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. IPR2025-00687 and IPR2025-00688
Patent No. 10,933,370

DECLARATION OF DR. STEPHEN NIKSA

TABLE OF CONTENTS

I. INTRODUCTION 20
II. EDUCATION AND PROFESSIONAL EXPERIENCE 21
III. THE CHALLENGED CLAIMS OF THE '370 PATENT 22
IV. SCOPE OF WORK AND MATERIALS REVIEWED 25
V. LIST OF EXHIBITS 26
VI. SUMMARY OF CONCLUSIONS AND GROUNDS FOR CHALLENGE 39
A. Based On References That Qualify As Prior Art Before Aug. 30, 2004 39
B. Based on References that Qualify as Prior Art After Aug. 30, 2004 40
VII. LEGAL STANDARDS 40
A. Level of Ordinary Skill in the Art 41
B. Legal Standard for Claim Construction 42
C. Legal Standard for Prior Art 45
D. Legal Standard for Patentability 47
1. Anticipation and Inherency 47
2. Obviousness 48
VIII. LEVEL OF ORDINARY SKILL IN THE ART 53
IX. TECHNOLOGY BACKGROUND AND STATE OF THE ART 54
A. Fundamental Principles of Chemistry 54
1. Periodic Table and Chemical Notation 54
2. Groups in the Periodic Table 56
3. Oxidation and Oxidation Number 56
4. Group I (Alkali Elements), Group II (Alkaline Earth Elements), and Alkali Substances 57
5. Group IV (Carbon) 58
6. Group V and Group VI Elements 58
7. Group VII Elements (Halogens) 58
8. Mercury 61

9. Common Units of Measurements 62
B. Coal Power Plants And Associated Units 63
1. Types of Coal 63
2. Combustion Chamber and Boiler 65
3. Components Typically Upstream of the Combustion Chamber 69
4. Flue Gas Constituents 70
5. Components Downstream of the Combustion Chamber 75
C. Sorbents / Activated Carbon 82
1. Sorbent Overview 82
2. Well-Known Structure of Activated Carbon 87
3. Reaction Between Activated Carbon and Halogens 91
4. Reaction Between Activated Carbon and Mercury 93
5. Removing Mercury by Controlling Sorbent Injection Rate 95
D. Regulations to Reduce Mercury Emissions 98
E. DOE and NETL 102
F. Additional Market Demand and Industry Trends 103
G. Enhancing Mercury Removal by Promoting Activated Carbon 106
1. Alkali Promoters of Activated Carbon 108
2. Halogen Promoters of Activated Carbon 108
X. OVERVIEW OF THE CHALLENGED PATENT FAMILY 122
A. Specification of the ’370 Patent 122
B. Family Tree 126
C. Prosecution History of the ’370 Patent 127
1. Filing of Application No. 15/951,970 (U.S. Patent No. 10,933,370) 128
2. Subsequent Prosecution History 131
D. Priority Date of the Challenged Claims of the ’370 Patent 137
1. The Provisional Does Not Support the ’370 Patent Claim Limitations 138

2. The ’558, ’270, ’768, ’665, ’219, ’595, and ’163 Applications in the ’370 Patent Chain also Do Not Support the ’370 Patent Claims....144
3. The Claims of U.S. Patent No. 8,168,147 (EX1065) Are Not Supported by Its Specification....153
E. Admitted Prior Art....173
XI. CLAIM CONSTRUCTION....175
XII. OVERVIEW OF THE PRIOR ART....177
A. The Vosteen589 Patent Publication [EX1005]....177
1. Prior-Art Status of Vosteen589....177
2. Vosteen589 Is Analogous Art....177
3. Overview of the Disclosure of Vosteen589....178
B. The Downs-Boiler Reference [EX1006]....180
1. Prior-Art Status of the Downs-Boiler Reference....180
2. Downs-Boiler Is Analogous Art....181
3. Overview of the Disclosure of Downs-Boiler....182
4. Comparison of Downs-Boiler [EX1006] to Downs-Boiler-Provisional [EX1007]....184
C. The Lissianski Reference [EX1014]....191
1. Prior-Art Status of Lissianski....192
2. Lissianski is Analogous Art....192
3. Overview of the Disclosure of Lissianski....193
D. AWMA Conference (2002) – Starns [EX1008]....196
1. Prior Art Status of Starns....200
2. Starns Is Analogous Art and Overview of the Disclosure....206
E. Mass-EPA [EX1009]....208
1. Prior Art Status of Mass-EPA....208
2. Mass-EPA Is Analogous Art and Overview of the Disclosure....215
F. EUEC Conference (2005) – Sjostrom [EX1010] and Eckberg [EX1011]....217
1. Prior Art Status of the 2005 EUEC Presentations....220

2. Sjostrom Is Analogous Art and Overview of the Disclosure 225
3. Eckberg Is Analogous Art and Overview of the Disclosure 233
G. The Olson-646 Reference [EX1012] 236
1. Prior-Art Status of the Olson-646 Reference.....236
2. Olson-646 Is Analogous Art 236
3. Overview of the Disclosure of Olson-646 237
H. The Baldrey Reference [EX1015].....241
1. Prior-Art Status of the Baldrey Reference 241
2. Baldrey Is Analogous Art 242
3. Overview of the Disclosure of Baldrey 243
XIII. GROUND A1 AND GROUND A2: OBVIOUSNESS OVER VOSTEEN589 IN VIEW OF STARNS [GROUND A1] AND VOSTEEN589 IN VIEW OF MASS-EPA [GROUND A2] 245
A. Reasons to Combine 245
1. Ground A1 (Combination of Vosteen589 with Starns).....248
2. Ground A2 (Combination of Vosteen589 with Mass-EPA).....253
B. Disclosure and Teachings of the Combinations 257
C. Independent Claim 1.....257
1. Claim 1: Preamble—"A method for separating mercury from a mercury-containing gas, the method comprising" 257
2. Claim 1: Element 1(a)—"combusting a mixture of coal and an additive in a combustion chamber, to form the mercury-containing gas, wherein the additive is chosen from halides, halogens, salts thereof, and combinations thereof;".....259
3. Claim 1: Element 1(b)—"adding a particulate sorbent material comprising activated carbon into the mercury-containing gas," 264
4. Claim 1: Element 1(c)—"wherein a weight ratio of the additive added to the coal, added to the combustion chamber, or a combination thereof, to an amount of the sorbent material added to the mercury-containing gas is from about 1:100 to about 30:100;".....274

5. Claim 1: Element 1(d)—"contacting mercury in the mercury-containing gas with the sorbent material, to form a mercury-sorbent; and".....283
6. Claim 1: Element 1(e)—"separating the mercury-sorbent from the mercury-containing gas." 285

D. Claims Depending from Claim 1 289

1. Claim 2: "The method of claim 1, further comprising adding the additive to the coal before combusting the coal." 289
2. Claim 3: "The method of claim 2, wherein the additive mixed with the coal is in a liquid." 289
3. Claim 4: "The method of claim 3, wherein the liquid is a hydrocarbon, supercritical carbon dioxide, water, salt solution, or a combination thereof.".....290
4. Claim 5: The method of claim 1, wherein carbocations in the activated carbon of the mercury-sorbent accept electrons from mercury atoms of the mercury-sorbent.....290
5. Claim 6: "The method of claim 1, wherein the additive is substantially in vapor form in the mercury-containing gas." 290
6. Claim 7: "The method of claim 1, wherein the additive is chosen from Cl_2, HCl, sodium chloride, calcium chloride, and a combination thereof." 292
7. Claim 8: "The method of claim 1, wherein the additive is chosen from Br_2, HBr, sodium bromide, calcium bromide, and a combination thereof." 294
8. Claim 10: "The method of claim 1, wherein the additive is chosen from I_2, HI, sodium iodide, calcium iodide, potassium iodide, and combinations thereof.".....295
9. Claim 11: "The method of claim 1, wherein the activated carbon is chosen from powdered activated carbon, granular activated carbon, carbon black, carbon fiber, aerogel carbon, pyrolysis char, and combinations thereof." 297
10. Claim 12: "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.” 298

11. Claim 13: “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.” 300
12. Claim 14: “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.” 301
13. Claim 15: “The method of claim 14, wherein the secondary component is chosen from halogens, halide salts, HI, HBr, HCl, and combinations thereof.” 304
14. Claim 16: “The method of claim 14, wherein the secondary component is chosen from I_2, HI, and combinations thereof.” 304
15. Claim 18: “The method of claim 1, wherein the additive comprises a and b, b and c, a and c, or a, b, and c: a) I^- and/or I_2, b) Br^- and/or Br_2, c) Cl^- and/or Cl_2.” 304

E. Independent Claim 17 305

1. Claim 17: Preamble—“A method for separating mercury from a mercury-containing gas, the method comprising:” 306
2. Claim 17: Element 17(a)—“combusting coal comprising an additive in a combustion chamber, wherein the additive is chosen from halides, halogens, salts thereof, and combinations thereof, to form the mercury-containing gas, wherein the additive comprises a and b, b and c, a and c, or a, b, and c: a) I^- and/or I_2, b) Br^- and/or Br_2, c) Cl^- and/or Cl_2;” 307
3. Claim 17: Element 17(b)—“injecting a sorbent material comprising activated carbon into the mercury-containing gas,” 307
4. Claim 17: Element 17(c)—“wherein a weight ratio of the additive added to the coal, added to the combustion chamber, or a combination thereof, to an amount of the sorbent material added to the mercury-containing gas is from about 1:100 to about 30:100;” 308

5. Claim 17: Element 17(d)—"contacting mercury in the mercury-containing gas with the sorbent material, to form a mercury-sorbent; and".....308
6. Claim 17: Element 17(e)—"separating the mercury-sorbent from the mercury-containing gas."....308

XIV. GROUND A3 AND GROUND A4: OBVIOUSNESS OVER DOWNS-BOILER IN VIEW OF STARNS [GROUND A3] AND DOWNS-BOILER IN VIEW OF MASS-EPA [GROUND A4] 309

A. Reasons to Combine.....309
1. Ground A3 (Combination of Downs-Boiler with Starns).....311
2. Ground A4 (Combination of Downs-Boiler with Mass-EPA).....315

B. Disclosure and Teachings of the Combinations.....319

C. Independent Claim 1.....319
1. Claim 1: Preamble—"A method for separating mercury from a mercury-containing gas, the method comprising".....319
2. Claim 1: Element 1(a)—"combusting a mixture of coal and an additive in a combustion chamber, to form the mercury-containing gas, wherein the additive is chosen from halides, halogens, salts thereof, and combinations thereof;".....320
3. Claim 1: Element 1(b)—"adding a particulate sorbent material comprising activated carbon into the mercury-containing gas,".....328
4. Claim 1: Element 1(c)—"wherein a weight ratio of the additive added to the coal, added to the combustion chamber, or a combination thereof, to an amount of the sorbent material added to the mercury-containing gas is from about 1:100 to about 30:100;".....331
5. Claim 1: Element 1(d)—"contacting mercury in the mercury-containing gas with the sorbent material, to form a mercury-sorbent; and".....339
6. Claim 1: Element 1(e)—"separating the mercury-sorbent from the mercury-containing gas.".....341

D. Claims Depending from Claim 1.....342
1. Claim 2: "The method of claim 1, further comprising adding the additive to the coal before combusting the coal.".....342

2. Claim 3: "The method of claim 2, wherein the additive mixed with the coal is in a liquid." 343
3. Claim 4: "The method of claim 3, wherein the liquid is a hydrocarbon, supercritical carbon dioxide, water, salt solution, or a combination thereof."..... 344
4. Claim 5: The method of claim 1, wherein carbocations in the activated carbon of the mercury-sorbent accept electrons from mercury atoms of the mercury-sorbent. 344
5. Claim 6: "The method of claim 1, wherein the additive is substantially in vapor form in the mercury-containing gas." 344
6. Claim 8: "The method of claim 1, wherein the additive is chosen from Br_2, HBr, sodium bromide, calcium bromide, and a combination thereof." 348
7. Claim 11: "The method of claim 1, wherein the activated carbon is chosen from powdered activated carbon, granular activated carbon, carbon black, carbon fiber, aerogel carbon, pyrolysis char, and combinations thereof." 348
8. Claim 12: "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."..... 349
9. Claim 14: "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." 351
10. Claim 15: "The method of claim 14, wherein the secondary component is chosen from halogens, halide salts, HI, HBr, HCl, and combinations thereof." 351
11. Claim 16: "The method of claim 14, wherein the secondary component is chosen from I_2, HI, and combinations thereof."..... 352

XV. GROUND A5 AND GROUND A6: OBVIOUSNESS OVER LISSIANSKI IN VIEW OF STARNS [GROUND A5] AND LISSIANSKI IN VIEW OF MASS-EPA [GROUND A6] 352

A. Reasons to Combine 352

1. Ground A5 (Combination of Lissianski with Starns).....357
2. Ground A6 (Combination of Lissianski with Mass-EPA) 360

B. Disclosure and Teachings of the Combinations 364

C. Independent Claim 1.....364

1. Claim 1: Preamble—"A method for separating mercury from a mercury-containing gas, the method comprising" 364
2. Claim 1: Element 1(a)—"combusting a mixture of coal and an additive in a combustion chamber, to form the mercury-containing gas, wherein the additive is chosen from halides, halogens, salts thereof, and combinations thereof;".....366
3. Claim 1: Element 1(b)—"adding a particulate sorbent material comprising activated carbon into the mercury-containing gas," 369
4. Claim 1: Element 1(c)—"wherein a weight ratio of the additive added to the coal, added to the combustion chamber, or a combination thereof, to an amount of the sorbent material added to the mercury-containing gas is from about 1:100 to about 30:100;".....374
5. Claim 1: Element 1(d)—"contacting mercury in the mercury-containing gas with the sorbent material, to form a mercury-sorbent; and".....383
6. Claim 1: Element 1(e)—"separating the mercury-sorbent from the mercury-containing gas." 384

D. Claims Depending from Claim 1 388

1. Claim 5: The method of claim 1, wherein carbocations in the activated carbon of the mercury-sorbent accept electrons from mercury atoms of the mercury-sorbent.....388
2. Claim 6: "The method of claim 1, wherein the additive is substantially in vapor form in the mercury-containing gas." 388
3. Claim 11: "The method of claim 1, wherein the activated carbon is chosen from powdered activated carbon, granular activated carbon, carbon black, carbon fiber, aerogel carbon, pyrolysis char, and combinations thereof." 389
4. Claim 12: "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.” 390

5. Claim 14: “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.” 391
6. Claim 15: “The method of claim 14, wherein the secondary component is chosen from halogens, halide salts, HI, HBr, HCl, and combinations thereof.” 392
7. Claim 16: “The method of claim 14, wherein the secondary component is chosen from I_2, HI, and combinations thereof.” 392

XVI. GROUND B1: ANTICIPATION BY BALDREY 392

A. Independent Claim 1 393

1. Claim 1: Preamble—“A method for separating mercury from a mercury-containing gas, the method comprising” 393
2. Claim 1: Element 1(a)—“combusting a mixture of coal and an additive in a combustion chamber, to form the mercury-containing gas, wherein the additive is chosen from halides, halogens, salts thereof, and combinations thereof;” 394
3. Claim 1: Element 1(b)—“adding a particulate sorbent material comprising activated carbon into the mercury-containing gas,” 397
4. Claim 1: Element 1(c)—“wherein a weight ratio of the additive added to the coal, added to the combustion chamber, or a combination thereof, to an amount of the sorbent material added to the mercury-containing gas is from about 1:100 to about 30:100;” 398
5. Claim 1: Element 1(d)—“contacting mercury in the mercury-containing gas with the sorbent material, to form a mercury-sorbent; and” 403
6. Claim 1: Element 1(e)—“separating the mercury-sorbent from the mercury-containing gas.” 404

B. Claims Depending from Claim 1 405

1. Claim 2: “The method of claim 1, further comprising adding the additive to the coal before combusting the coal.” 405

2. Claim 3: "The method of claim 2, wherein the additive mixed with the coal is in a liquid." 406
3. Claim 4: "The method of claim 3, wherein the liquid is a hydrocarbon, supercritical carbon dioxide, water, salt solution, or a combination thereof."..... 407
4. Claim 6: "The method of claim 1, wherein the additive is substantially in vapor form in the mercury-containing gas." 408
5. Claim 7: "The method of claim 1, wherein the additive is chosen from Cl_2, HCl, sodium chloride, calcium chloride, and a combination thereof." 409
6. Claim 8: "The method of claim 1, wherein the additive is chosen from Br_2, HBr, sodium bromide, calcium bromide, and a combination thereof." 409
7. Claim 10: "The method of claim 1, wherein the additive is chosen from I_2, HI, sodium iodide, calcium iodide, potassium iodide, and combinations thereof."..... 410
8. Claim 11: "The method of claim 1, wherein the activated carbon is chosen from powdered activated carbon, granular activated carbon, carbon black, carbon fiber, aerogel carbon, pyrolysis char, and combinations thereof." 410
9. Claim 13: "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." 410
10. Claim 14: "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." 412
11. Claim 15: "The method of claim 14, wherein the secondary component is chosen from halogens, halide salts, HI, HBr, HCl, and combinations thereof." 414
12. Claim 16: "The method of claim 14, wherein the secondary component is chosen from I_2, HI, and combinations thereof."..... 414
13. Claim 18: "The method of claim 1, wherein the additive comprises a and b, b and c, a and c, or a, b, and c: a) I^- and/or I_2, b) Br^- and/or Br_2, c) Cl^- and/or Cl_2."..... 414

C. Independent Claim 17 415

1. Claim 17: Preamble—"A method for separating mercury from a mercury-containing gas, the method comprising:" 416
2. Claim 17: Element 17(a)—"combusting coal comprising an additive in a combustion chamber, wherein the additive is chosen from halides, halogens, salts thereof, and combinations thereof, to form the mercury-containing gas, wherein the additive comprises a and b, b and c, a and c, or a, b, and c: a) I^- and/or I_2, b) Br^- and/or Br_2, c) Cl^- and/or Cl_2;" 416
3. Claim 17: Element 17(b)—"injecting a sorbent material comprising activated carbon into the mercury-containing gas," 416
4. Claim 17: Element 17(c)—"wherein a weight ratio of the additive added to the coal, added to the combustion chamber, or a combination thereof, to an amount of the sorbent material added to the mercury-containing gas is from about 1:100 to about 30:100;" 417
5. Claim 17: Element 17(d)—"contacting mercury in the mercury-containing gas with the sorbent material, to form a mercury-sorbent; and" 417
6. Claim 17: Element 17(e)—"separating the mercury-sorbent from the mercury-containing gas." 417

XVII. GROUND B2: OBVIOUSNESS OVER BALDREY IN VIEW OF OLSON-646 418

A. Reasons to Combine 418

B. Disclosure and Teachings of the Combinations 423

C. Independent Claim 1 424

1. Claim 1: Element 1(b)—"adding a particulate sorbent material comprising activated carbon into the mercury-containing gas," 424
2. Claim 1: Element 1(c)—"wherein a weight ratio of the additive added to the coal, added to the combustion chamber, or a combination thereof, to an amount of the sorbent material added to the mercury-containing gas is from about 1:100 to about 30:100;" 424

3. Claim 1: Element 1(d)—"contacting mercury in the mercury-containing gas with the sorbent material, to form a mercury-sorbent; and".....426
4. Claim 1: Element 1(e)—"separating the mercury-sorbent from the mercury-containing gas." 428

D. Claims Depending from Claim 1 428

1. Claim 5: The method of claim 1, wherein carbocations in the activated carbon of the mercury-sorbent accept electrons from mercury atoms of the mercury-sorbent. 428
2. Claim 6: "The method of claim 1, wherein the additive is substantially in vapor form in the mercury-containing gas." 429
3. Claim 9: "The method of claim 1, wherein the additive is chosen from PBr_3, SCl_2, and a combination thereof." 430
4. Claim 12: "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." 430
5. Claim 13: "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." 432
6. Claim 14: "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." 432
7. Claim 15: "The method of claim 14, wherein the secondary component is chosen from halogens, halide salts, HI, HBr, HCl, and combinations thereof." 436
8. Claim 16: "The method of claim 14, wherein the secondary component is chosen from I_2, HI, and combinations thereof." 437

E. Other Claims 437

XVIII. GROUND B3: OBVIOUSNESS OVER SJOSTROM IN VIEW OF OLSON-646 437

A. Reasons to Combine 437

B. Disclosure and Teachings of the Combinations 445
C. Independent Claim 1.....445
1. Claim 1: Preamble—"A method for separating mercury from a mercury-containing gas, the method comprising" 445
2. Claim 1: Element 1(a)—"combusting a mixture of coal and an additive in a combustion chamber, to form the mercury-containing gas, wherein the additive is chosen from halides, halogens, salts thereof, and combinations thereof;".....447
3. Claim 1: Element 1(b)—"adding a particulate sorbent material comprising activated carbon into the mercury-containing gas," 453
4. Claim 1: Element 1(c)—"wherein a weight ratio of the additive added to the coal, added to the combustion chamber, or a combination thereof, to an amount of the sorbent material added to the mercury-containing gas is from about 1:100 to about 30:100;".....457
5. Claim 1: Element 1(d)—"contacting mercury in the mercury-containing gas with the sorbent material, to form a mercury-sorbent; and".....459
6. Claim 1: Element 1(e)—"separating the mercury-sorbent from the mercury-containing gas." 461
D. Claims Depending from Claim 1 462
1. Claim 2: "The method of claim 1, further comprising adding the additive to the coal before combusting the coal."....462
2. Claim 3: "The method of claim 2, wherein the additive mixed with the coal is in a liquid." 463
3. Claim 4: "The method of claim 3, wherein the liquid is a hydrocarbon, supercritical carbon dioxide, water, salt solution, or a combination thereof.".....463
4. Claim 5: The method of claim 1, wherein carbocations in the activated carbon of the mercury-sorbent accept electrons from mercury atoms of the mercury-sorbent.....463
5. Claim 6: "The method of claim 1, wherein the additive is substantially in vapor form in the mercury-containing gas." 464

6. Claim 7: "The method of claim 1, wherein the additive is chosen from Cl_2, HCl, sodium chloride, calcium chloride, and a combination thereof." 466
7. Claim 8: "The method of claim 1, wherein the additive is chosen from Br_2, HBr, sodium bromide, calcium bromide, and a combination thereof." 467
8. Claim 9: "The method of claim 1, wherein the additive is chosen from PBr_3, SCl_2, and a combination thereof."....467
9. Claim 10: "The method of claim 1, wherein the additive is chosen from I_2, HI, sodium iodide, calcium iodide, potassium iodide, and combinations thereof."....468
10. Claim 11: "The method of claim 1, wherein the activated carbon is chosen from powdered activated carbon, granular activated carbon, carbon black, carbon fiber, aerogel carbon, pyrolysis char, and combinations thereof." 469
11. Claim 12: "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."....470
12. Claim 13: "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." 471
13. Claim 14: "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." 474
14. Claim 15: "The method of claim 14, wherein the secondary component is chosen from halogens, halide salts, HI, HBr, HCl, and combinations thereof." 479
15. Claim 16: "The method of claim 14, wherein the secondary component is chosen from I_2, HI, and combinations thereof."....480
16. Claim 18: "The method of claim 1, wherein the additive comprises a and b, b and c, a and c, or a, b, and c: a) I^- and/or I_2, b) Br^- and/or Br_2, c) Cl^- and/or Cl_2."....481

E. Independent Claim 17 482

1. Claim 17: Preamble—"A method for separating mercury from a mercury-containing gas, the method comprising:" 482
2. Claim 17: Element 17(a)—"combusting coal comprising an additive in a combustion chamber, wherein the additive is chosen from halides, halogens, salts thereof, and combinations thereof, to form the mercury-containing gas, wherein the additive comprises a and b, b and c, a and c, or a, b, and c: a) I^- and/or I_2, b) Br^- and/or Br_2, c) Cl^- and/or Cl_2;" 483
3. Claim 17: Element 17(b)—"injecting a sorbent material comprising activated carbon into the mercury-containing gas," 483
4. Claim 17: Element 17(c)—"wherein a weight ratio of the additive added to the coal, added to the combustion chamber, or a combination thereof, to an amount of the sorbent material added to the mercury-containing gas is from about 1:100 to about 30:100;" 484
5. Claim 17: Element 17(d)—"contacting mercury in the mercury-containing gas with the sorbent material, to form a mercury-sorbent; and" 484
6. Claim 17: Element 17(e)—"separating the mercury-sorbent from the mercury-containing gas." 484

XIX. GROUND B4: OBVIOUSNESS OVER SJOSTROM IN VIEW OF OLSON-646, FURTHER IN VIEW OF ECKBERG 485

A. Reasons to Combine 485

B. Disclosure and Teachings of the Combinations 494

C. Independent Claim 1 494

1. Claim 1: Element 1(a)—"combusting a mixture of coal and an additive in a combustion chamber, to form the mercury-containing gas, wherein the additive is chosen from halides, halogens, salts thereof, and combinations thereof;" 494

D. Claims Depending from Claim 1 497

1. Claim 3: "The method of claim 2, wherein the additive mixed with the coal is in a liquid." 497

2. Claim 4: "The method of claim 3, wherein the liquid is a hydrocarbon, supercritical carbon dioxide, water, salt solution, or a combination thereof."....498
3. Claim 6: "The method of claim 1, wherein the additive is substantially in vapor form in the mercury-containing gas." 498
4. Claim 7: "The method of claim 1, wherein the additive is chosen from Cl_2, HCl, sodium chloride, calcium chloride, and a combination thereof." 501
5. Claim 8: "The method of claim 1, wherein the additive is chosen from Br_2, HBr, sodium bromide, calcium bromide, and a combination thereof." 501
6. Claim 18: "The method of claim 1, wherein the additive comprises a and b, b and c, a and c, or a, b, and c: a) I^- and/or I_2, b) Br^- and/or Br_2, c) Cl^- and/or Cl_2."....501

E. Independent Claim 17....502
1. Claim 17: Preamble—"A method for separating mercury from a mercury-containing gas, the method comprising:" 503
2. Claim 17: Element 17(a)—"combusting coal comprising an additive in a combustion chamber, wherein the additive is chosen from halides, halogens, salts thereof, and combinations thereof, to form the mercury-containing gas, wherein the additive comprises a and b, b and c, a and c, or a, b, and c: a) I^- and/or I_2, b) Br^- and/or Br_2, c) Cl^- and/or Cl_2;"....504
3. Claim 17: Element 17(b)—"injecting a sorbent material comprising activated carbon into the mercury-containing gas," 504
4. Claim 17: Element 17(c)—"wherein a weight ratio of the additive added to the coal, added to the combustion chamber, or a combination thereof, to an amount of the sorbent material added to the mercury-containing gas is from about 1:100 to about 30:100;" 505
5. Claim 17: Element 17(d)—"contacting mercury in the mercury-containing gas with the sorbent material, to form a mercury-sorbent; and"....505
6. Claim 17: Element 17(e)—"separating the mercury-sorbent from the mercury-containing gas."....505

F. Other Claims 506
XX. CONCLUSION 506

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. 10,933,370, which I may abbreviate as "the '370 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 '370 PATENT

8. The Challenged Claims of the '370 Patent, which are Claims 1-18, are set forth below. Some of the claim elements have been further sub-divided for ease of reference.

