation I provide above for Claim 1 applies equally to Claim 17.

XIX. CONCLUSION

677. 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 March 4, 2025

Dr. Stephen Niksa