Claim Element	Claim Language from '370 Patent
1(Preamble)	1(pre). A method for separating mercury from a mercury-containing gas, the method comprising:
1(a)	combusting a mixture of coal and an additive in a combustion chamber, to form the mercury-containing gas, wherein the additive is chosen from halides, halogens, salts thereof, and combinations thereof;
1(b)	adding a particulate sorbent material comprising activated carbon into the mercury-containing gas,
1(c)	wherein a weight ratio of the additive added to the coal, added to the combustion chamber, or a combination thereof, to an amount of the sorbent material added to

Claim Element	Claim Language from '370 Patent
	the mercury-containing gas is from about 1:100 to about 30:100;
1(d)	contacting mercury in the mercury-containing gas with the sorbent material, to form a mercury-sorbent; and
1(e)	separating the mercury-sorbent from the mercury-containing gas.
2	2. The method of claim 1, further comprising adding the additive to the coal before combusting the coal.
3	3. The method of claim 2, wherein the additive mixed with the coal is in a liquid.
4	4. The method of claim 3, wherein the liquid is a hydrocarbon, supercritical carbon dioxide, water, salt solution, or a combination thereof.
5	5. The method of claim 1, wherein carbocations in the activated carbon of the mercury-sorbent accept electrons from mercury atoms of the mercury-sorbent.
6	6. The method of claim 1, wherein the additive is substantially in vapor form in the mercury-containing gas.
7	7. The method of claim 1, wherein the additive is chosen from Cl_2, HCl, sodium chloride, calcium chloride, and a combination thereof.
8	8. The method of claim 1, wherein the additive is chosen from Br_2, HBr, sodium bromide, calcium bromide, and a combination thereof.
9	9. The method of claim 1, wherein the additive is chosen from PBr_3, SCl_2, and a combination thereof.
10	10. The method of claim 1, wherein the additive is chosen from I_2, HI, sodium iodide, calcium iodide, potassium iodide, and combinations thereof.
11	11. The method of claim 1, wherein the activated carbon is chosen from powdered activated carbon, granular activated carbon, carbon black, carbon fiber, aerogel carbon, pyrolysis char, and combinations thereof.

Claim Element	Claim Language from '370 Patent
12	12. 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.
13	13. 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.
14	14. 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.
15	15. The method of claim 14, wherein the secondary component is chosen from halogens, halide salts, HI, HBr, HCl, and combinations thereof.
16	16. The method of claim 14, wherein the secondary component is chosen from I_2, HI, and combinations thereof.
17(preamble)	17. A method for separating mercury from a mercury-containing gas, the method comprising:
17(a)	combusting coal comprising an additive in a combustion chamber, wherein the additive is chosen from halides, halogens, salts thereof, and combinations thereof, to form the mercury-containing gas, wherein the additive comprises a and b, b and c, a and c, or a, b, and c: a) I^- and/or I_2, b) Br^- and/or Br_2, c) Cl^- and/or Cl_2;

Claim Element	Claim Language from '370 Patent
17(b)	injecting a sorbent material comprising activated carbon into the mercury-containing gas,
17(c)	wherein a weight ratio of the additive added to the coal, added to the combustion chamber, or a combination thereof, to an amount of the sorbent material added to the mercury-containing gas is from about 1:100 to about 30:100;
17(d)	contacting mercury in the mercury-containing gas with the sorbent material, to form a mercury-sorbent; and
17(e)	separating the mercury-sorbent from the mercury-containing gas.
18	18. The method of claim 1, wherein the additive comprises a and b, b and c, a and c, or a, b, and c: a) I^- and/or I_2, b) Br^- and/or Br_2, c) Cl^- and/or Cl_2.

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 April 2018. Unless otherwise noted, my opinions expressed in this report remain unchanged regardless of the date used.

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

V. LIST OF EXHIBITS

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

Exhibit	Description of Exhibits Used in IPR2025-00687 and -00688 ['370 Patent]
1001	U.S. Patent No. 10,933,370 to Olson et al. (filed April 12, 2018) **("'370 Patent" or "Challenged Patent")**
1002	Declaration of Dr. Stephen Niksa in Support of Petition for *Inter Partes* Review of U.S. Patent No. 10,933,370 **("'370 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 Used in IPR2025-00687 and -00688 ['370 Patent]
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")**

Exhibit	Description of Exhibits Used in IPR2025-00687 and -00688 ['370 Patent]
1012	U.S. Patent Pub. No. 2006/0048646 to Olson et al. (published Mar. 9, 2006) **("Olson-646")**
1013	U.S. Patent No. 6,953,494 to Nelson (filed May 6, 2003) **("Nelson")**
1014	U.S. Patent No. 7,514,052 to Lissianski et al. (filed Apr. 7, 2009) **("Lissianski")**
1015	U.S. Patent Publication No. 2011/0030592 to Baldrey (filed Feb. 10, 2011)
1016	RESERVED
1017	RESERVED
1018	RESERVED
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")**

Exhibit	Description of Exhibits Used in IPR2025-00687 and -00688 ['370 Patent]
1023	Excerpts of File History of U.S. Patent Application No. 15/951,970, which ultimately issued as U.S. Patent No. 10,933,370 **("'370 Patent File History")**
1024	RESERVED
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.

Exhibit	Description of Exhibits Used in IPR2025-00687 and -00688 ['370 Patent]
	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
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")**

Exhibit	Description of Exhibits Used in IPR2025-00687 and -00688 ['370 Patent]
1042	B.R. Puri, *Surface Complexes on Carbons*, *in* CHEMISTRY AND PHYSICS OF CARBON 191 (Philip L. Walker, ed.) (Marcel Dekker: 1970) **("Puri")**
1043	Frank E. Huggins et al., "XAFS Examination of Mercury Sorption on Three Activated Carbons," *Energy & Fuels* 1999(13), p. 114-121 (1999) **("XAFS")**
1044	S. Niksa et al., *Predicting Complete Hg Speciation Along Coal-Fired Utility Exhaust Systems*, MEGA SYMPOSIUM, Paper # 45 (Washington, DC: Aug. 2004) **("Hg Speciation")**
1045	D.L. Laudal et al., *Evaluation of Mercury Speciation at Power Plants Using SCR and SNCR NOx Control Technologies*, Paper No. A5-01, 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")**

Exhibit	Description of Exhibits Used in IPR2025-00687 and -00688 ['370 Patent]
1050	Proposed National Emission Standards for Hazardous Air Pollutants; and, in the Alternative, Proposed Standards of Performance for New and Existing Stationary Sources: Electric Utility Steam Generating Units, 69 Fed. Reg. 4652-4752 [Volume 69, No. 20] (Jan. 30, 2004) **("EPA-Proposal")**
1051	U.S. EPA, "Study of Hazardous Air Pollutant Emissions from Electric Utility Steam Generation Units -- Final Report to Congress," (Vol. 1 1998), available at https://www3.epa.gov/ttn/utox/eurtc1.pdf (**"U.S. EPA – Vol. 1 1998"**)
1052	U.S. EPA, "Mercury Study Report to Congress Volume 1: Executive Summary," EPA-452/R-97-003 (Dec. 1997), available at https://www.epa.gov/sites/production/files/2015-09/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")**

Exhibit	Description of Exhibits Used in IPR2025-00687 and -00688 ['370 Patent]
1056	EPA Newsroom, "EPA Announces First-Ever Rule to Reduce Mercury Emissions from Power Plants" (Mar. 15, 2005), available at https://archive.epa.gov/epapages/newsroom_archive/newsreleases/91ab7266e65751b985256fc50067d9b0.html **("3/15/2005 EPA Press Release")**
1057	EPA Newsroom, "Public Comment Period Begins for Proposed Power Plant Regulations" (Jan. 29, 2004), available at https://archive.epa.gov/epapages/newsroom_archive/newsreleases/4daf1d46e8dd755c85257036005511f9.html **("1/29/2004 EPA Press Release")**
1058	EPA Newsroom, "EPA Supplements Proposal to Reduce Power Plant Mercury Emissions," (Feb. 24, 2004), available at https://archive.epa.gov/epapages/newsroom_archive/newsreleases/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/

Exhibit	Description of Exhibits Used in IPR2025-00687 and -00688 ['370 Patent]
1062	Charlene R. Crocker et al., "Mercury Control with the Advanced Hybrid Particulate Collector Technical Progress Report," U.S. DOE-NETL (Nov. 2003) **("Crocker")**
1063	Redline Comparison, showing changes from '163 Application (as published at 2006/0048646) to '970 Application (as published at 2018/0229182)
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	U.S. Patent No. 10,589,225
1068	RESERVED
1069	U.S. Patent Pub. No. 2018/0229182 to Olson et al. (published Aug. 16, 2018) **("Published '970 Application")**
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")**

Exhibit	Description of Exhibits Used in IPR2025-00687 and -00688 ['370 Patent]
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 & 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)**

Exhibit	Description of Exhibits Used in IPR2025-00687 and -00688 ['370 Patent]
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")**
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 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")**

Exhibit	Description of Exhibits Used in IPR2025-00687 and -00688 ['370 Patent]
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 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

Exhibit	Description of Exhibits Used in IPR2025-00687 and -00688 [’370 Patent]
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
1099	Affidavit of Tanya Zeif, Custodian of Records for Internet Archive (1/13/2025), sponsoring Exhibits 1009, 1061, 1087-1090
1100-1105	RESERVED
1106	Clarion Energy Content Directors, “A Variety of Hg Capture Solutions Are Available” (June 1, 2009), available at https://www.power-eng.com/environmental-emissions/a-variety-of-

Exhibit	Description of Exhibits Used in IPR2025-00687 and -00688 ['370 Patent]
	hg-capture-solutions-are-available/ **("Variety of Hg Capture Solutions")**
1107	Modern Power Systems, "Full scale tests show KNXTM is effective for mercury control" (October 1, 2009), available at https://www.modernpowersystems.com/analysis/full-scale-tests-show-knxtm-is-effective-for-mercury-control/ **("KNXTM is effective")**

Other than citations to prosecution histories, EX1019-EX1023, EX1025-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	1-8, 10-18	Obvious over Vosteen589 (EX1005) in view of Starns (EX1008)

Ground	Claims Challenged	Prior Art
A2	1-8, 10-18	Obvious over Vosteen589 (EX1005) in view of Mass-EPA (EX1009)
A3	1-6, 8, 11	Obvious over Downs-Boiler (EX1006) in view of Starns (EX1008)
A4	1-6, 8, 11-12, 14-16	Obvious over Downs-Boiler (EX1006) in view of Mass-EPA (EX1009)
A5	1, 5-6, 11	Obvious over Lissianski (EX1014) in view of Starns (EX1008)
A6	1, 5-6, 11-12, 14-16	Obvious over Lissianski (EX1014) in view of Mass-EPA (EX1009)

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

Ground	Claims Challenged	Prior Art
B1	1-4, 6-8, 10-11, 13-18	Anticipated by Baldrey (EX1015)
B2	1-18	Baldrey (EX1015) in view of Olson-646 (EX1012)
B3	1-18	Sjostrom (EX1010) in view of Olson-646 (EX1012)
B4	1-18	Sjostrom (EX1010) in view of Olson-646 (EX1012) and Eckberg (EX1011)

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 patentable 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 not patentable. A patent claim can be anticipated, or a patent claim can be obvious. I address each of these below.

1. Anticipation and Inherency

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

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

2. Obviousness

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

VIII. LEVEL OF ORDINARY SKILL IN THE ART

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

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

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

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

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

IX. TECHNOLOGY BACKGROUND AND STATE OF THE ART

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

A. FUNDAMENTAL PRINCIPLES OF CHEMISTRY

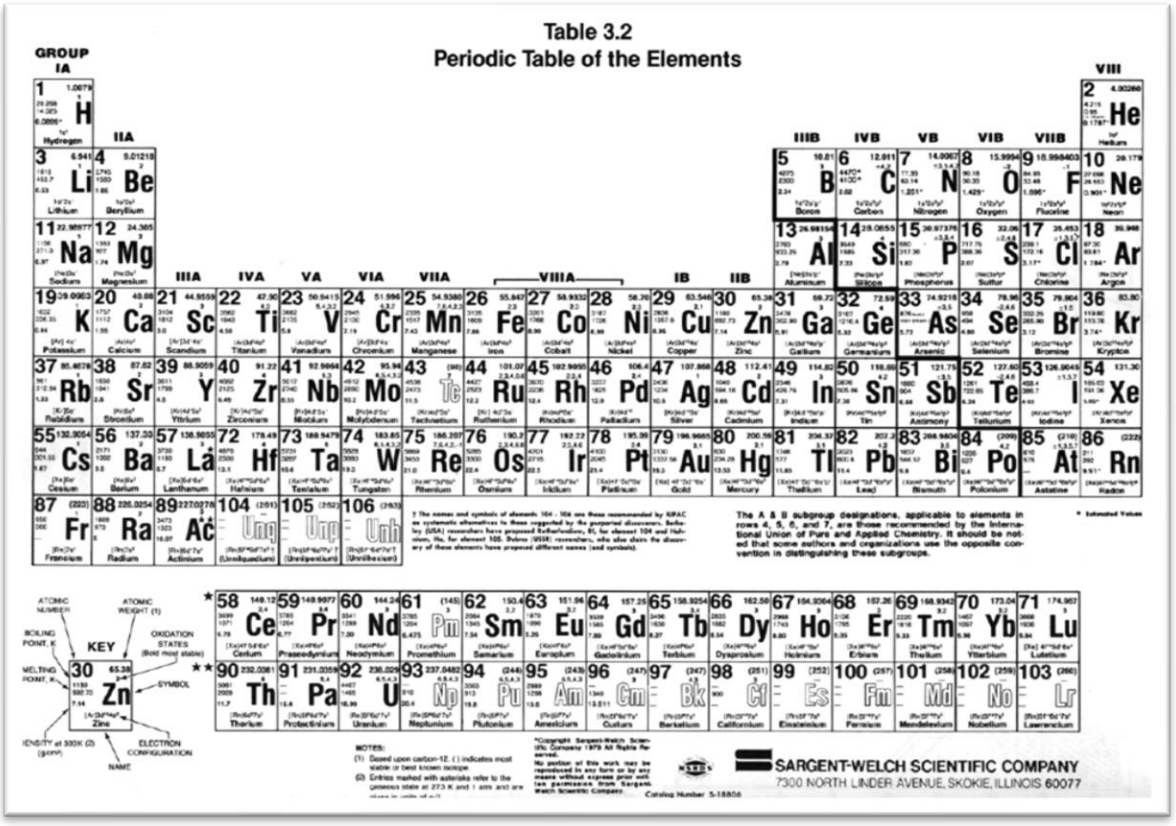
1. Periodic Table and Chemical Notation

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

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conditions found in coal-fired power plants." That litigation involved the alleged infringement of a patent (8,168,147) with claims directed more to the surface chemistry, with limitations such as: "activated carbon contains graphene sheets having carbene species edge sites." 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.

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 electron configuration in their valence (outermost electron) shell. For example, both

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

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

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, 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

[4] EX1040 (Oxtoby) at 85.

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

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

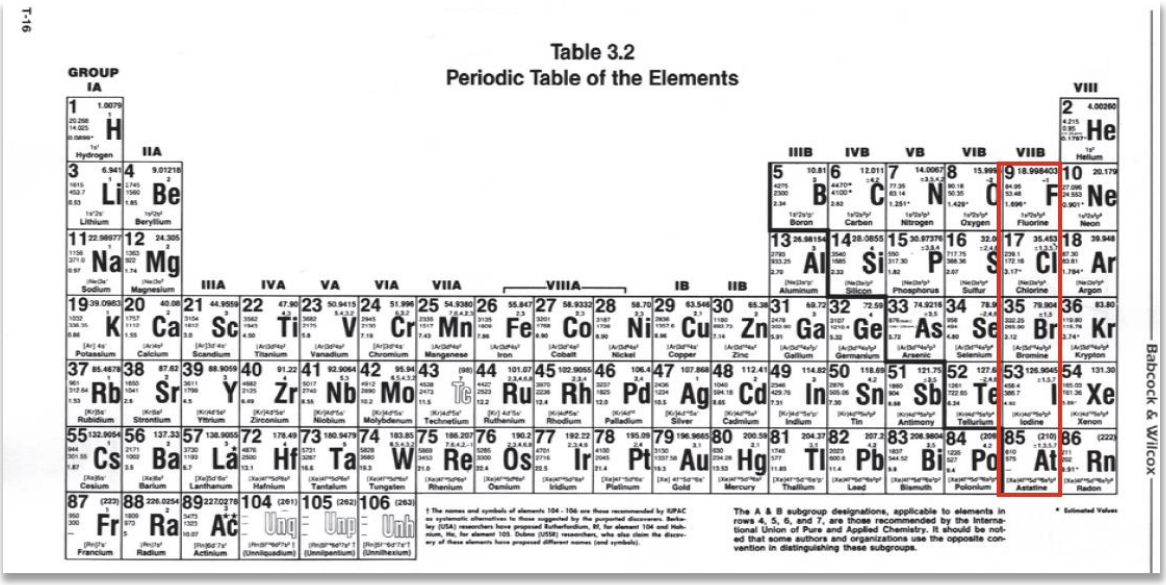
60. As shown in the periodic table above ("Periodic Table and Chemical Notation" section), Group V of the periodic table contains nitrogen (N), phosphorus (P), and other less common elements. Group VI contains oxygen (O), sulfur (S), and other less common elements. Oxygen is present, by definition, in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

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

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



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

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]

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

- 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 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).

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

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

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 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]

[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.

[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.

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 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 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

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

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

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

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, 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.

[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").

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

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]

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

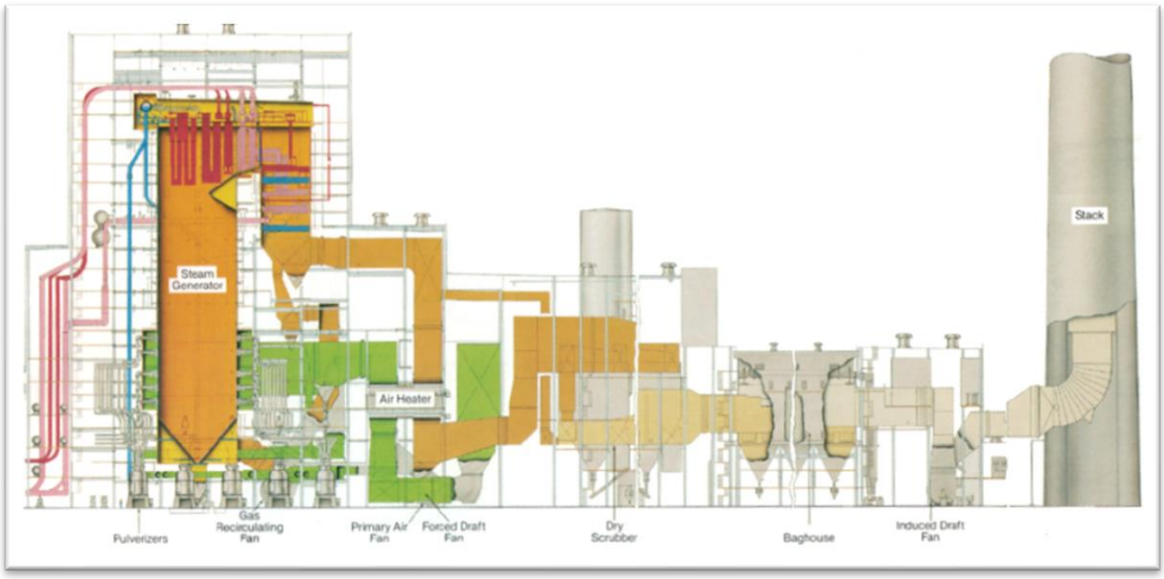
[21] EX1027 (B&W: Steam) at 8-3.

[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.

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

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]



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

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

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

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

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

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

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 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.

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

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

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]

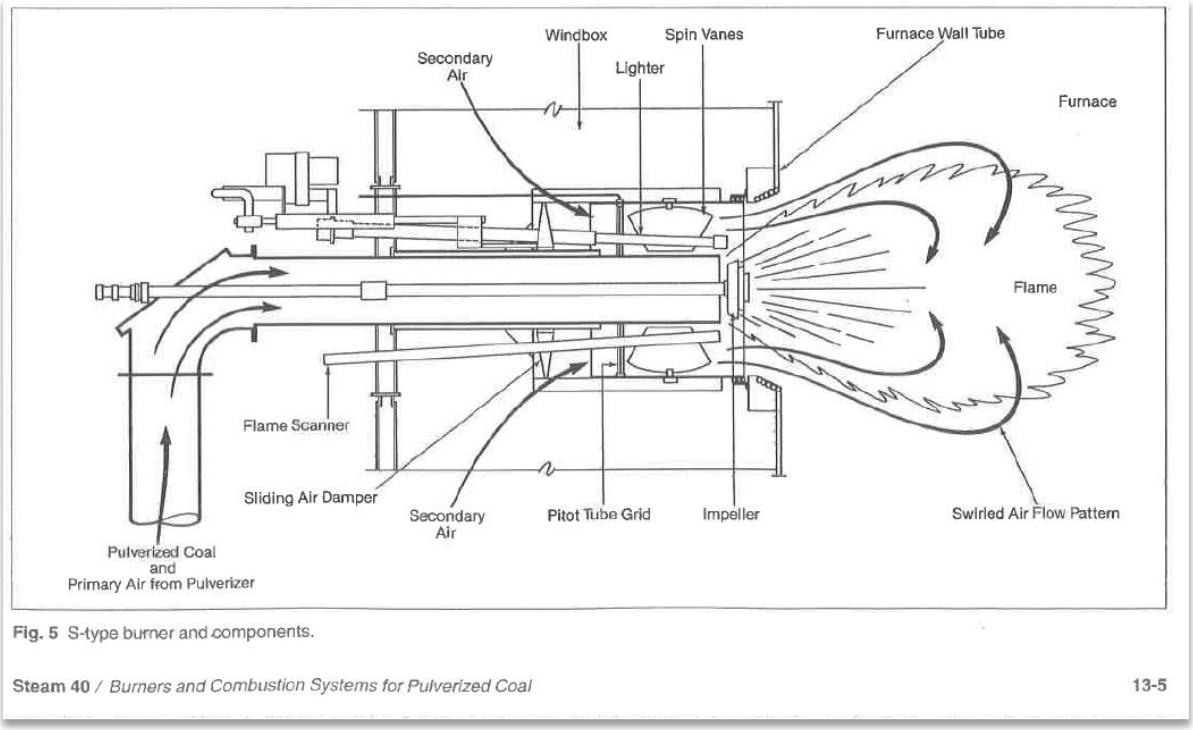


Fig. 5 S-type burner and components.

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

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

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

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 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

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

[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.

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.

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

[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.

[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.

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 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]

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

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

[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.

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 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

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

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

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

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.
>
> 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]

[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.

[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.

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]

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

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

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

[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.

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) 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]

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

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

[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.

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 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

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

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

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

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]

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]

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

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

[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.

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 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

[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.

[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

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 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]

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.

[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.

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 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

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

[80] EX1045 (Laudal).

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 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

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

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

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

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

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 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

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

[86] EX1070 (Bansal) at vii.

[87] EX1070 (Bansal) at vii.

[88] EX1070 (Bansal) at viii.

[89] EX1029 (Stock).

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]

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:

[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.

[93] EX1038 (Granite) at 4.

[94] EX1038 (Granite) at 5.

[95] EX1038 (Granite) at 5.

> 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 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,

[96] EX1008 (Starns) at 2.

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

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]

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]

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

[99] EX1039 (Feeley) at 10.

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

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

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 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

[102] EX1070 (Bansal) at 391.

[103] EX1070 (Bansal).

[104] EX1070 (Bansal) at iv.

[105] EX1070 (Bansal) at iii.

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 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

[106] EX1070 (Bansal) at iii.

[107] EX1070 (Bansal) at viii.

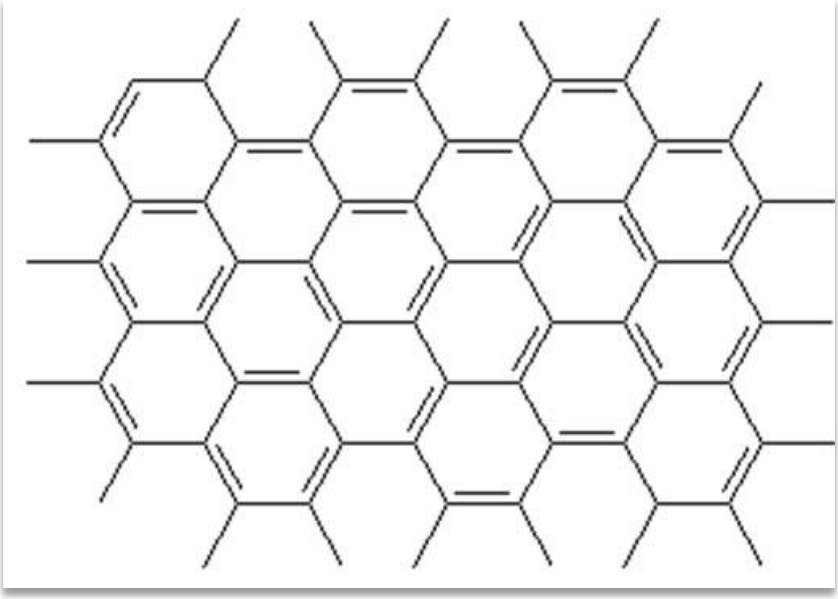
[108] EX1070 (Bansal) at viii.

[109] EX1070 (Bansal) at viii.

[110] EX1070 (Bansal) at viii.

"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:



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

[111] EX1070 (Bansal) at viii.

[112] EX1070 (Bansal) at 238.

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 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]

[113] EX1070 (Bansal) at 238.

[114] EX1070 (Bansal) at 238.

[115] EX1070 (Bansal) at 238.

[116] EX1070 (Bansal) at 238.

[117] EX1070 (Bansal) at iv.

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 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,

[118] EX1070 (Bansal) at 259.

[119] EX1070 (Bansal) at 259.

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 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

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

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

[122] EX1042 (Puri) at 260.

[123] EX1042 (Puri) at 260.

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

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 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

[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.

[128] EX1042 (Puri) at 256.

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 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

[129] EX1038 (Granite) at 40.

[130] EX1043 (XAFS) at 119.

[131] EX1043 (XAFS) at 114.

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

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

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]

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

[134] EX1044 (Hg Speciation).

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

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 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]

[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.

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

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

[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.

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

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

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] 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

[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.

[148] EX1054 (Mercury Emissions Control).

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

[149] EX1054 (Mercury Emissions Control).

[150] EX1039 (Feeley) at 4.

[151] EX1039 (Feeley) at 3.

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

[153] EX1039 (Feeley) at 4.

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 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

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

[155] EX1039 (Feeley) at 8.

[156] EX1055 (Clean Air Mercury Rule).

[157] EX1055 (Clean Air Mercury Rule).

> 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 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

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

[159] EX1009 (Mass-EPA).

[160] EX1050 (EPA-Proposal).

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

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

"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 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-

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

[164] EX1009 (Mass-EPA).

[165] EX1039 (Feeley) at 2.

[166] EX1008 (Starns).

[167] EX1010 (Sjostrom).

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]

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

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

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

[170] EX1009 (Mass-EPA).

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 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.

[171] EX1039 (Feeley).

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]

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.

[172] EX1039 (Feeley) at 11.

[173] EX1039 (Feeley) at 11.

[174] EX1039 (Feeley) at 11.

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 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

[175] EX1039 (Feeley) at 2.

[176] EX1039 (Feeley) at 2.

[177] EX1039 (Feeley) at 2.

[178] EX1009 (Mass-EPA).

[179] EX1008 (Starns).

[180] EX1038 (Granite) at 5.

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—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]

[181] EX1038 (Granite) at 5.

[182] EX1038 (Granite) at 5.

[183] EX1038 (Granite) at 5.

[184] EX1038 (Granite) at 15.

[185] EX1038 (Granite) at 15.

[186] EX1038 (Granite) at 15.

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 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

[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").

[190] EX1038 (Granite) at 5.

> 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 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

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

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

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

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 "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

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

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

[196] EX1041 (Greenwood) p. 1212.

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

[198] EX1041 (Greenwood) p. 1212.

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-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

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

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

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

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 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, 203]

Granite reported in 1998 that elemental mercury had a solubility in water of only 20 micrograms/liter at 68ºF.[204] 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

[202] EX1005 (Vosteen589) ¶[0003].

[203] Vosteen's commercial embodiment used "KNX," which was is an aqueous solution of calcium bromide. EX1106 (Variety of Hg Capture Solutions); EX 1107 (KNXTM is effective).

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

grams/liter.[205] 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."[206]

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."[207]

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.[208] These trials showed that the efficiencies increased in proportion to the halogen:coal ratio, which prompted

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

[206] EX1005 (Vosteen589) ¶[0016].

[207] EX1038 (Granite) at 5.

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

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.[209] Moreover, it was known for nearly a century[210] 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 sorbent that may be viable for use in sorbent injection include two basic types of activated carbon (AC; regular and impregnated)."[211] 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-

[209] EX1028 (Bustard).

[210] EX1042 (Puri) at 255.

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

> 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.[212]

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 activated carbons are three times more costly than unpromoted carbons.[213]

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

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

[213] EX1038 (Granite) at 32.

effective."[214] 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.[215] 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 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

[214] EX1038 (Granite) at 6.

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

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.[216] 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.

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 $HgCl_2$."[217]

[216] EX1041 (Greenwood) at 804.

[217] EX1005 (Vosteen589) ¶[0019].

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 station of Bayer AG in Uerdingen."[218, 219] 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."[220]

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

[218] EX1005 (Vosteen589) ¶[0046].

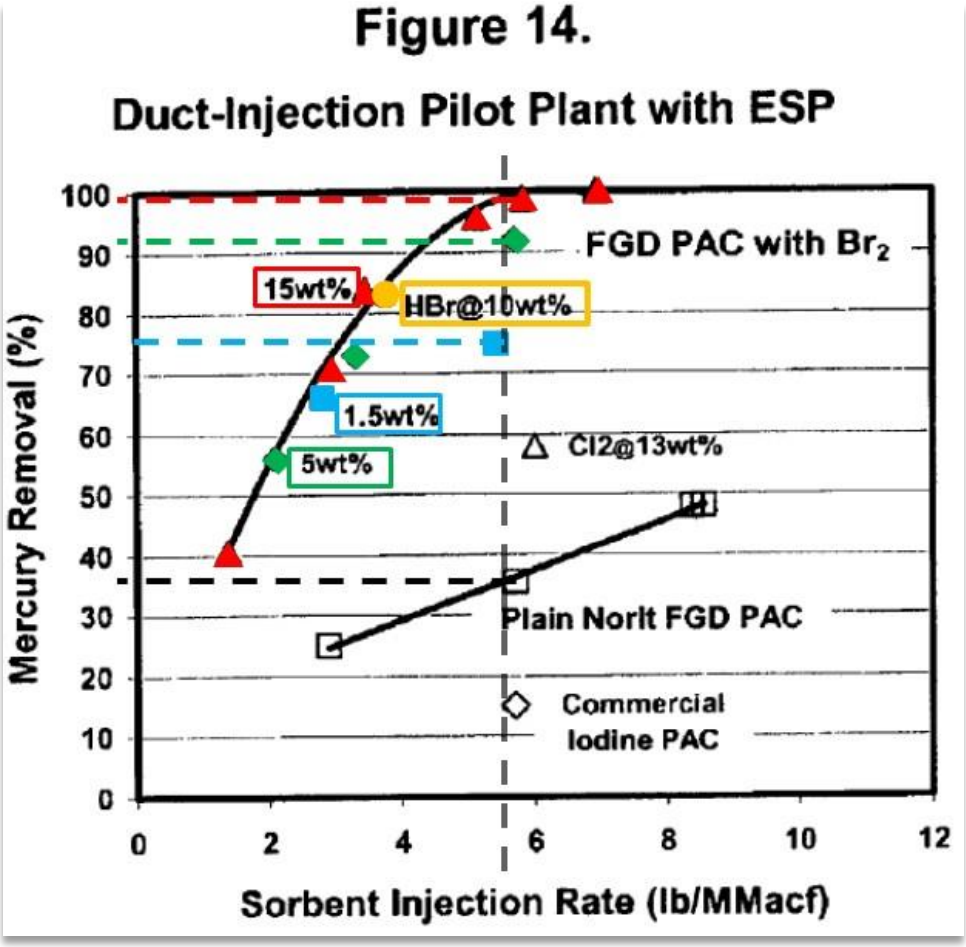
[219] Named inventor of the Challenged Patent, Dr. Olson, provided similar testimony. EX1095 (Olson) at 144:25-146:4 (recognizing that Vosteen disclosed adding a bromide compound to the furnace or the flue gas).

[220] EX1005 (Vosteen589) ¶[0047].

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.[221] 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.[222]

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

[222] 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 ▲).[223] 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 Vosteen589,224 Downs-Boiler, 225 or Lissianski.226

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

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

[224] EX1005 (Vosteen589).

[225] EX1006 (Downs-Boiler).

[226] 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.[227]

X. OVERVIEW OF THE CHALLENGED PATENT FAMILY

A. SPECIFICATION OF THE '370 PATENT

152. The '370 Patent "relates to methods and materials for the removal of pollutants from flue gas[.]"[228] The '370 Patent discloses that "mercury is removed from gas streams generated during the burning … of fossil fuels by highly reactive regenerable sorbents."[229]

153. The '370 Patent admits that known "mercury control methods" included "injection of fine sorbent particles into a flue gas duct" such as "activated carbon."[230] The '370 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

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

[228] EX1001 ('370 Patent) at 1:41-43.

[229] EX1001 ('370 Patent) at 1:43-45.

[230] EX1001 ('370 Patent) at 2:5-9.

mercury."[231] The '370 Patent states that activated carbon is "relatively expensive and cannot be easily separated from the ash for regeneration and reuse."[232]

154. To address the problem discussed above, the '370 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 '370 Patent further explains that "[t]he reactivity of the sorbent toward the pollutants is greatly enhanced, and the sorption capacity can be regenerated, the promoted sorbent may be regenerated, recycled and/or reused."[234]

155. Figure 1 of the '370 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 [*sic*, stream]."[235]

[231] EX1001 ('370 Patent) at 2:25-31.

[232] EX1001 ('370 Patent) at 2:31-33.

[233] EX1001 ('370 Patent) at 6:42-46.

[234] EX1001 ('370 Patent) at 6:50-54.

[235] EX1001 ('370 Patent) at 6:64-7:1, Figure 1.

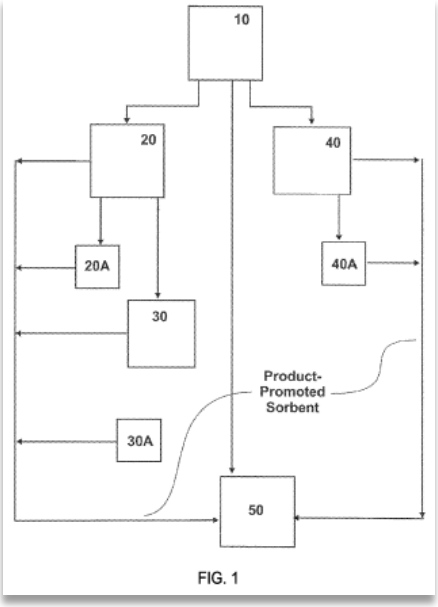


FIG. 1

The specification contemplates that "[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 carbon sorbent."[236] The specification also describes a second embodiment that includes "providing a base activated carbon as shown by block 10, adding a halogen or halide promoter that reacts with the carbon, illustrated at block 20, and adding a secondary component illustrated at block 30 that reacts with the result of block 20 to produce a product promoted carbon sorbent."[237] The specification describes a third embodiment that includes "providing a base activated

[236] EX1001 ('370 Patent) at 7:1-7:6.

[237] EX1001 ('370 Patent) at 7:11-17.

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."[238] For all embodiments, the specification explains that block 50 is "a flue gas stream [that] is treated with product promoted carbon sorbent prepared as described above."[239]

156. Figure 11 of the '370 Patent "is a block diagram illustrating the use of the invention in a coal fueled facility."[240]

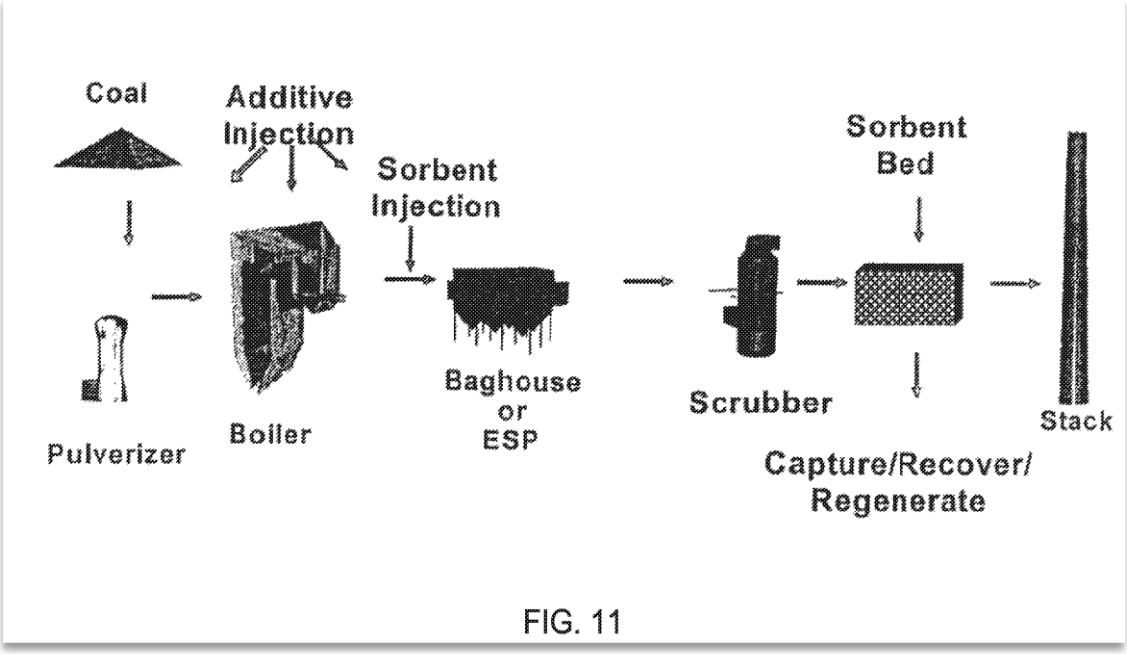


FIG. 11

[238] EX1001 ('370 Patent) at 7:25-31.

[239] EX1001 ('370 Patent) at 7:37-40.

[240] EX1001 ('370 Patent) at 6:23-24, Figure 11.

Figure 11 "shows a boiler for burning pulverized coal" that includes "various devices to clean the exhaust of the boiler."[241] For example, Figure 11 shows "a baghouse or ESP used to collect particulates in the exhaust."[242] The specification explains that "[a] scrubber and sorbent bed are also used to remove undesired constituents from the flue gas stream, before being fed to the stack."[243] I discuss this figure in more detail regarding the priority date of the challenged claims.

B. FAMILY TREE

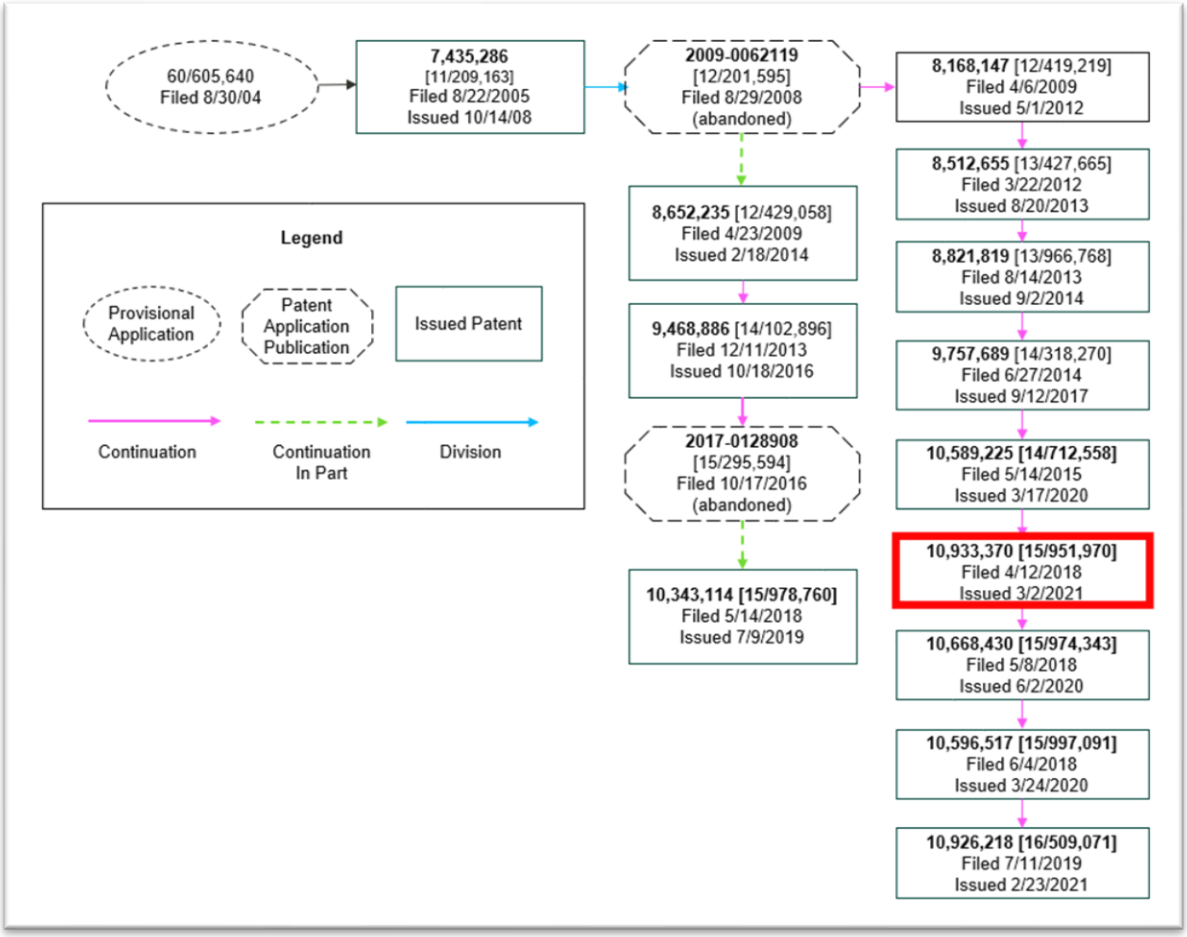
157. I understand that the family tree below depicts the '370 Patent, and the patent applications to which it claims priority.[244]

[241] EX1001 ('370 Patent) at 32:41-43.

[242] EX1001 ('370 Patent) at 32:43-45.

[243] EX1001 ('370 Patent) at 32:45-47.

[244] EX1004 (Family Tree).



C. PROSECUTION HISTORY OF THE '370 PATENT

158. As shown in the family tree above, the '370 Patent was filed as U.S. Patent Application No. 15/951,970 (the "'970 Application") and claims priority as a continuation of U.S. Patent Application No. 14/712,558 (the "'558 Application"). 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 but aimed at pursuing a broader or different scope of patent protection. The '970 Application and the '558 Application are from a long line of other patent applications, which are

reflected above in the family tree. 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.[245] I refer to this as the "Provisional."

1. Filing of Application No. 15/951,970 (U.S. Patent No. 10,933,370)

159. The application that ultimately issued as the '370 Patent was filed on April 12, 2018 as U.S. Patent Application No. 15/951,970 (the "'970 Application"). As originally filed, the '970 Application included 20 claims and 11 drawings (Figures 1-11).[246] Independent Claims 1 and 20 of the '970 Application are reproduced below as originally filed:[247]

[245] EX1023 ('370 Patent File History) at exhibit page 406.

[246] EX1023 ('370 Patent File History) at exhibit pages 463-465, 467-477.

[247] EX1023 ('370 Patent File History) at exhibit pages 463, 465 .

CLAIMS

1. A method for separating mercury from a mercury-containing gas, the method comprising:

combusting a mixture of coal and an additive, to form the mercury-containing gas, wherein the additive 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 additive in the mercury-containing gas, to form a promoted sorbent material;

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

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

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

combusting coal mixed with an additive, wherein the additive is chosen from halides, halogens, salts thereof, and combinations thereof, to form the mercury-containing gas;

injecting a 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 additive in the mercury-containing gas, to form a promoted sorbent material;

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

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

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

160. The ’970 Application included substantial changes to the specification and figures, as compared to the earlier patents from which it claims priority. Attached as Exhibit 1064 is a redline comparison between the ’970 Application and the ’558 Application. I understand that the redline was prepared by using the ’558 Application as the starting document and then showing what was changed with the filing of the ’970 Application. One addition to the ’970 Application was Figure 11, which was not included in any non-provisional application preceding the ’970

Application. The application was published as U.S. Patent App. Pub. 2018/0229182 A1 on August 16, 2018.[248]

2. Subsequent Prosecution History

161. On May 27, 2020, the examiner issued a non-final rejection of claims 1-20, including rejections over prior art.[249]

162. After the non-final rejection, applicants filed a response on November 25, 2020. This response cancelled Claims 4-7, amended Claims 1, 2, 4, 16, 17, and 20, and added new Claims 21-23.[250] Claims 3, 8-15, 18, and 19 were not amended but were dependent on amended Claim 1, either directly or indirectly. The amended independent claims and additional claims are reproduced as filed below:[251]

[248] EX1023 (’370 Patent File History) at exhibit pages 1791.

[249] EX1023 (’370 Patent File History) at exhibit pages 1622-1634.

[250] EX1023 (’370 Patent File History) at exhibit page 1592.

[251] EX1023 (’370 Patent File History) at exhibit page 1606-1609.

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

combusting a mixture of coal and an additive in a combustion chamber, to form the mercury-containing gas, wherein the additive is chosen from halides, halogens, salts thereof, and combinations thereof;

adding a particulate sorbent material comprising activated carbon into the mercury-containing gas, wherein a weight ratio of I^-, I_2, Br^-, Br_2, Cl^-, Cl_2, or a combination thereof in the additive fed to the combustion chamber to an amount of the sorbent material added to the mercury-containing gas is from 1:100 to 30:100;

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

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

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

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

combusting ~~coal mixed with an additive~~coal comprising an additive in a combustion chamber, wherein the additive is chosen from halides, halogens, salts thereof, and combinations thereof, to form the mercury-containing gas, wherein the additive comprises a and b, b and c, a and c, or a, b, and c:

a) I^- and/or I_2,

b) Br^- and/or Br_2,

c) Cl^- and/or Cl_2;

injecting a sorbent material comprising activated carbon into the mercury-containing gas, wherein a weight ratio of I^-, I_2, Br^-, Br_2, Cl^-, Cl_2, or a combination thereof in the additive fed to the combustion chamber to an amount of the sorbent material added to the mercury-containing gas is from 1:100 to 30:100;

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

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

separating the mercury-sorbent from the mercury-containing gas~~;~~

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

21. (New) The method of claim 1, wherein the additive comprises a and b, b and c, a and c, or a, b, and c:

a) I^- and/or I_2,

b) Br^- and/or Br_2,

c) Cl^- and/or Cl_2.

22. (New) The method of claim 1, wherein a weight ratio of I^-, I_2, Br^-, Br_2, or a combination thereof in the additive fed to the combustion chamber to an amount of the sorbent material added to the mercury-containing gas is from 1:100 to 30:100.

23. (New) The method of claim 1, wherein a weight ratio of I^-, Br^-, Br_2, or a combination thereof in the additive fed to the combustion chamber to an amount of the sorbent material added to the mercury-containing gas is from 1:100 to 30:100.

163. The applicant cited paragraphs [0021], [0025], and [0072] of the published application (EX1069) as support for the amendments to the Independent Claims. As further support for the amendments to Independent Claim 20, the applicant cited paragraphs [0012], [0015], [0022]-[0023], [0073], and [0103].[252]

164. The amendments to the claims added "wherein a weight ratio of I^-, I_2, Br^-, Br_2, Cl^-, Cl_2 or a combination thereof in the additive fed to the combustion chamber to an amount of the sorbent material added to the mercury-containing gas

[252] EX1023 ('370 Patent File History) at exhibit page 1592.

is from 1:100 to 30:100." The applicant distinguished the prior art at issue based on this amendment. For example, applicants stated:[253]

III. The Office Action rejected claim 11 under 35 U.S.C. § 103 over U.S. patent no. 5,435,980 ("Felsvang") in view of U.S. patent publication no. 2004/0086439 ("Vosteen").

This rejection is respectfully traversed.

Independent claim 1 is presently amended to recite "…wherein a weight ratio of I^-, I_2, Br^-, Br_2, Cl^-, Cl_2, or a combination thereof in the additive fed to the combustion chamber to an amount of the sorbent material added to the mercury-containing gas is from 1:100 to 30:100…."

As explained herein at **I**, Felsvang fails to describe or suggest a weight ratio of I^-, I_2, Br^-, Br_2, Cl^-, Cl_2, or a combination thereof in the additive fed to the combustion chamber to an amount of the sorbent material added to the mercury-containing gas of from 1:100 to 30:100. Similarly, Vosteen fails to mention any specific amount of activated carbon in the emission control system and therefore fails to describe or suggest any specific ratio of any halogen species added to coal with respect to the activated carbon used. Felsvang and Vosteen fail to describe or suggest all the

IV. The Office Action rejected claim 12 under 35 U.S.C. § 103 over U.S. patent no. 5,435,980 ("Felsvang") in view of U.S. patent publication no. 2006/0057044 ("Chang").

This rejection is respectfully traversed.

Independent claim 1 is presently amended to recite "…wherein a weight ratio of I^-, I_2, Br^-, Br_2, Cl^-, Cl_2, or a combination thereof in the additive fed to the combustion chamber to an amount of the sorbent material added to the mercury-containing gas is from 1:100 to 30:100…."

As explained herein at **I**, Felsvang fails to describe or suggest a weight ratio of I^-, I_2, Br^-, Br_2, Cl^-, Cl_2, or a combination thereof in the additive fed to the combustion chamber to an amount of the sorbent material added to the mercury-containing gas of from 1:100 to 30:100. Chang fails to describe or suggesting adding halogens or halides to coal, and therefore fails to describe or suggest any specific ratio of any halogen species added to coal with respect to the activated carbon used. Felsvang and Chang fail to describe or suggest all the features of independent claim 1; therefore, this claim is patentable over this combination of references.

[253] EX1023 ('370 Patent File History) at exhibit page 1593-1595.

165. In an examiner-initiated interview on December 23, 2020, applicant agreed to further proposed amendments.[254] The amendments included correcting "a phrase raising a new matter issue." Claims 1 and 20 were amended and Claims 22 and 23 were cancelled.[255] Following these amendments, the Examiner allowed Claims 1-4 and 8-21 on January 28, 2021.[256] Allowed and amended Claims 1 and 20 are produced below:[257]

---1. (Currently Amended) A method for separating mercury from a mercury-containing gas, the method comprising:

combusting a mixture of coal and an additive in a combustion chamber, to form the mercury-containing gas, wherein the additive is chosen from halides, halogens, salts thereof, and combinations thereof;

adding a particulate sorbent material comprising activated carbon into the mercury-containing gas, wherein a weight ratio of ~~I^-, I_2, Br^-, Br_2, Cl^-, Cl_2, or a combination thereof in~~ the additive ~~fed~~added to the coal, added to the combustion chamber, or a combination thereof, to an amount of the sorbent material added to the mercury-containing gas is from about 1:100 to about 30:100;

[254] EX1023 ('370 Patent File History) at exhibit page 1576.

[255] EX1023 ('370 Patent File History) at exhibit pages 1572-1573.

[256] EX1023 ('370 Patent File History) at exhibit page 1571.

[257] EX1023 ('370 Patent File History) at exhibit page 1572-1573.

contacting mercury in the mercury-containing gas with the ~~promoted~~ sorbent material, to form a mercury-sorbent; and

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

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

combusting coal comprising an additive in a combustion chamber, wherein the additive is chosen from halides, halogens, salts thereof, and combinations thereof, to form the mercury-containing gas, wherein the additive comprises a and b, b and c, a and c, or a, b, and c:

a) I^- and/or I_2,

b) Br^- and/or Br_2,

c) Cl^- and/or Cl_2;

injecting a sorbent material comprising activated carbon into the mercury-containing gas, wherein a weight ratio of ~~I^-, I_2, Br^-, Br_2, Cl^-, Cl_2, or a combination thereof in~~ the additive ~~fed~~added to the coal, added to the combustion chamber, or a combination thereof, to an amount of the sorbent material added to the mercury-containing gas is from about 1:100 to about 30:100;

contacting mercury in the mercury-containing gas with the sorbent material, to form a mercury-sorbent; and

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

The Examiner "agree[d] with applicant's characterization of how the amended claims distinguish over the prior art of record, which fails to disclose or suggest a motivation for using weight ratio of additive added to the coal and/or combustion chamber, to an amount of injected sorbent is from about 1:100 to about 30:100, in combination with the other recited process steps."[258]

[258] EX1023('370 Patent File History) at exhibit page 1574.

D. PRIORITY DATE OF THE CHALLENGED CLAIMS OF THE '370 PATENT

166. I have been asked to review the '370 Patent, and its earlier filed parent applications,[259] 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 '370 Patent are disclosed (either expressly or inherently) in those earlier filed parent applications. Second, I have been asked to analyze whether each of the claim limitations of the '370 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.

167. First, I conclude that there are claim limitations in each of the issued claims of the '370 Patent that are not disclosed (either expressly or inherently) in earlier-filed applications. These include limitations missing from each independent claim (Claims 1 and 17), such as the limitations below:

- "combusting … coal and an additive in a combustion chamber …, wherein the additive is chosen from halides, halogens, salts thereof, and combinations thereof…the additive added to the coal, added to the combustion chamber, or a combination thereof" (Claims 1 and 17).
- "wherein the additive comprises a and b, b and c, a and c, or a, b: a) I^- and/or I_2, b) Br^- and/or Br_2 c) Cl^- and/or Cl_2" (Claim 17).

[259] EX1004 (Family Tree).

In the subsections below, I explain why these limitations were not present in Application No. 14/721,558 (filed May 14, 2015), which is the immediate parent of the '370 Patent. I also explain why these limitations were not present in other earlier patent applications.

168. Second, I conclude that there are claim limitations in each of the issued claims of the '370 Patent that are not disclosed (either expressly or inherently) in the Provisional.

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

1. The Provisional Does Not Support the '370 Patent Claim Limitations

170. As described above, the applicants copied and pasted the contents of the Provisional into the '970 Application when they filed the '970 Application.[260] Earlier applications in the priority chain of the '970 Application had not expressly included the contents of the Provisional, instead only including a generic statement of incorporation by reference. However, even if a person of ordinary skill in the art

[260] EX1064 (Redline Comparison, showing changes from '558 Application (as published at 2015/0246315) to '970 Application (as published at 2018/0229182)).

were to consider the technical disclosures of the Provisional, the Provisional fails to disclose limitations from the issued claims of the ’370 Patent.

a. An Additive Chosen from Halides, Halogens, Salts Thereof, and Combinations Thereof

171. The Provisional does not disclose the full scope of “the additive is chosen from halides, halogens, salts thereof, and combinations thereof” (Claims 1, 17). The Provisional also fails to disclose adding to the coal or to the combustion chamber specifically the “halides, halogens, salts thereof, and combinations thereof” recited in the claims of the ’370 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.”[261] Here, the Provisional refers to an “additional substance” rather than an “additive.”[262]

172. Where the Provisional does refer to additives, 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.”[263] These additives are explained in more detail by “outline of examples of the invention” number 9, reproduced below as annotated:[264]

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

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

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

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

> 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 are in Group VII and not Groups I or II. This makes clear that the "additive" disclosed by the Provisional is not composed of "halides, halogens, salts thereof, and combinations thereof" but is instead an additive of base chemistry of Ca (Calcium), Na (Sodium), or other alkali—those elements in the first two groups (columns) of the periodic table. Rather than be added to the coal or combustion chamber, this additive is "added to flue gas as a sorbent mixture or co-injected" with the sorbent. 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" on the sorbent.[265]

173. Any disclosure of a hydrohalide (e.g., HBr) in the Provisional also does not support an additive "chosen from halides, halogens, salts thereof, and combinations thereof" as is required by the independent claims of the '370 Patent.

[265] EX1020 (Provisional) at exhibit page 7 (Example 9).

Indeed, there are a nearly infinite number of forms and combinations of "halides, halogens, salts thereof, and combinations thereof," because as declared by Mr. Pavlish, even a "bromide compound" (a much narrower set than halides and halogens as a whole) may be any "chemical compound containing a bromide ion or ligand."[266] Thus, a disclosure in the Provisional of a particular type of chemical (hydrohalides) does not demonstrate that the inventors were in possession of the broad class of chemicals of any "halides, halogens, salts thereof, and combinations thereof." The Provisional also does not discuss any halide "salts thereof," let alone the entire class.

174. Furthermore, the Provisional suggests that the inventors had determined not to use halides or halide salts: "Halides are considered reduced forms that do not, alone, oxidize other compounds. In the conventional view therefore, a halide-salt-treated activated carbon will not effectively oxidize elemental mercury and capture elemental mercury."[267]

[266] EX1019 ('430 Patent File History) at exhibit page 425 ¶ 9 (3/15/2019 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).

[267] EX1020 (Provisional) at exhibit page 10.

b. The Additive Comprises "a and b, b and c, a and c, or a, b and c:" where "a) I^- and/or I_2, b) Br^- and/or Br_2 c) Cl^- and/or Cl_2."

175. Claim 17 requires that the additive comprises specifically "a and b, b and c, a and c, or a, b and c: a) I^- and/or I_2, b) Br^- and/or Br_2 c) Cl^- and/or Cl_2." In addition to the reasons described above, the provisional does not provide support because it does not disclose the six specific chemicals, nor the claimed combinations.

176. The Provisional instead specifically highlights the unsuitability of each of Cl_2, Br_2, I_2, (alongside Cl, Br, and I).[268] The Provisional further describes that "[t]he sorbent that contains bromine is expected to be more reactive than the corresponding sorbent containing chlorine and much less expensive than the sorbent containing iodine." These statements were also copied into the '970 Application.

177. 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 Mr. Pavlish, "hydrogen bromide" is "the diatomic molecule with the formula HBr. It is a colorless compound and a hydrogen halide."[269] This is different than the Br_2 recited in Claim 17.

[268] EX1020 (Provisional) at exhibit page 10.

[269] EX1019 ('430 Patent File History) at exhibit pages 426-427 ¶ 12 (3/15/2019 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).

178. As stated by Mr. Pavlish during prosecution of related patents, "[h]ydrogen halides have different properties than elemental halogens and are therefore different compounds…. Hydrogen halides are not part of and cannot be extracted or isolated from elemental halides; rather, only via a chemical reaction that results in a chemical and structural change can hydrogen halides be formed from elemental halides."[270] As Mr. Pavlish stated more succinctly: "Br_2 is not HBr and does not include HBr."[271] Thus, the Provisional does not disclose adding Br_2 to the combustion chamber or to the coal, and Br_2 is one of the species recited in the claim.

179. To the extent that any of the six chemicals from Claim 17 of the '370 Patent are individually disclosed by the Provisional, the Provisional still fails to support the additive comprising each combination "a and b, b and c, a and c, or a, b and c." As discussed, the additives in the provisional are "additives of base chemistry," rather than any of the claimed chemicals. Furthermore, even if the additive of the Provisional is not limited to "a compound comprised of Group I or II elements" as described, the specific combinations are still not disclosed. For

[270] EX1019 ('430 Patent File History) at exhibit page 428 ¶ 17 (3/15/2019 Decl. C from John Pavlish and Nicholas Lentz); EX1026 ('114 Patent File History) at exhibit page 322 ¶ 17 (3/20/2019 Decl. C from John Pavlish and Nicholas Lentz).

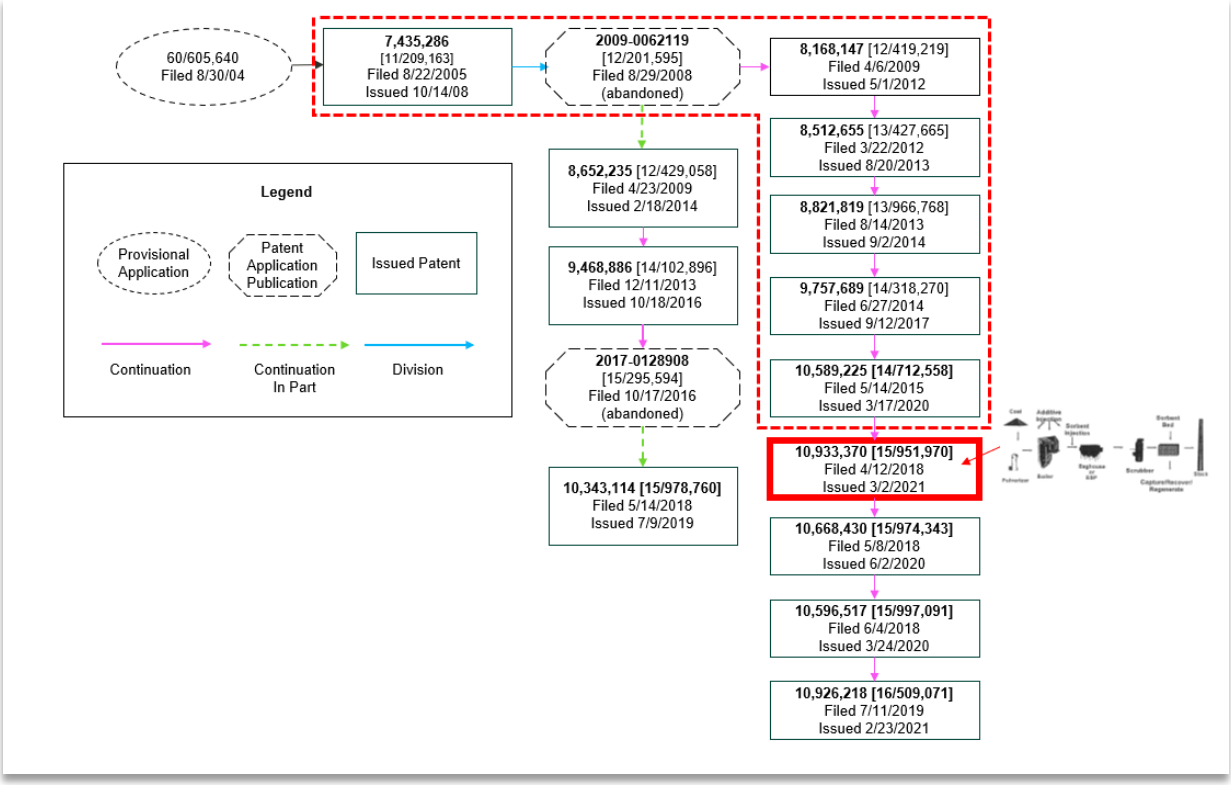
[271] EX1019 ('430 Patent File History) at exhibit page 428 ¶ 17 (3/15/2019 Decl. C from John Pavlish and Nicholas Lentz); EX1026 ('114 Patent File History) at exhibit page 322 ¶ 17 (3/20/2019 Decl. C from John Pavlish and Nicholas Lentz).

example, there is no disclosure of the additive comprising "I^- and/or I_2" and "Cl^- and/or Cl_2" to therefore comprise "a and c."

2. The '558, '270, '768, '665, '219, '595, and '163 Applications in the '370 Patent Chain also Do Not Support the '370 Patent Claims

180. As discussed above, the specification was amended in application number 15/951,970 (U.S. Patent No. 10,933,370), which eventually issued into the '370 Patent, on April 12, 2018, to include a host of material not found in earlier applications. These earlier applications were all filed before 2018 and are indicated by the red dashed line in the following graphic:[272]

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



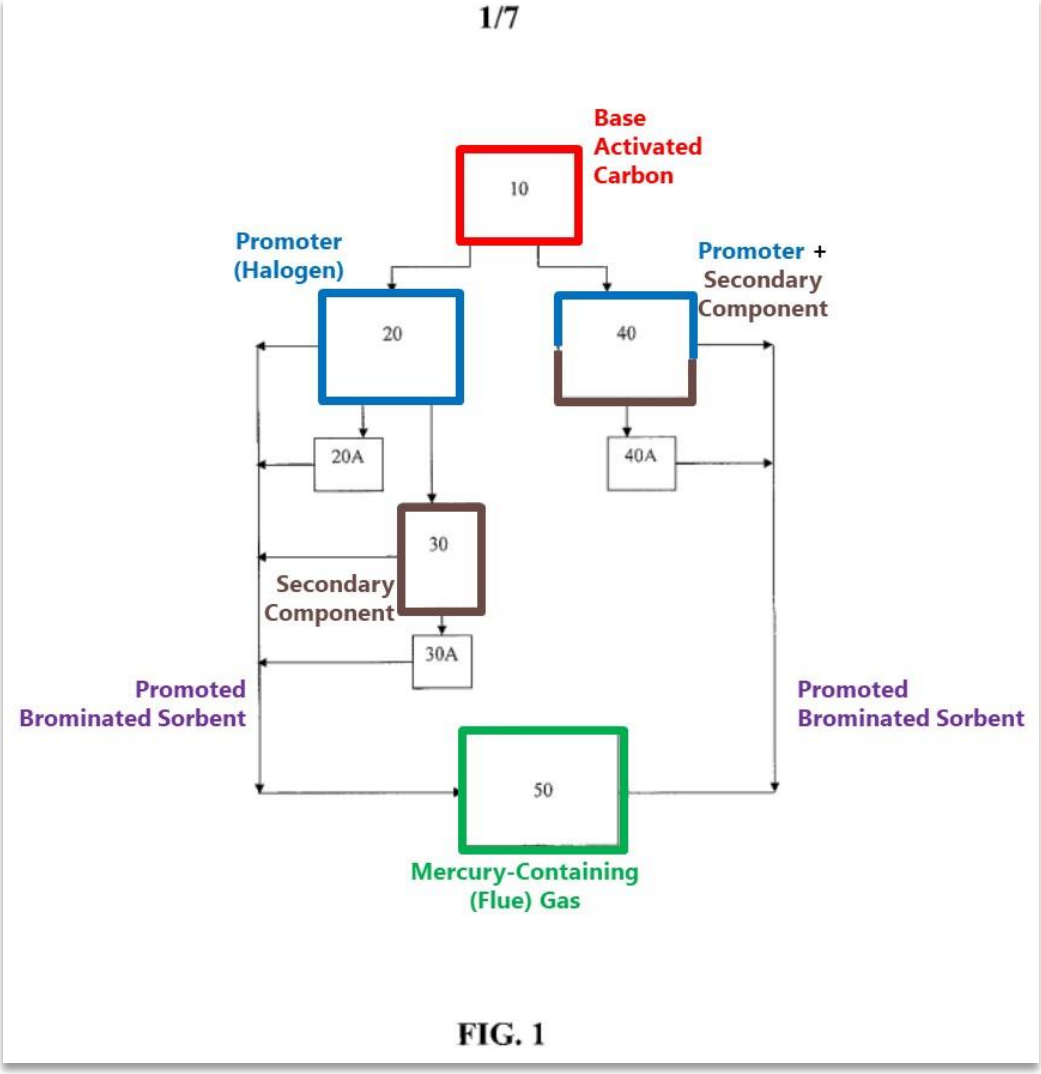
With the exception of alterations made to a replacement-Figure 1 during prosecution of the ’219 Application (’147 Patent, discussed below), the figures and description (i.e., everything other than the claims) are substantively identical between the ’558, ’270, ’768, ’665, ’219, ’595, and ’163 Applications (collectively, “Pre-2018 Applications”), shown in the dotted red box above. Figure 11 of the ’370 Patent was not present in any of the Pre-2018 Applications (’558, ’270, ’768, ’665, ’219, ’595, and ’163 Applications). Nothing in the text or figures of the Pre-2018 Applications (’558, ’270, ’768, ’665, ’219, ’595, and ’163 Applications) discloses the following limitations from the independent claims of the ’370 Patent:

- "combusting a mixture of coal and an additive in a combustion chamber, to form the mercury-containing gas, wherein the additive is chosen from halides, halogens, salts thereof, and combinations thereof" (Claims 1, 17).

  "wherein the additive comprises a and b, b and c, a and c, or a, b, and c: a) I^- and/or I_2, b) Br^- and/or Br_2 c) Cl^- and/or Cl_2" (Claim 17).

181. 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 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.

182. Nothing in the '595 Application discloses adding any of "halides, halogens, salts thereof, and combinations thereof" in the combustion chamber or to the coal, let alone all of them. 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."[273] 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

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

and a secondary component to the activated carbon together, with which they react as illustrated by block 40."[274] For both embodiments, the '595 Application explain that block 50 is "a flue gas stream [that] is treated with product promoted carbon sorbent prepared as described above."[275] Whether through block 20 (left path) or block 40 (right path), both of these embodiments describe adding the promoter to the activated carbon and allowing them to react ***before*** introducing them to the flue gas, as represented by block 50.

183. Similarly for Figure 3 of the '595 Application, the bromine promoter contacts the sorbent outside of the mercury-containing gas (i.e., the brominated halogen or halide promoted sorbent is prepared outside the system and then injected). A transport gas is used to co-inject the promoter and sorbent material *from* the non-mercury-containing transport gas *into* the mercury-containing flue gas. The transport (purple) occurs before the mercury-containing gas (green). Fig. 3 from the '595 Application is annotated below:[276]

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

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

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

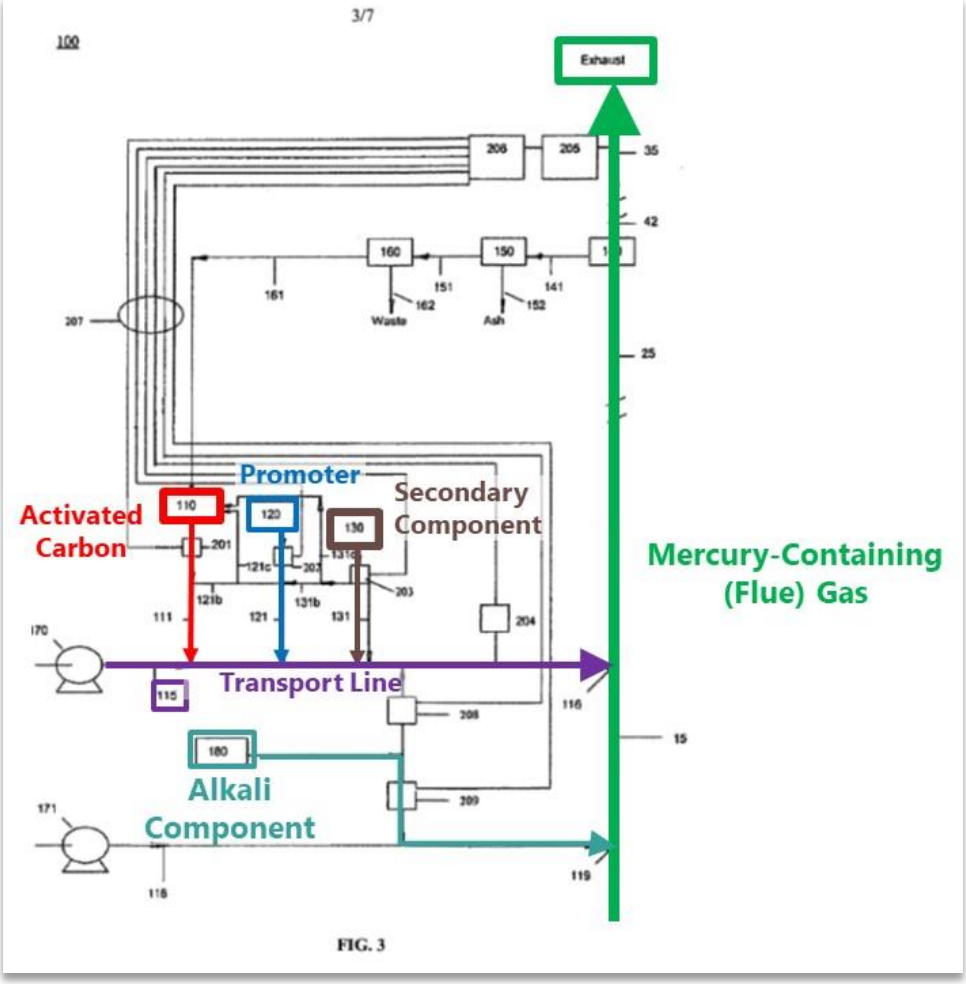


Figure 3 depicts four reservoirs: "base activated carbon reservoir 110" (red), "halogen/halide promoter reservoir 120" (blue), "secondary component reservoir 130" (brown), and "alkali component reservoir 180" (turquoise).[277] The reservoirs 110, 120, and 130 "each connect through respective flow control devices and via associated piping, to transport line 115."[278] Transport line 115 is highlighted purple.

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

[278] 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]."[279]

184. There is no disclosure of adding halogen-containing chemicals to the coal or to the combustion chamber.[280] As further confirmed by Dr. Olson regarding the '147 Patent, there is not "any bromine-containing promoter introduced in the system by injecting it into the combustion zone in the examples of the '147 Patent."[281] Rather, the bromine is contacted with the activated-carbon system outside the gas-cleaning system, and then the brominated powdered activated carbon (BPAC) is then 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

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

[280] The named inventors of the '370 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.

[281] EX1095 (Olson) at 129:1-129:10.

> inventive sorbent can be injected where desired (e.g., before, after, or within the boiler).[282]

Nothing in the above paragraph discusses where to add the halogen-containing promoter itself, and it certainly does not describe its addition to the coal or to the combustion chamber. The quote is not related to the production or formation of the promoted sorbent at all. Rather, the quote discusses testing the promoted sorbent (the patent's alleged "inventive sorbent") that, as discussed above for Figures 1 and 3, had 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 or halides to coal, as a POSITA would know that adding activated carbon to or before a combustion chamber would defeat the purpose of the invention, as the activated carbon would be combusted in a fireball and thus unavailable to adsorb mercury. Activated carbon can be expensive, and there would be no reason to add the activated carbon sorbent before the combustion chamber.

185. In short, nothing in the '595 Application describes adding the bromine promoter independently from the mercury sorbent, let alone to the coal or to the combustion chamber. As the description and figures of the '595 Application are

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

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 before at least the ’970 Application fail to describe adding the promoter independently from the mercury sorbent, let alone to the coal or to the combustion chamber as required.

186. Furthermore, as seen throughout the discussion above, the Pre-2018 Applications (as well as the specification of the ’370 Patent) refer to a “halogen/halide” or “halogen or halide” promoter. There is no disclosure of the required “salts thereof,” and instead the Pre-2018 specifications, like the Provisional, criticizes using halide salts: “In the conventional view therefore, a halide-salt-treated activated carbon will not effectively oxidize elemental mercury and capture elemental mercury.”[283]

187. The dependent claims of the ’370 Patent illustrate the scope of “halides, halogens, salts thereof, and combinations thereof.” This scope includes Cl_2 (Claim 7) and I_2 (Claim 10). The Pre-2018 Applications criticize Cl_2 and I_2, while not disclosing adding them to the coal or to the combustion chamber: “In the molecular elemental form of the halogens, including F_2, Cl_2, Br_2, I_2, the reaction with a hot flue

[283] EX1022 (’595 Application File History) at exhibit page 269 ¶[0069].

gas components leave little to react with elemental mercury."[284] Similarly, "sodium bromide" and "calcium bromide" (Claim 8) and "sodium iodide, calcium iodide, [and] potassium iodide" (Claim 10) are also within this scope. These species are not mentioned in the Pre-2018 Applications.

188. Additionally, there is no support for the additional limitations in Independent Claim 17 and Dependent Claim 18, which require adding combinations of Br_2 I_2, Cl_2, bromide ions, iodide ions, and chloride ions. There is no disclosure of using any of those ions as additive, nor of combining them with each other. The Newly-Introduced Limitations are not supported by the Pre-2018 Applications.

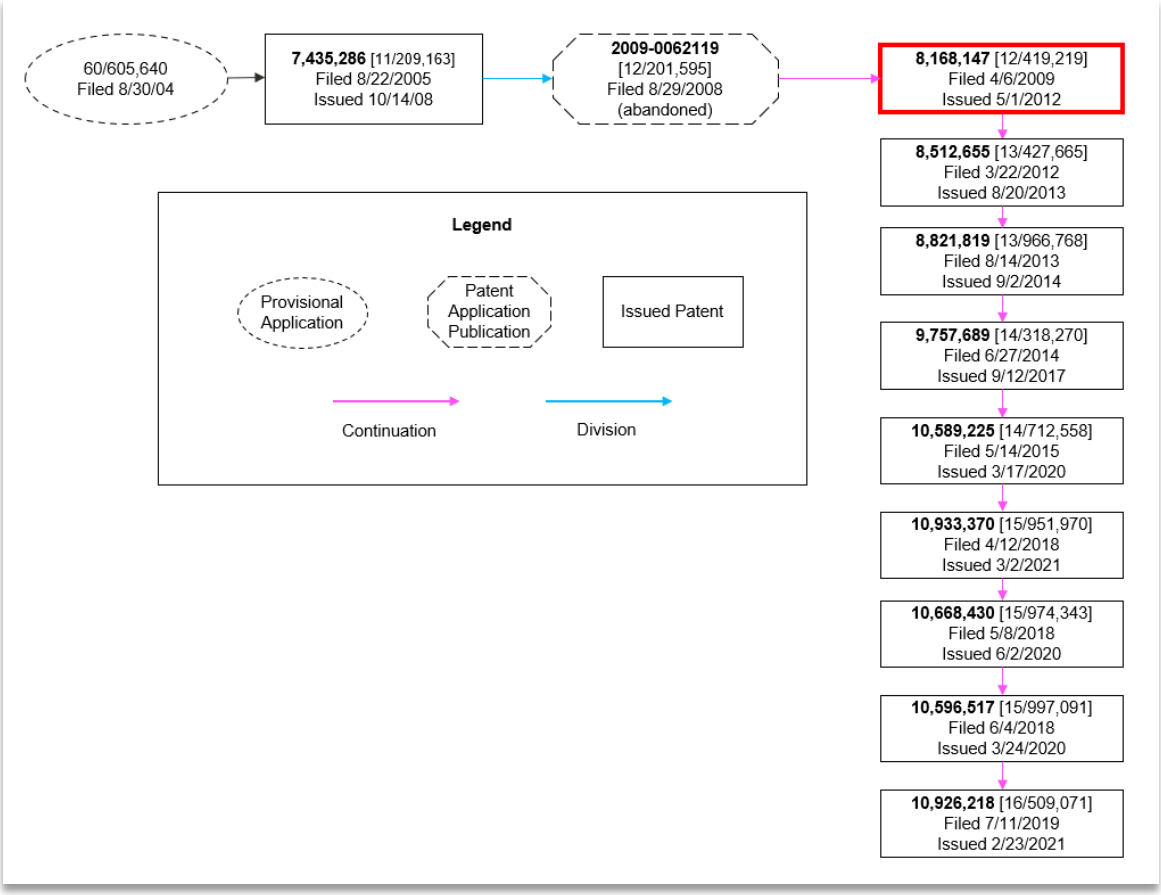
3. The Claims of U.S. Patent No. 8,168,147 (EX1065) Are Not Supported by Its Specification

189. I understand that the '219 Application I discuss above (U.S. Patent Application No. 12/419,219) ultimately issued into U.S. Patent No. 8,168,147 ('147 Patent).[285] This patent is shown below:[286]

[284] EX1022 ('595 Application File History) at exhibit page 268-269 ¶[0068].

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

[286] 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.

190. The '147 Patent contains a single independent claim (claim 1) directed to "[a] method for separating mercury from a mercury containing gas."[287] Claim 1

[287] EX1065 ('147 Patent) at 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."[288] 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."[289] Claim 18 depends from claim 17 and specifies that "the gas stream [of claim 17] is a mercury containing gas."[290] Claim 19 depends from Claim 18 and further specifies that "the gas stream is a transport gas."[291]

191. 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.

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

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

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

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

192. 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."

193. 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-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.

194. 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

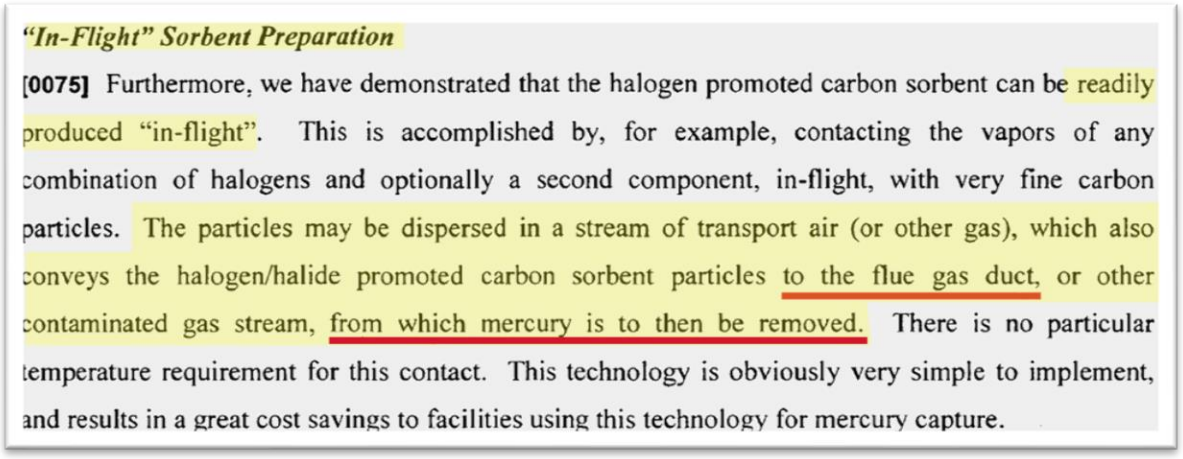
195. The '163 Application and the '595 Application, which are parents to the '147 Patent, do not disclose the subject matter of claims 18 and 19.[292] As I discuss above, these applications repeatedly describe treating a base activated-carbon sorbent with a bromine promoter ***prior to*** injecting the prepared promoted sorbent into a mercury-containing flue gas, such that: (a) the sorbent material and bromine containing promoter are ***not*** injected "separately" into the mercury-containing gas (they are injected together); and (b) an 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."

196. 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."[293] 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.

[292] 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.

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

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.[294]



"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.

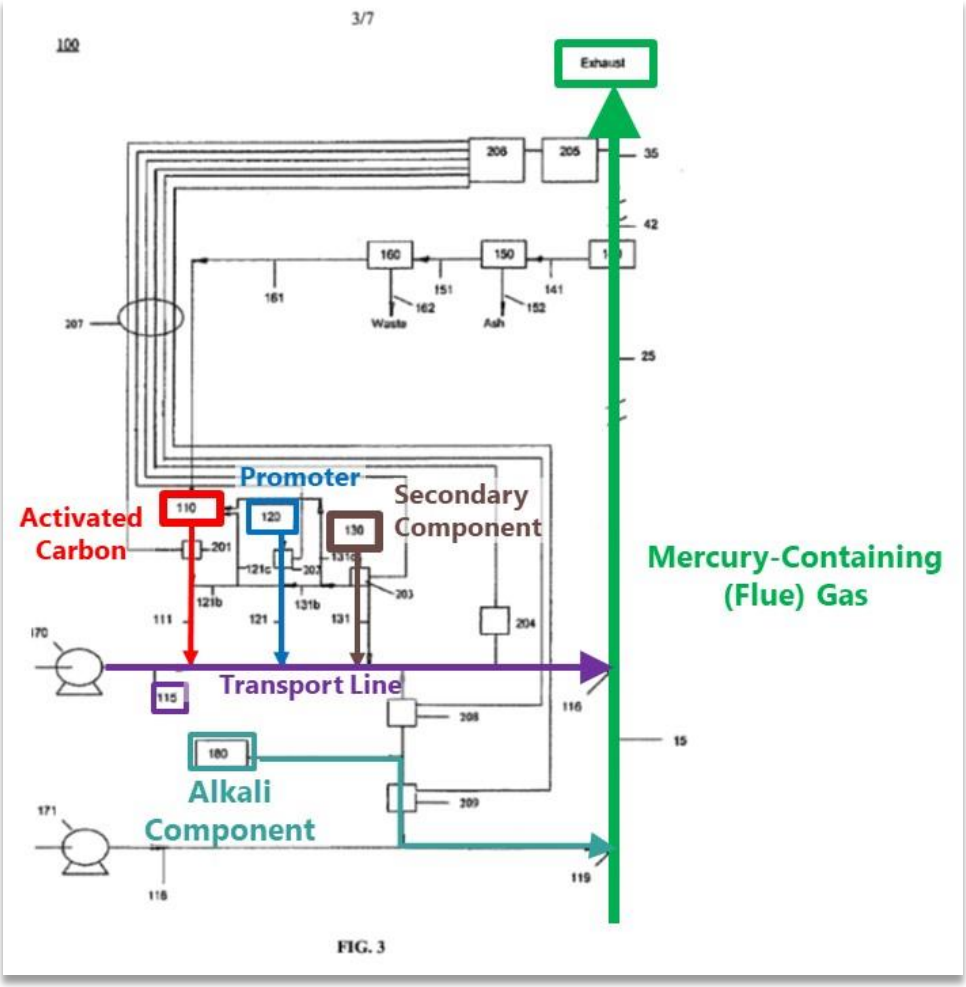
The "in-flight" promotion occurs on the way "to" the flue gas duct—before the sorbent contacts the mercury-containing gas.

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

197. 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

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

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:[295]



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***,

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

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.

198. 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.[296]

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,

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

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

199. 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 transport gas. Figure 1 from the ’163 Application is shown to the left,[297] and Figure 1 from the ’595 Application is shown to the right:[298]

[297] EX1021 (’163 Application File History) at exhibit page 272.

[298] EX1022 (’595 Application File History) at exhibit page 295.

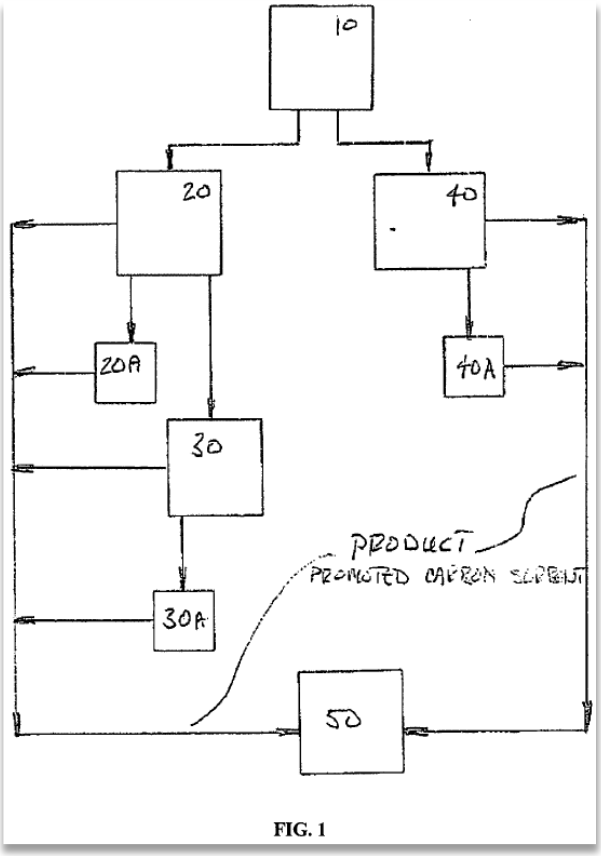


FIG. 1

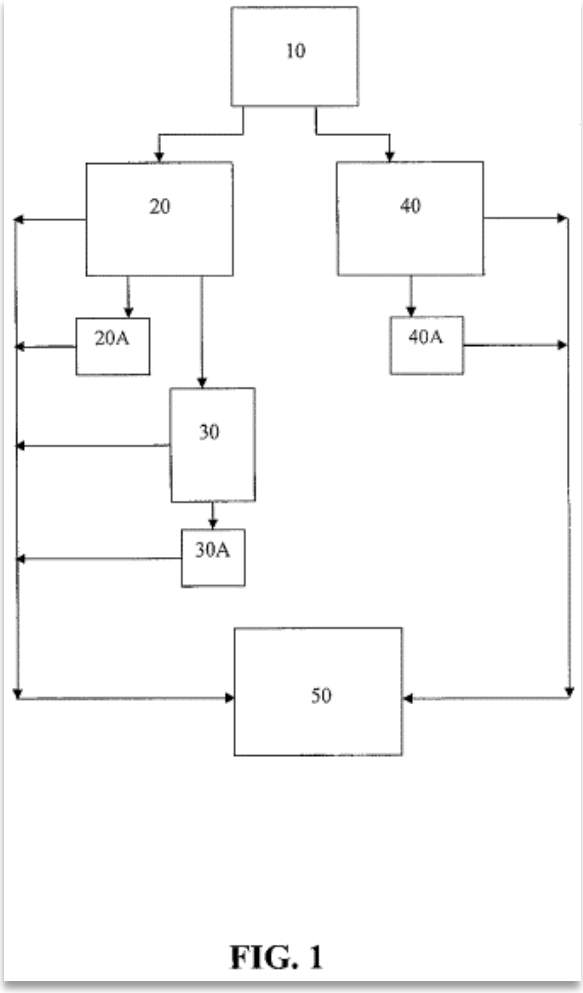


FIG. 1

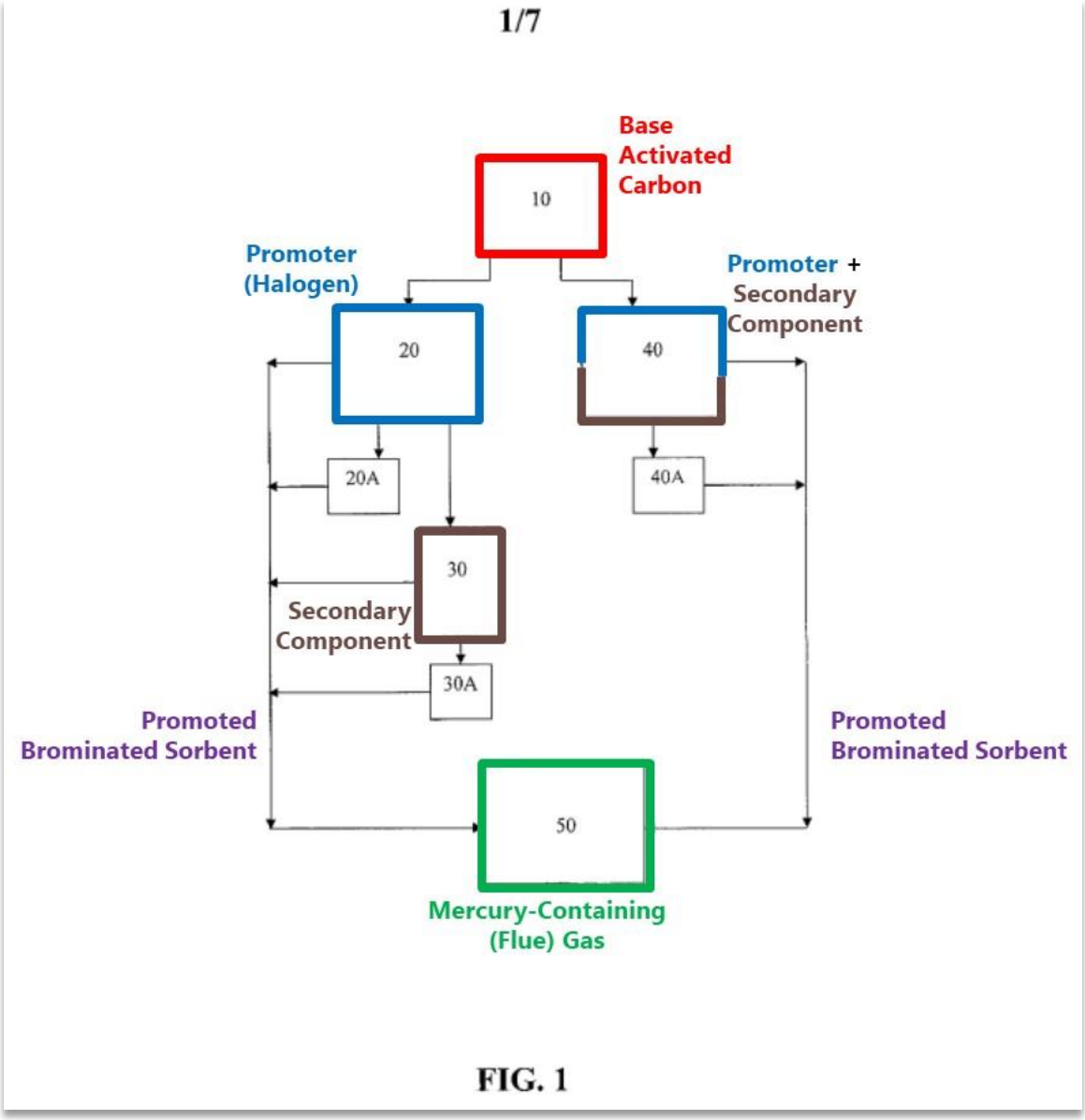
The ’163 and ’595 Applications introduce, with reference to Figure 1, two embodiments for adding the base activated carbon (10) to a mercury-containing flue gas stream (50). First, Figure 1 identifies an embodiment along the left path, in which “block 10 illustrates providing a base activated carbon, and adding a halogen or halide promoter that reacts with the carbon, illustrated at block 20.”[299] Second,

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

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."[300] These paths are shown below, in annotated Figure 1 from the '595 Application.[301]

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

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



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."[302]

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

200. 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

201. 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:[303]

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

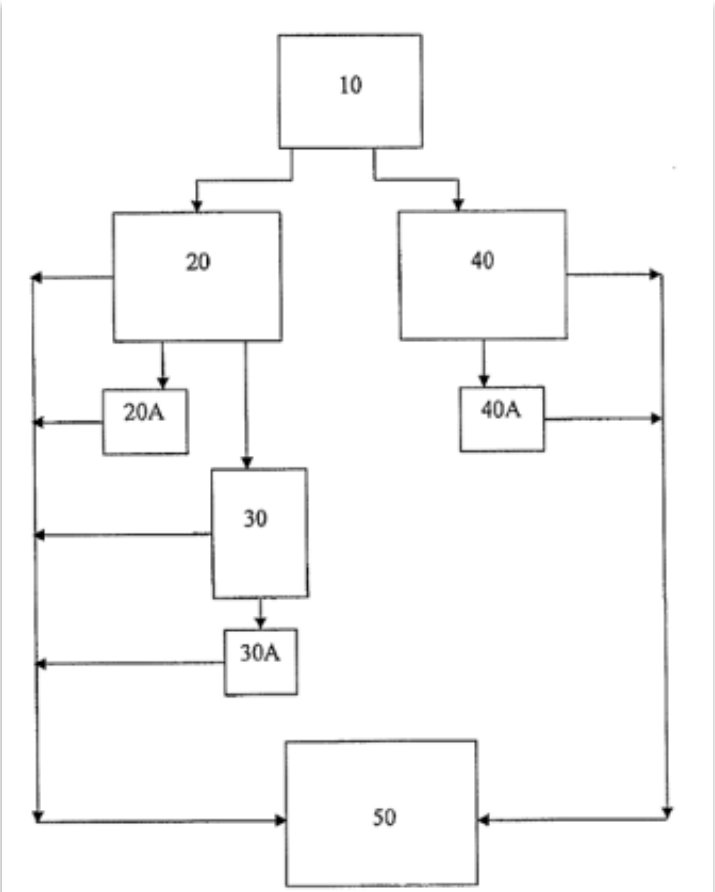


FIG. 1

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.[304] Importantly, the

[304] *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).

202. After the initial filing of the ’219 Application, the USPTO issued a Notice to File Corrected Application Papers on September 4, 2009.[305] This notice requested corrections to Figures 2 and 4-10 of the application.[306] On November 4, 2009, the applicant filed a complete replacement set of Figures 1-10.[307] 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.[308] The revised version of Figure 1 that was filed on November 4, 2009[309] is shown on the right, with an annotation in yellow indicating the modification to the figure:[310]

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

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

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

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

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

[310] *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.

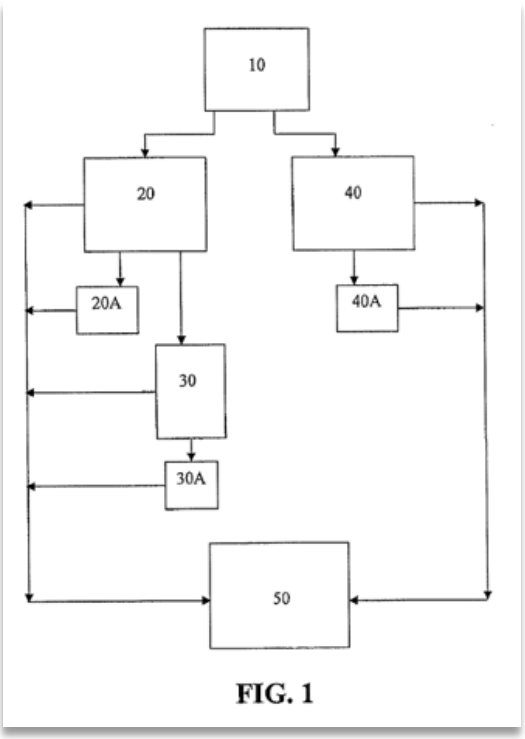


FIG. 1

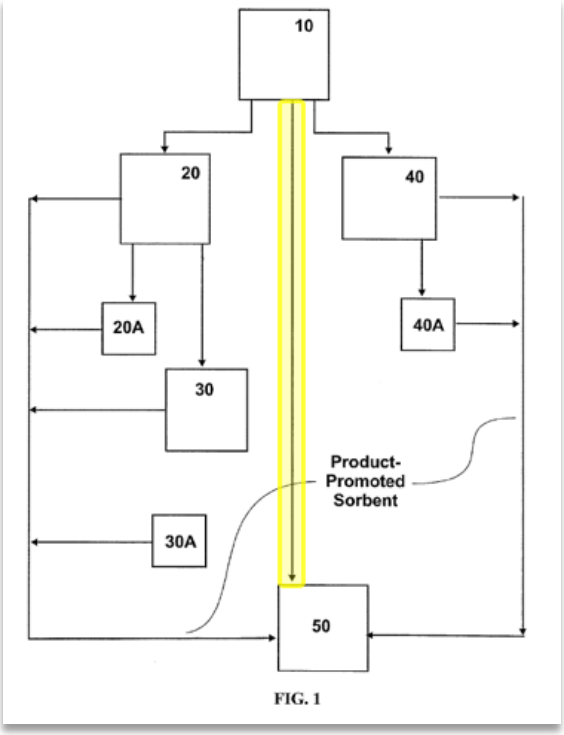


FIG. 1

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.

203. 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.[311]

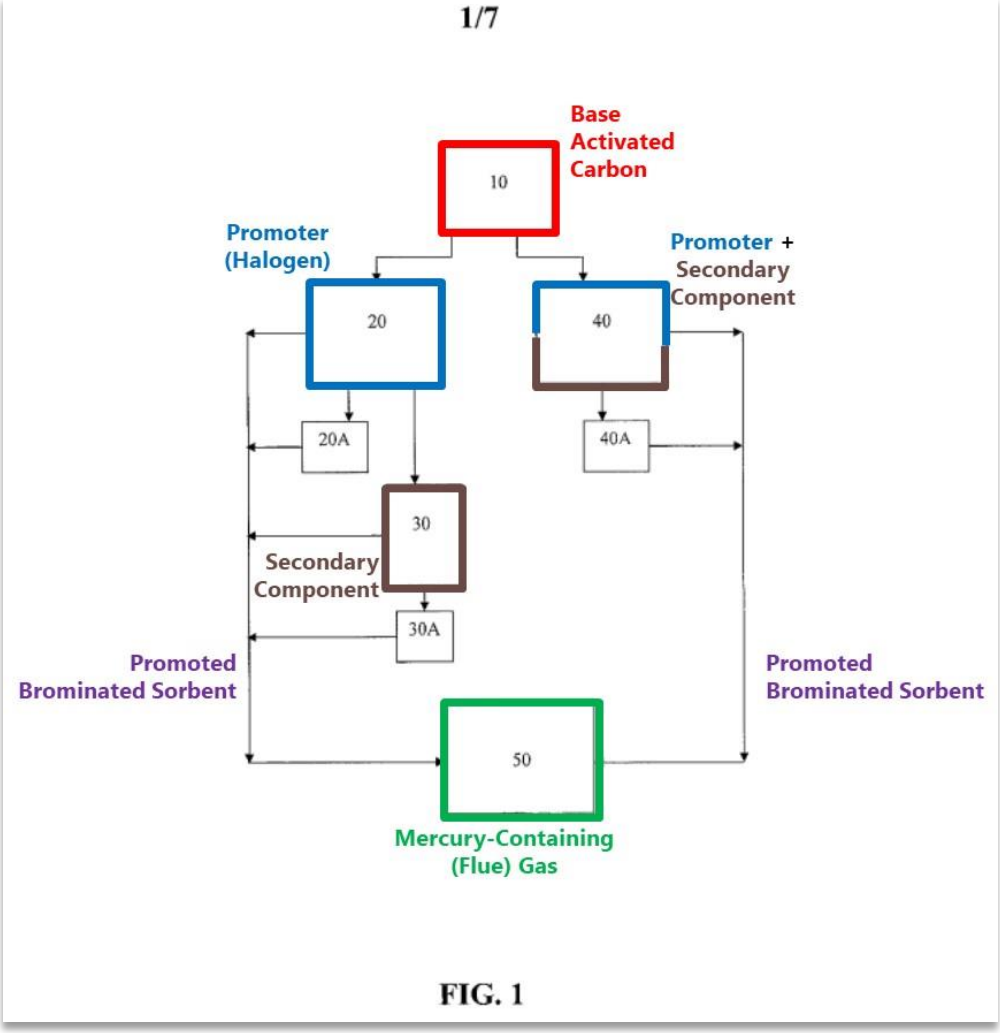


FIG. 1

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

[311] 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:[312]

> 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).[313]

204. 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

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

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

occurs, such as where an alkali component is used instead of a halide promoter.[314] 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.[315] 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.

205. 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.

iv. The '163 and '595 Applications Omit Substantial Portions of the Provisional

206. Notably, portions of the Provisional were omitted from the '163 and the '595 Applications. For example, the '163 and '595 Applications omit the series of numbered "outline[s] of examples of the invention"—namely, the example number

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

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

1E in the Provisional referring to an "additional substance" is not carried over to the '163 and '595 Applications.[316] Nor is Figure 2 of the Provisional.

207. 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:[317]

~~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 be injected where desired (e.g., before, after, or within the boiler.)"[318] Thus, the '163

[316] *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.

[317] *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].

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

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.

E. ADMITTED PRIOR ART

208. The ’370 Patent makes numerous admissions regarding what was known in the art.[319]

209. The ’370 Patent admits that activated carbon, including powdered activated carbon, was known in the art.

> 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, 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.[320]

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

[319] EX1001 (’370 Patent) at 32:24-28, 34:8-35:46.

[320] EX1001 (’370 Patent) at 7:49-57.

> in a bag house or electrostatic precipitator (ESP) and collected along with ash particulate.[321]

210. The '370 Patent admits that it was "known in the art" to remove "mercury from a combustion gas" by exposing "finely powdered activated carbon to a molecular bromine gas at an elevated temperature or to HBr to produce a sorbent with good mercury removal ability when injected into the flue gas duct."[322] The patent explains that using the efficacy of the above stated approach is presumed to be due to "some bromine form will help capture the mercury, as does iodine and chlorine."[323]

211. The '370 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*.[324]

[321] EX1001 ('370 Patent) at 2:8-15; *see also* 28:11-22 (similar quote).

[322] EX1001 ('370 Patent) at 30:28-32.

[323] EX1001 ('370 Patent) at 30:33-36.

[324] EX1001 ('370 Patent) at 9:24-28.

XI. CLAIM CONSTRUCTION

212. I have reviewed how a POSITA would have understood terms in the Challenged Claims. While no terms of the '370 Patent have been previously construed, I note that Magistrate Judge Burke in the District of Delaware provided constructions for two terms in patents from the same family as the '370 Patent.

213. 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 (EX1067) to have their plain and ordinary meaning.[325] 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

[325] 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)).

be combusted along with the coal and the bromine compound in the combustor (Plaintiffs' position), or whether the coal, bromine compound and pyrolysis char must each be added to the combustor, and then be combusted (Defendants' position)."[326] Judge Burke concluded that "[t]he plain language of the claims at issue supports Plaintiffs' position."[327]

214. 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 (EX1065) to have its plain and ordinary meaning.[328] 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

[326] 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)).

[327] 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)).

[328] 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."[329]

215. In conducting my analysis below, I did not apply any special meaning to any of the claim terms. Each of the claim terms in the Challenged Patent have well-understood plain meanings to a POSITA.

XII. OVERVIEW OF THE PRIOR ART

A. THE VOSTEEN589 PATENT PUBLICATION [EX1005]

216. 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

217. 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.

2. Vosteen589 Is Analogous Art

218. 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

[329] 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)).

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."[330] The specific problem faced by the inventors of the Challenged Patent was "a need for more economical and effective mercury removal technology."[331] 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."[332]

3. Overview of the Disclosure of Vosteen589

219. Vosteen589 describes processes for the "removal of mercury from the flue gases in a flue gas emission control system downstream of the combustion," in plants such as "power stations, for example bituminous coal-fired or lignite-fired power stations."[333] Vosteen589 describes removing mercury by applying "bromine

[330] EX1001 ('370 Patent) at 1:41-45.

[331] EX1001 ('370 Patent) at 2:38-39.

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

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

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."[334] 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."[335]

220. 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 $HgCl_2$."[336] The adsorbent is part of the "dry emission control system" of Vosteen589, also referred to as a "dry or semi-dry adsorption-based emission control stage."[337] As a result, Vosteen589 discloses the ability to remove more than 90% of mercury.[338]

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

[335] EX1005 (Vosteen589) ¶[0016].

[336] EX1005 (Vosteen589) ¶[0019].

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

[338] EX1005 (Vosteen589) at Figure 5.

B. THE DOWNS-BOILER REFERENCE [EX1006]

221. 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 '370 Patent.

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

222. 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"),[339] which was filed on March 22, 2004.

223. 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;

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

and the provisional application must also describe the subject matter relied upon in the issued U.S. patent.

224. 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

225. 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."[340] The specific problem faced by the inventors of the Challenged Patent was "a need for more economical and effective mercury removal technology."[341] So too, the field of endeavor of Down-Boiler, as reflected in its title, is "removal of mercury from flue gas," and the problem faced was a need for "cost-effective mercury control techniques."[342]

3. Overview of the Disclosure of Downs-Boiler

226. Downs-Boiler describes processes for improving the removal of mercury released from the combustion of coals. Downs-Boiler discloses that the "mercury removal" may be performed with "carbonaceous sorbents [that] include, but are not limited to, powdered activated carbon (PAC)."[343] 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.[344]

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[340] EX1001 ('370 Patent) at 1:41-45..

[341] EX1001 ('370 Patent) at 2:38-39.

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

[343] EX1006 (Downs-Boiler) ¶[0025].

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

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:[345]

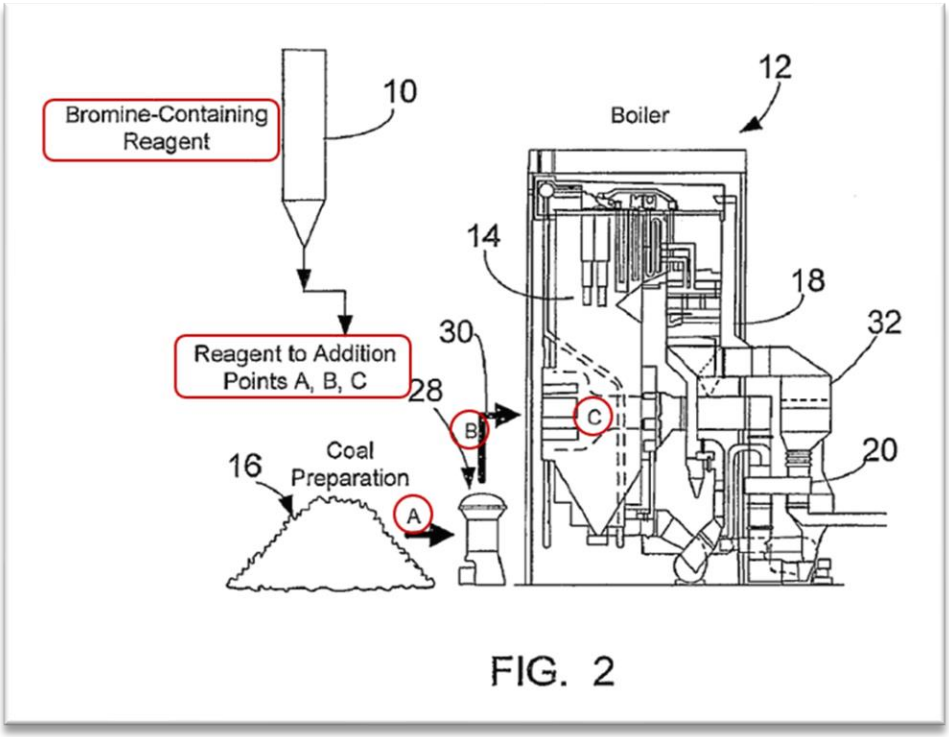


FIG. 2

227. 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

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

> downstream pollution control systems such as wet 22 and SDA 24 FGD systems, and PAC injection systems.[346]

Downs-Boiler describes that the bromine-containing reagent can be fed in either "gaseous, liquid, or solid form."[347] The reagent could be made from "alkali metal and alkaline earth metal bromides, hydrogen bromide (HBr) or bromine (Br_2)."[348] Examples of alkali earth metal bromides include calcium bromide ($CaBr_2$).[349]

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

228. Exhibit 1032 ("Downs-Boiler-Redline") is a redline comparison between U.S. Patent Pub. No. 2008/0107579 (Downs-Boiler) and U.S. Provisional Application No. 60/555,353 (Downs-Boiler-Provisional), using Downs-Boiler-Provisional as the original version.[350] 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

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

[347] EX1006 (Downs-Boiler) ¶[0022].

[348] EX1006 (Downs-Boiler) ¶[0021].

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

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

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.

229. 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:"

230. Downs-Boiler-Provisional discloses this preamble. The title of the disclosure is "Bromine Addition for the Improved Removal of Mercury from Flue Gas."[351] Downs-Boiler-Provisional further discloses that the "invention promises to significantly reduce the cost of mercury removal at coal-fired electric plants."[352]

[351] 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.

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

Downs-Boiler-Provisional discloses that it removes both oxidized mercury and elemental mercury from mercury-containing flue gases.[353] 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."[354]

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

231. Downs-Boiler-Provisional discloses this element. Again, the title of the disclosure is "Bromine Addition for the Improved Removal of Mercury from Flue Gas."[355] Downs-Boiler-Provisional further describes the ability "to promote the oxidation of elemental mercury if the correct species (in this case bromine species) are present in the flue gases."[356]

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

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

[355] 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.

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

232. 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."[357]

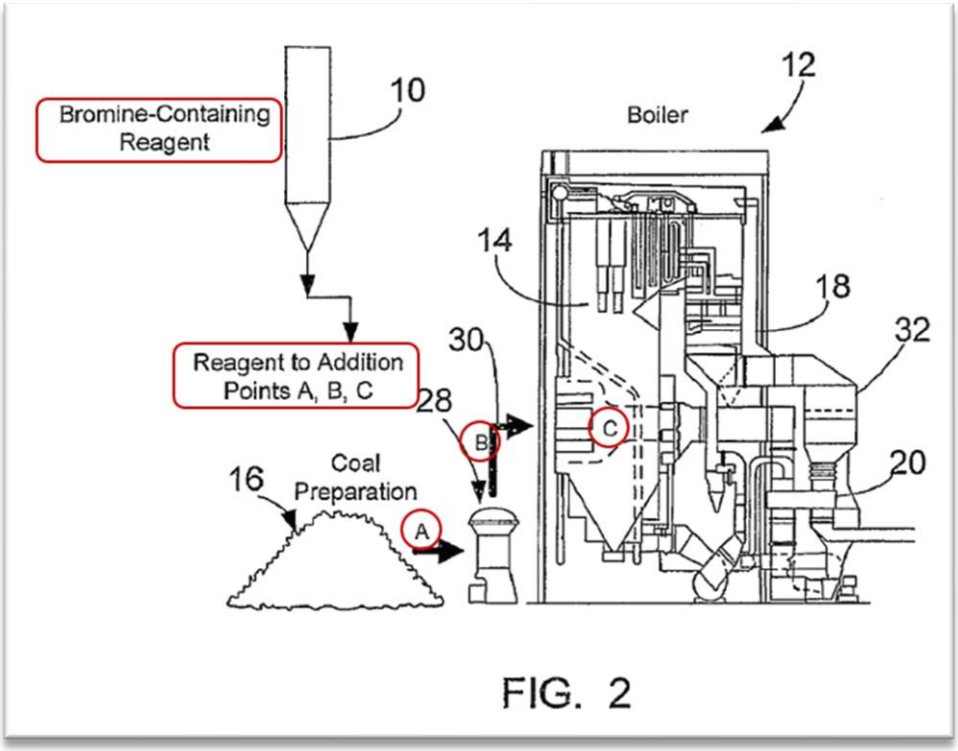


FIG. 2

233. 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

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

then "enhances mercury removal in downstream pollution control systems such as wet and SDA FGD systems, and PAC injection systems."[358]

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

234. 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 injection process, due to the higher reactivity of oxidized mercury with PAC.[359]

235. Downs-Boiler-Provisional makes clear that the effect of the bromine-containing reagent is a promotion of the oxidation of elemental mercury, describing

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

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

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."[360]

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

236. 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."[361]

237. 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).[362] Thus, Downs-Broiler-Provision teaches to

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

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

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

create oxidized forms of mercury from the elemental mercury by oxidizing the available elemental mercury.[363] 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."[364]

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

238. 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."[365]

239. 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

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

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

[365] 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.

injection [which] removes both oxidized and elemental mercury species, although removal efficiencies are higher for the oxidized form."[366] 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."[367] The mercury-sorbent composition can be removed with "electrostatic precipitators (ESP) or fabric filters (FF), sometimes called baghouses," as well as in "wet and spray dryer absorber (SDA) flue gas desulfurization (FGD) systems."[368]

C. THE LISSIANSKI REFERENCE [EX1014]

240. EX1014 ("Lissianski") is U.S. Patent No. 7,514,052, which names Vitali Victor Lissianski as the sole inventor, and was assigned to General Electric Company. Lissianski is entitled, "Method for Removal of Mercury Emissions from Coal Combustion."[369]

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

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

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

[369] EX1014 (Lissianski) at Title.

1. Prior-Art Status of Lissianski

241. Lissianski was issued by the USPTO on April 7, 2009 as U.S. Patent No. 7,514,052, from U.S. Patent Application No. 10/751,496, which was filed January 6, 2004. Accordingly, I understand that Lissianski qualifies as prior art at least as of January 6, 2004.

2. Lissianski is Analogous Art

242. Lissianski 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."[370] The specific problem faced by the inventors of the Challenged Patent was "a need for more economical and effective mercury removal technology."[371] So too, the field of endeavor of Lissianski is "the reduction of mercury (Hg) and nitrogen oxides (NOx) in flue gas generated during coal combustion," and the problem faced was a "need

[370] EX1001 ('370 Patent) at 1:41-45.

[371] EX1001 ('370 Patent) at 2:38-39.

to reduce Hg and NOx in gaseous emissions from coal-fired boilers and other industrial coal combustion systems."[372]

3. Overview of the Disclosure of Lissianski

243. Lissianski describes the use of halides—including NH_4Cl, NH_4Br, and NH_4I—for reducing mercury emissions during coal combustion. The abstract of Lissianski summarizes the process as follows, with the paragraph spacing added by me to divide the steps:

> A method to reduce emissions in flue gas due to combustion of coal in a combustion unit including the steps of:
>
> combusting coal in a primary combustion zone of the combustion unit;
>
> releasing elemental mercury from the combustion into the flue gas;
>
> injecting NH_4Cl, NH_4Br, or NH_4I into the flue gas;
>
> oxidizing the elemental mercury with halogen from the additive;
>
> adsorbing the oxidized mercury generated by the combustion of the coal with an adsorbent in the flue gas, and collecting the adsorbent with the oxidized mercury in a combustion waste treatment system.[373]

[372] EX1014 (Lissianski) at 1:6-13, 3:45-49, claim 8.

[373] EX1014 (Lissianski) at Abstract.

244. Lissianski describes that during coal combustion, mercury is emitted in two different states—elemental mercury (Hg^0) and oxidized mercury (Hg^{+2}).[374] Lissianski further describes in the background section, "Oxidized mercury (Hg^{+2}) is more easily collected by emission control devices than is elemental mercury. Oxidization of mercury is a known technique to capture mercury and remove it from flue gases."[375] Oxidized mercury is more easily removed because it is "easily adsorbed upon high carbon fly ash *or activated carbon*."[376]

245. Lissianski improves the mercury capture by injecting a "halogen agent," such as ammonium iodide (NH_4I), ammonium bromide (NH_4Br), and ammonium chloride (NH_4Cl), as an aqueous solution into the "coal combustion furnace **12**, e.g., a boiler."[377] This is shown in Lissianski's Figure 1 below:[378]

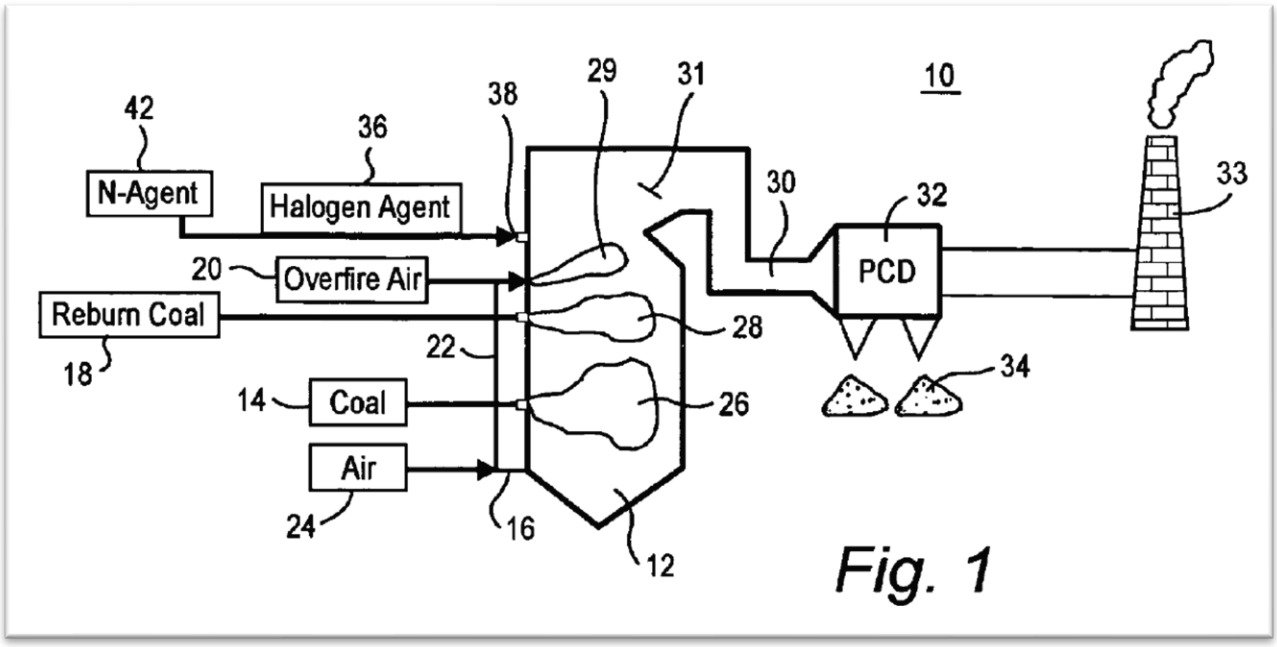
[374] EX1014 (Lissianski) at 1:22-23.

[375] EX1014 (Lissianski) at 1:24-25.

[376] EX1014 (Lissianski) at 1:35-36.

[377] EX1014 (Lissianski) at 3:59-60, 4:15-16.

[378] EX1014 (Lissianski) at Fig. 1.



The halogen is provided at "flue gas temperatures of, for example, 1600ºF to 2300ºF," and is transported to the flue gas with "air, recycled flue gas, nitrogen or another carrier gas," or in ammonia.[379] The halogen is dispersed into the gaseous phase, especially at the flue-gas temperatures. The "hot flue gas causes the additive to thermally decompose to form HCl, HBr or HI which results in more significant mercury oxidation. The increase in mercury oxidation allows for improved efficiency of mercury removal by activated carbon (AC) injection."[380] The halogens

[379] EX1014 (Lissianski) at 4:13-29.

[380] EX1014 (Lissianski) at 3:45-49; *see also* EX1014 (Lissianski) at claim 8.

of Lissianski also "increase efficiency of NOx reduction," another harmful pollutant, "by reducing oxides of nitrogen to molecular nitrogen."[381]

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

246. The Air & Waste Management Association ("AWMA") Conference has been held annually since 1907.[382] The primary purpose of AWMA is to provide training, information, and networking opportunities to thousands of environmental professionals in 65 countries across the world.[383] 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.[384] I delivered presentations at the 94th conference in 2001 entitled, "Interpreting

[381] EX1014 (Lissianski) at 3:23-25, 4:55-59.

[382] 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/.

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

[384] 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.

247. 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.[385] Exhibit 1077 is a true and correct copy of the label and jacket of

[385] 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").[386]



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

[386] EX1077 (AWMA CD Photo).

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.[387]

249. 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.[388]

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[387] 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.

[388] 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

250. The 2002 AWMA Conference took place on June 23-27, 2002 at the Baltimore Convention Center, in Baltimore, Maryland:[389]



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

[389] 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:[390]

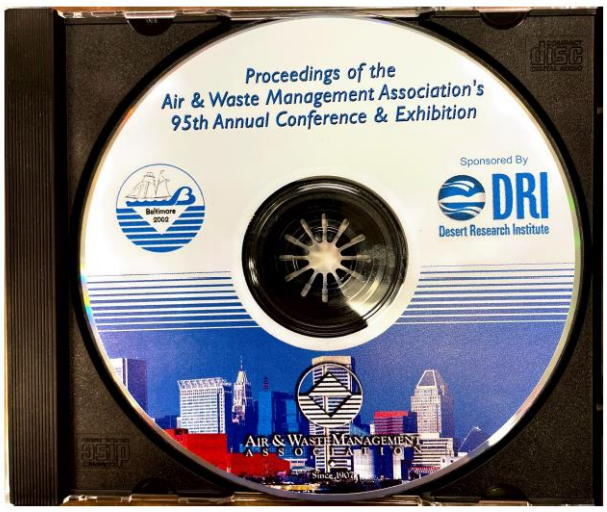


I received the CD from the 2002 AWMA Conference in summer 2002 ("AWMA CD Scan"), and photographs of the physical CD from which the Starns reference (EX1008) was copied, are shown below:[391]

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

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





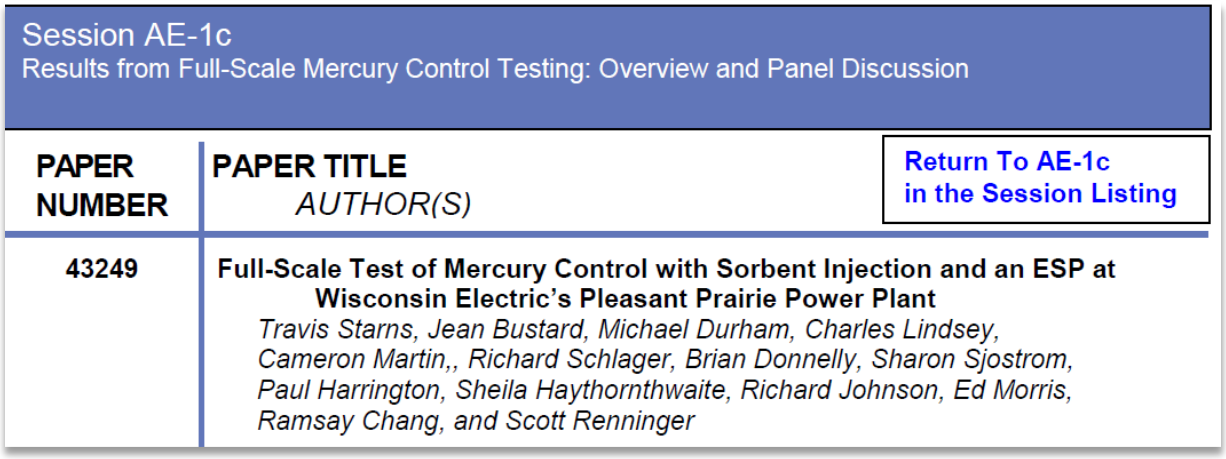
The author listing for the Starns paper is shown below, which is on a file from the physical CD:[392]

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**

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

The session listing, showing the Starns paper, is below[393]:



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*	

251. 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:[394]

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

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

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Annual Conference Proceedings CD-ROMs

2002
2001
2000
1999
1998
1997
1996

Air Pollution Engineering Manual, second edition



252. 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")):[395]

[395] 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

253. 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.[396] 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.[397]

2. Starns Is Analogous Art and Overview of the Disclosure

254. 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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[396] 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.

[397] 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."[398] The specific problem faced by the inventors of the Challenged Patent was "a need for more economical and effective mercury removal technology."[399] 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."[400] Both references address the problem through using activated carbon sorbents.[401] 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.

[398] EX1001 ('370 Patent) at 1:41-45.

[399] EX1001 ('370 Patent) at 2:38-39.

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

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

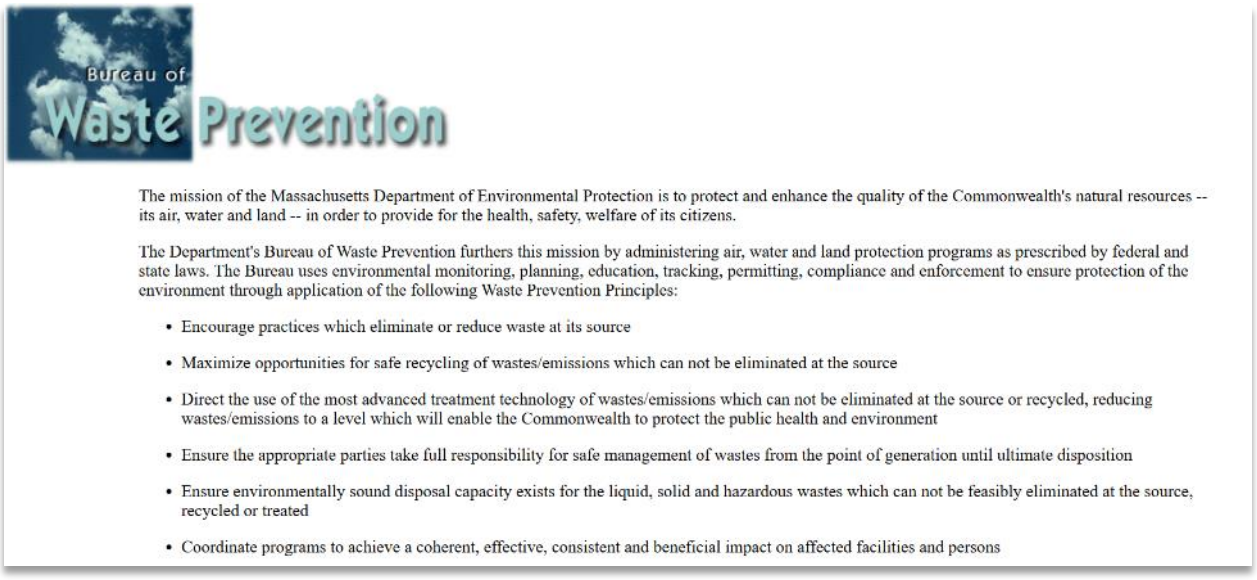
E. MASS-EPA [EX1009]

1. Prior Art Status of Mass-EPA

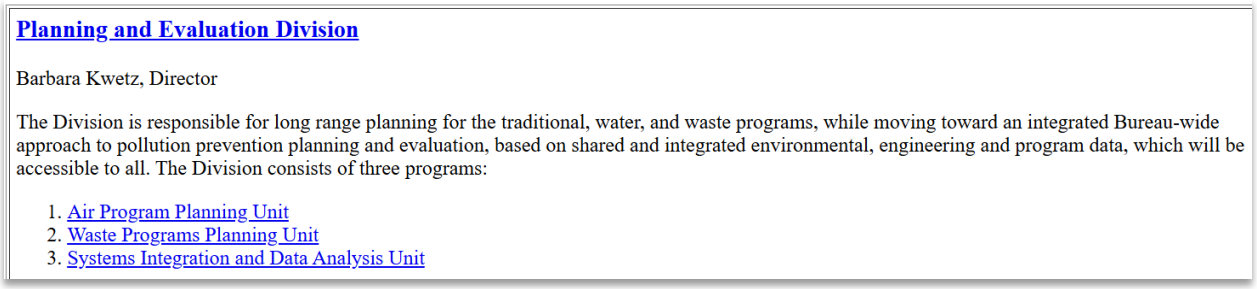
255. Mass-EPA was published by the Massachusetts Department of Environmental Protection, which is an administrative agency of the Commonwealth of Massachusetts with the established goal of protecting and enhancing the quality of Massachusetts' natural resources to provide for the health, safety, and welfare of its citizens.[402] Within the Massachusetts Department of Environmental Protection is the Bureau of Waste Prevention, which administers air, water, and land protection programs:[403]

[402] 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.

[403] 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.[404] The tasks of the Planning and Evaluation Division were as follows:[405]



[404] 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.

[405] 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.

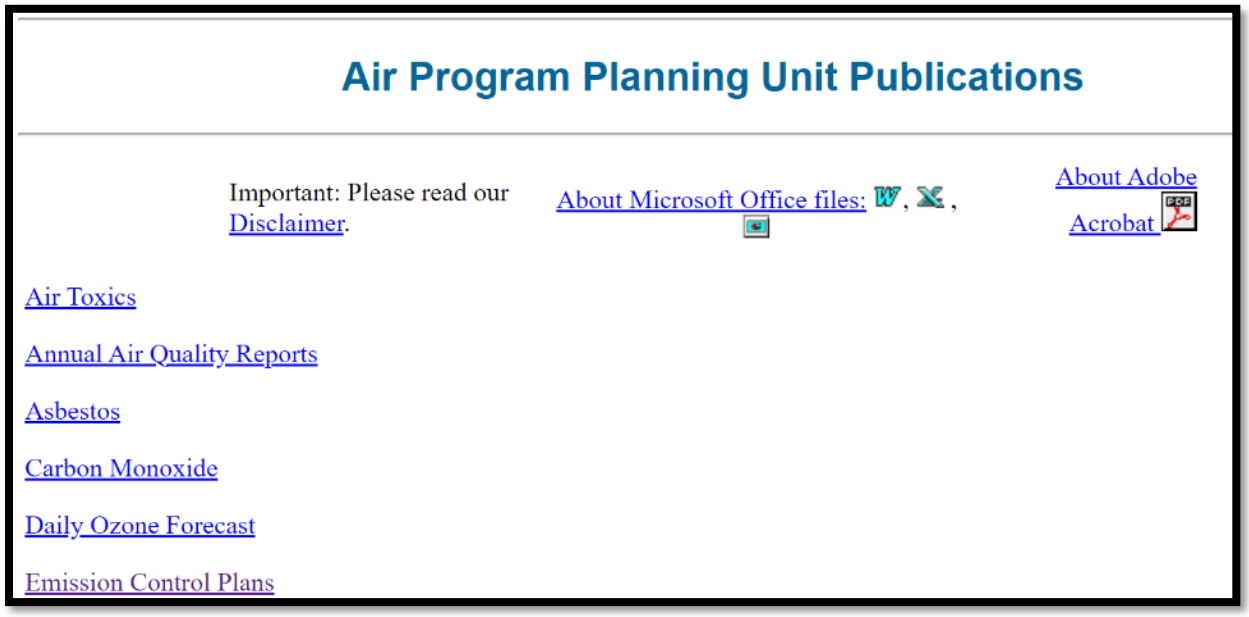
A POSITA would have looked to the Massachusetts EPA, including the Planning and Evaluation Division, as a repository for pollution mitigation, particularly since the goal of it was to provide "shared and integrated environmental, engineering and program data, which will be accessible to all."[406] Within the Planning and Evaluation Division is the Air Program Planning Unit.[407] 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:[408]

[406] 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.

[407] 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.

[408] 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

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Annual Air Quality Reports

Asbestos

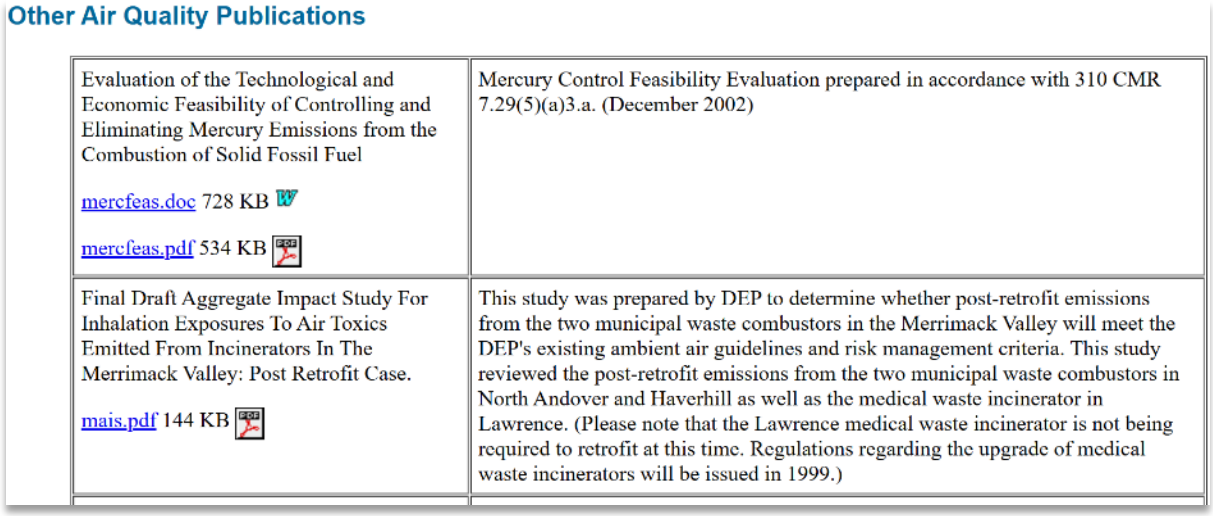
Carbon Monoxide

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.[409]

[409] 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.

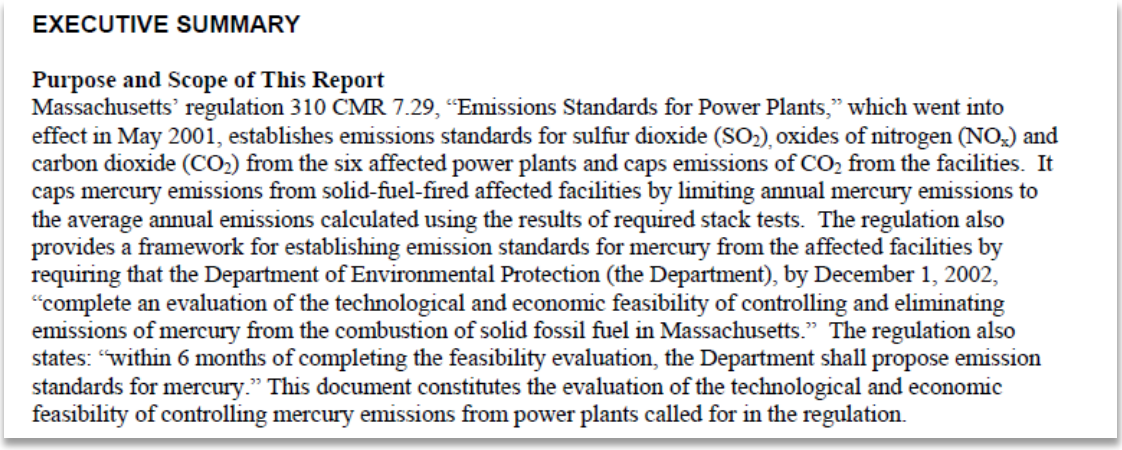


Other Air Quality Publications

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:[410]

[410] EX1009 (Mass-EPA) at 1 (Executive Summary).

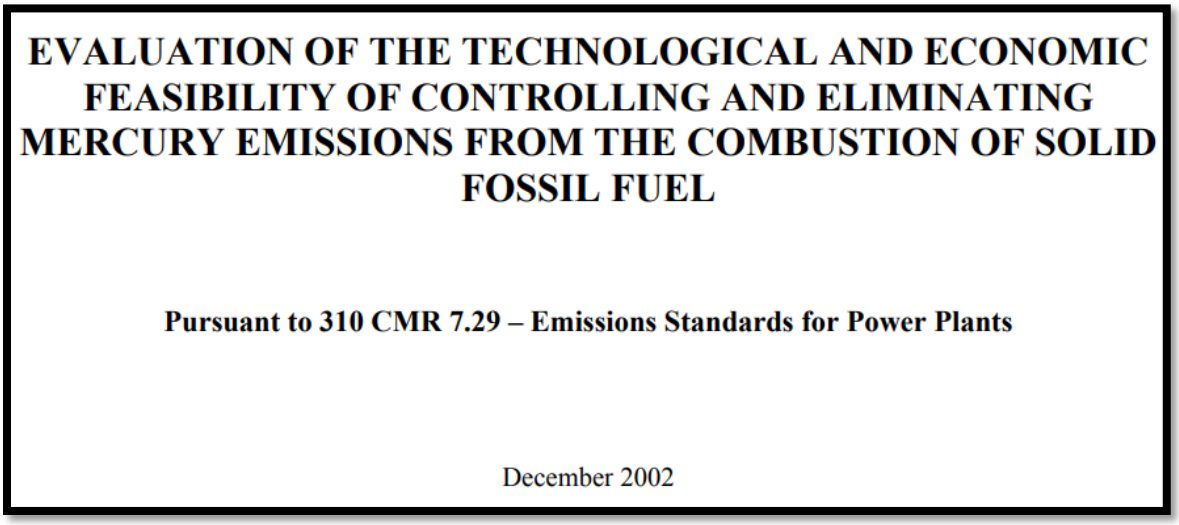


EXECUTIVE SUMMARY

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.

256. 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":[411]



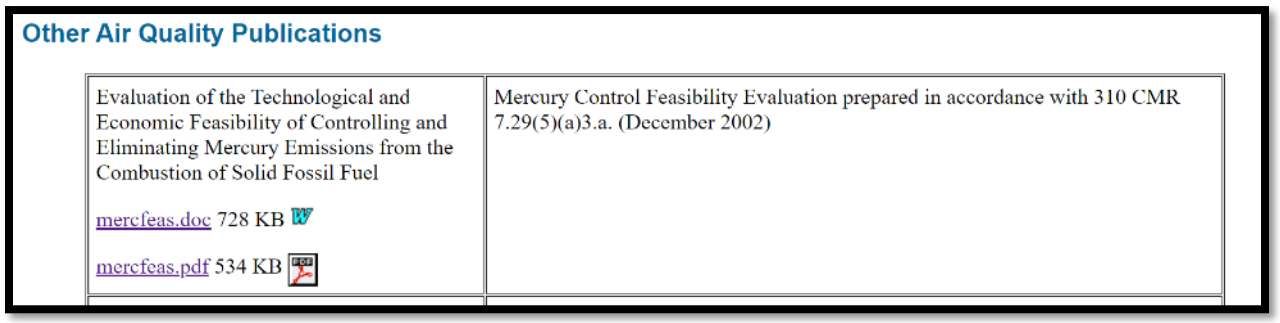
EVALUATION OF THE TECHNOLOGICAL AND ECONOMIC FEASIBILITY OF CONTROLLING AND ELIMINATING MERCURY EMISSIONS FROM THE COMBUSTION OF SOLID FOSSIL FUEL

Pursuant to 310 CMR 7.29 – Emissions Standards for Power Plants

December 2002

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

257. 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):[412]



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.[413]

258. 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.

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

[413] 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."[414] 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.[415] 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

259. 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

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

[415] 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."[416] The specific problem faced by the inventors of the Challenged Patent was "a need for more economical and effective mercury removal technology."[417] 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."[418] 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."[419] Mass-EPA provides details as to how to inject activated carbon at a coal-fired power plant.

[416] EX1001 ('370 Patent) at 1:41-45.

[417] EX1001 ('370 Patent) at 2:38-39.

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

[419] 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.

F. EUEC CONFERENCE (2005) – SJOSTROM [EX1010] AND ECKBERG [EX1011]

260. 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.[420] 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.

261. 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

[420] 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").[421]

262. 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.

263. 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,

[421] 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.

264. 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.

265. 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

266. The 2005 EUEC took place on January 24-25, 2005 at the Westin La Paloma Resort, in Tucson, Arizona.[422] The conference included four separate presentation tracks: Track A – Air quality; Track B – Global Climate Change; Track C – Renewable Energy; and Track D – Other.[423] 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").[424]

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

[423] EX1030 (EUEC Handout) at 2.

[424] EX1031 (EUEC CD Scan).

267. I personally presented at the 2005 EUEC in Track A – Air Quality proceedings and attended most presentations for Track A – Air Quality proceedings.[425] An excerpt of the program schedule discussing my presentation is shown below:[426]

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.[427]

[425] EX1030 (EUEC Handout) at 3.

[426] EX1030 (EUEC Handout) at 32.

[427] EX1031 (EUEC CD Scan).

268. In addition to myself, over 800 people attended the 2005 EUEC, as described in the attendee list included in the EUEC Handout.[428] 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.

269. 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.[429] 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

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

[429] EX1030 (EUEC Handout) at 23.

the other conference attendees, as reflected in Sjostrom, correlates with the presentation I attended at the 2005 EUEC.[430]

270. 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.[431] 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.[432]

271. 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.[433] The attendees for the A3 session were generally the same as those described above with regards to Track A as a

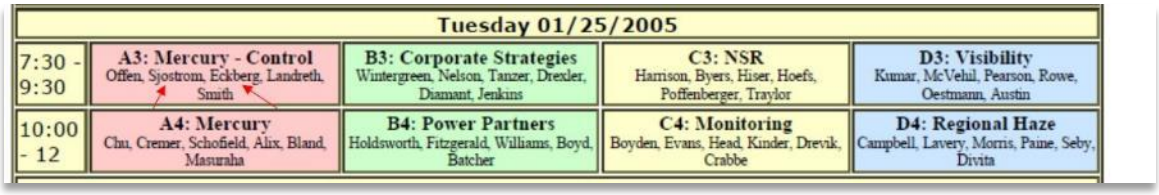
[430] EX1010 (Sjostrom).

[431] EX1030 (EUEC Handout) at 23.

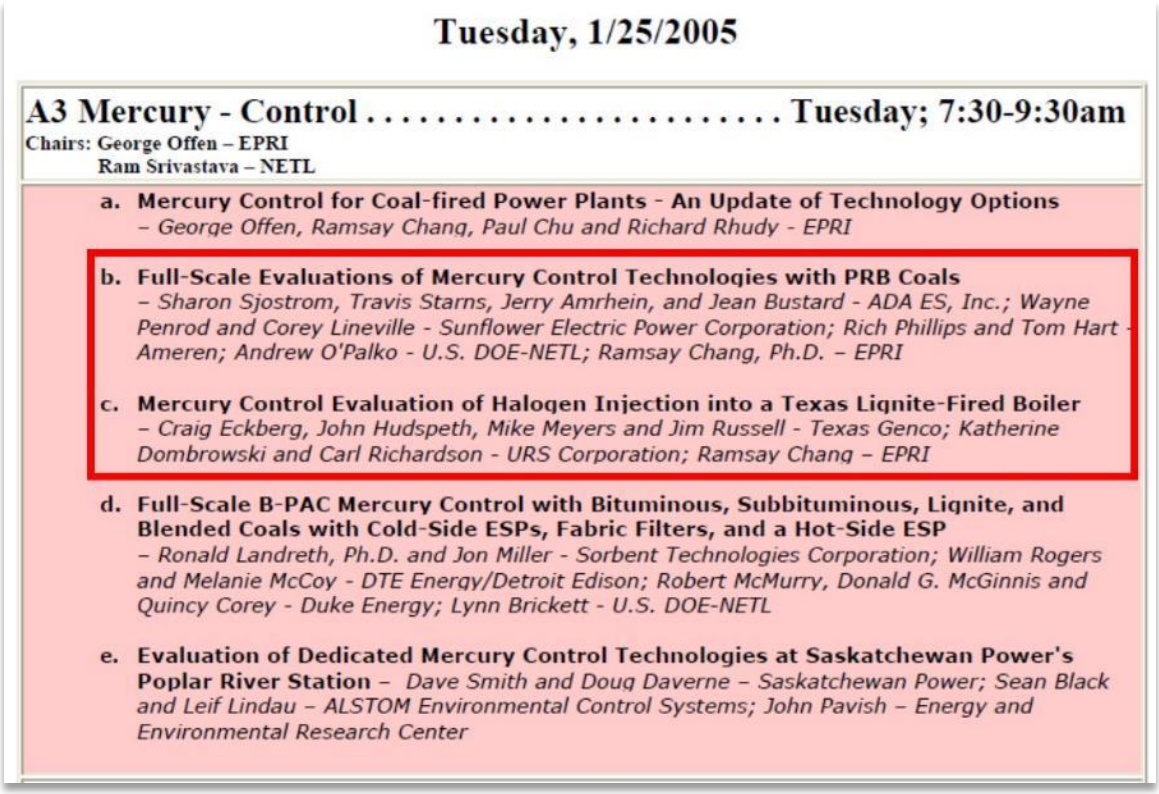
[432] EX1011 (Eckberg).

[433] EX1030 (EUEC Handout) at 23.

whole. In fact, Sjostrom and Eckberg were presented consecutively, in the same room.[434]



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.[435]

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

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

2. Sjostrom Is Analogous Art and Overview of the Disclosure

272. 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."[436] The specific problem faced by the inventors of the Challenged Patent was "a need for more economical and effective mercury removal technology."[437] 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."[438]

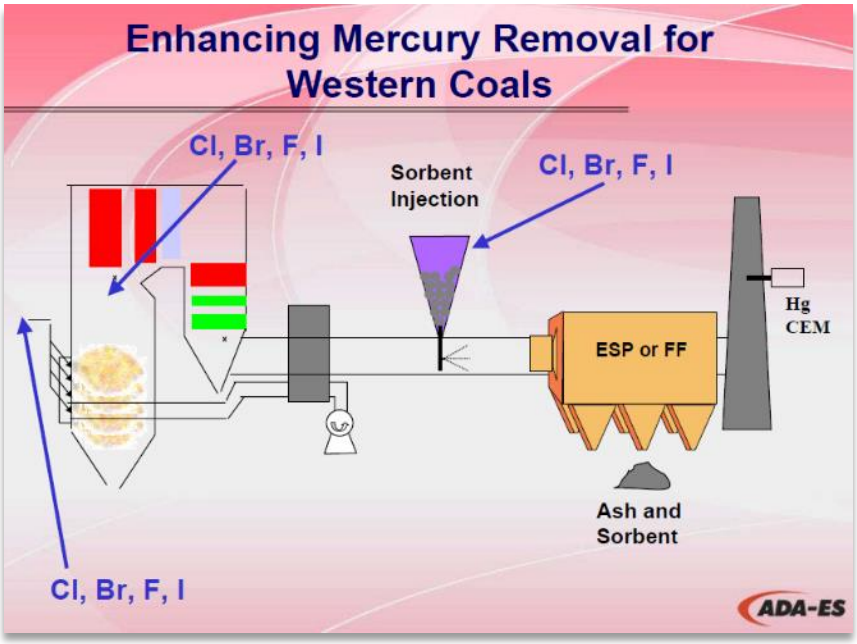
273. Sjostrom discussed the results of full-scale testing that was focused on increasing the halogen concentration, including bromine and iodine, in coal-fired power-plant flue gas for the purpose of mercury removal from the flue gas. Sjostrom disclosed multiple methods of introducing the halogens, and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

[436] EX1001 ('370 Patent) at 1:41-45.

[437] EX1001 ('370 Patent) at 2:38-39.

[438] 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."[439] 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.[440]



In the figure above, the following abbreviations are used:

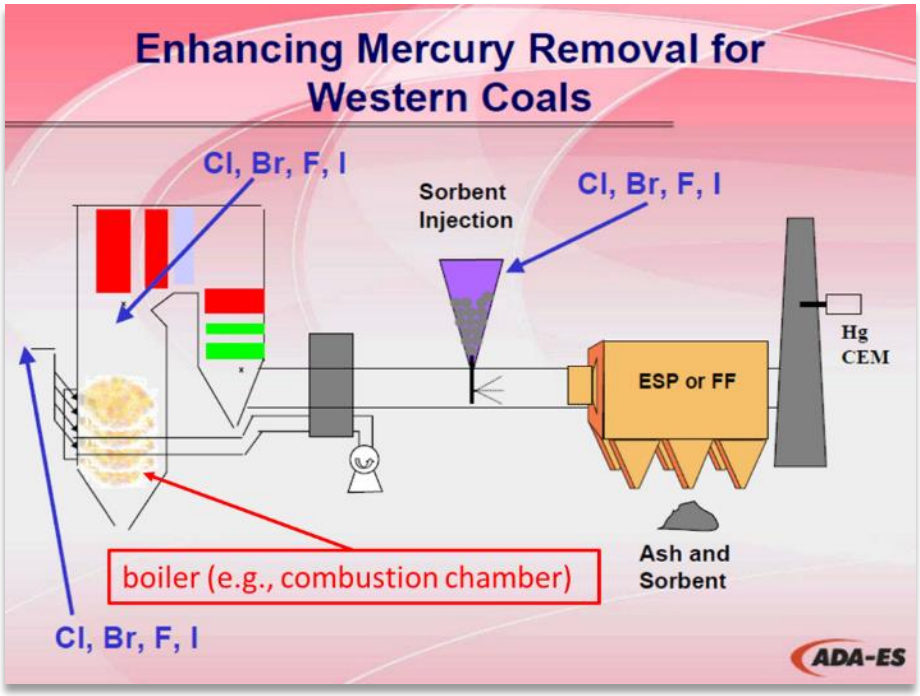
- Cl, Br, F, I: chemicals containing chlorine, bromine, fluorine, and iodine
- ESP or FF: electrostatic precipitator or fabric filter

[439] EX1030 (EUEC Handout) at 23.

[440] EX1010 (Sjostrom) at 4.

- Hg CEM: mercury (Hg) continuous emissions monitor

274. Sjostrom described various mercury control tests conducted at coal-fired power plants.[441] 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.[442]



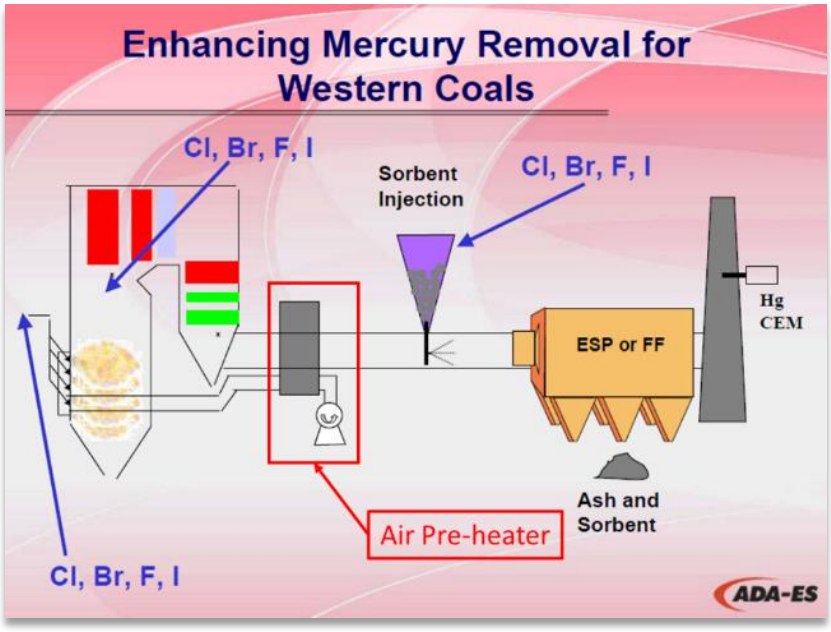
A POSITA would have understood that this unit was a boiler based on the image used to represent the unit in the drawing, which was a common and routine way to

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

[442] 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.[443]

275. 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.[444]



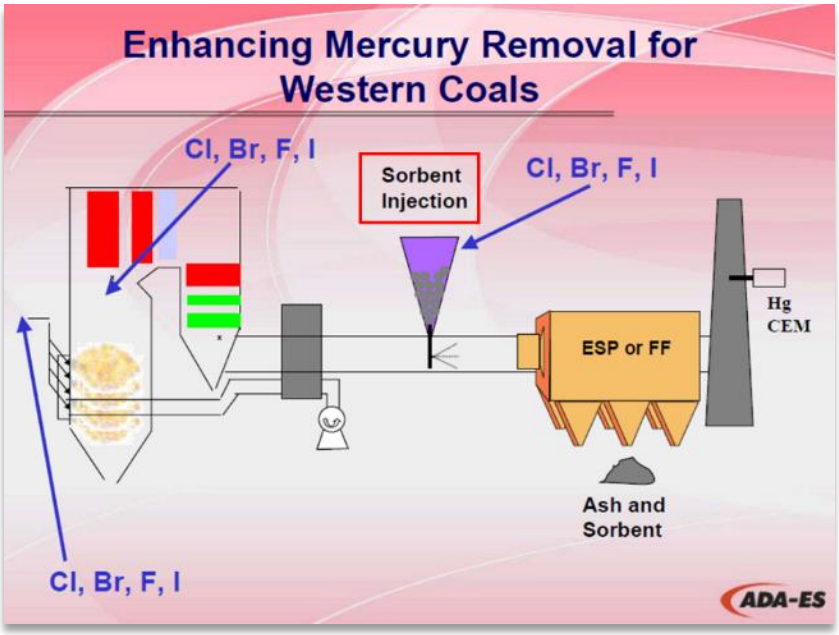
A POSITA would have understood that the labeled component is an air pre-heater based on the image used to portray the unit on the schematic of Sjostrom. For example, the image includes a fan connected to a flow-path loop going into the inlet of the boiler to mix preheated air and coal. The gray box indicates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

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

[444] 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.

276. 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.[445]

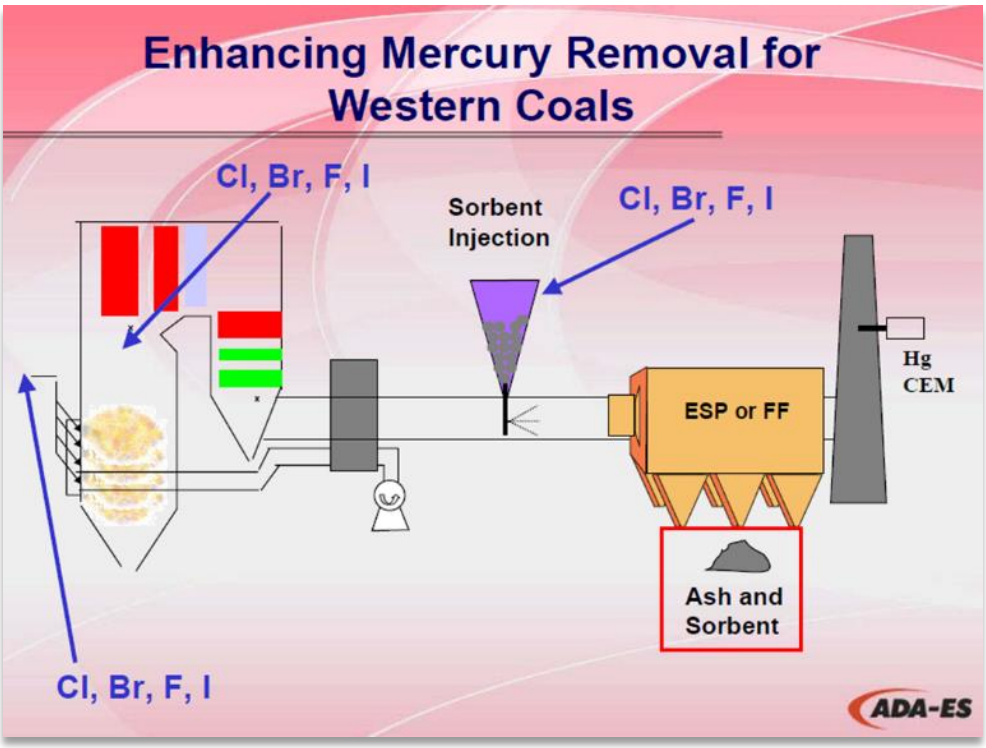


The sorbent used by Sjostrom is "activated carbon injection."[446]

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

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

277. 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").[447]

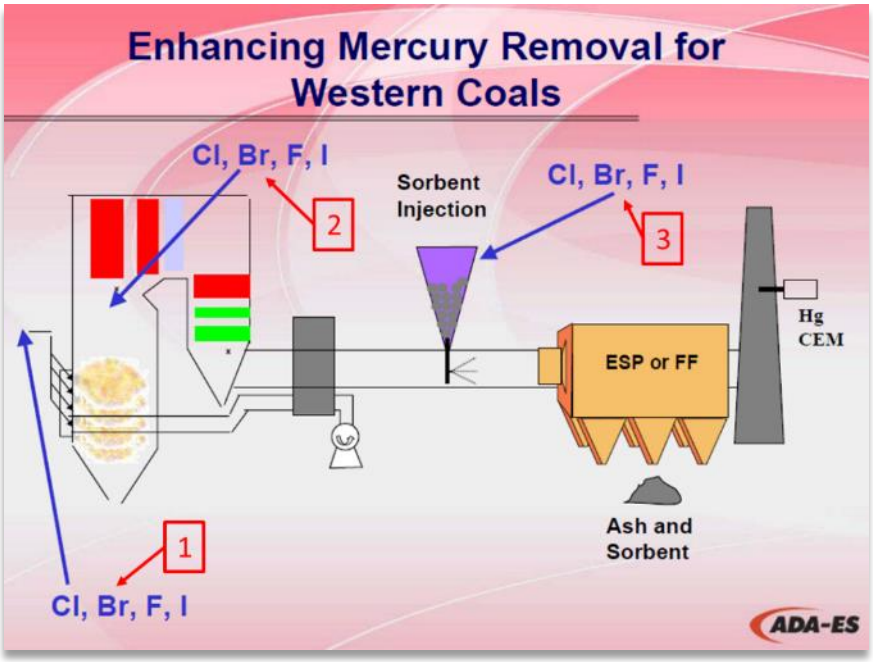


This annotated figure from Sjostrom specifically shows that particulate matter, including the mercury-sorbent composition, would have been separated from the flue gas by the ESP (electrostatic precipitator) or FF (fabric filter), because a

[447] 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.[448]

278. Sjostrom demonstrates that activated-carbon sorbent injection was a well-known way of treating mercury emissions in flue gas.[449] 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).[450]



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

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

[450] 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 halogens upstream of the combustion chamber, such as by adding it to the coal entering the boiler.[451] The figure should be read within the larger context of the paper, which specifically refers to "Coal Additives" at Meramec.[452] With this context in mind, the schematic shows an arrow at Location 1 indicating the addition of halogens to pulverized coal in the primary air lines.[453] For example, the schematic of Sjostrom shows the stream splitting into four burner injection lines.[454] The schematic further shows a combustion plume corresponding to Location 1 of each of these four burner injection lines.[455] Thus, a POSITA would have understood that this was the primary air injection stream that included pulverized coal. Location 2 of Sjostrom teaches injecting halogens into the

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

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

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

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

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

combustion chamber.[456,457] Location 3 of Sjostrom teaches adding halogens to the activated-carbon sorbent that is injected into the flue gas.[458]

3. Eckberg Is Analogous Art and Overview of the Disclosure

279. 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."[459] The specific problem faced by the inventors of the Challenged Patent was "a need for more economical and effective mercury removal technology."[460] So too, the field of endeavor of Eckberg, as reflected in its title, is "Mercury Control Evaluation of

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

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

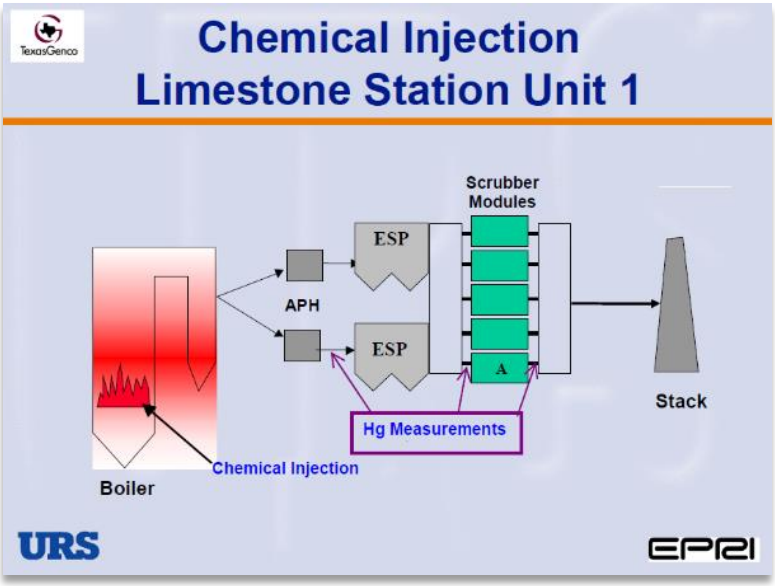
[458] EX1010 (Sjostrom) at 4 (annotations in red).

[459] EX1001 ('370 Patent) at 1:41-45.

[460] EX1001 ('370 Patent) at 2:38-39.

Halogen Injection into a Texas Lignite-Fired Boiler," and the problem faced was a need to "enhance mercury removal."[461]

280. 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."[462] 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").[463]

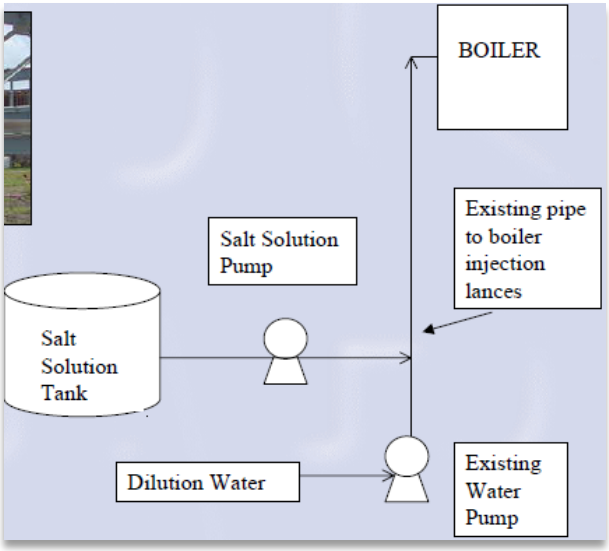


[461] EX1011 (Eckberg) at 1, 3.

[462] EX1030 (EUEC Handout) at 24.

[463] EX1011 (Eckberg) at 5.

281. Eckberg also includes a schematic showing the injection equipment used for the chemical injection.[464]



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 "$CaCl_2$ (25 wt%)" and "$CaBr_2$ (52 wt%)."[465] $CaBr_2$ 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, the feed

[464] EX1011 (Eckberg) at 8.

[465] EX1011 (Eckberg) at 9.

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.[466]

G. THE OLSON-646 REFERENCE [EX1012]

282. 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."[467]

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

283. 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

284. 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

[466] EX1011 (Eckberg) at 9.

[467] 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."[468] The specific problem faced by the inventors of the Challenged Patent was "a need for more economical and effective mercury removal technology."[469] 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."[470]

3. Overview of the Disclosure of Olson-646

285. Figure 2 of Olson-646, reproduced below, shows "a theory developed from scientific evidence to explain the nature of the promoting compounds."[471]

[468] EX1001 ('370 Patent) at 1:41-45.

[469] EX1001 ('370 Patent) at 2:38-39.

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

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

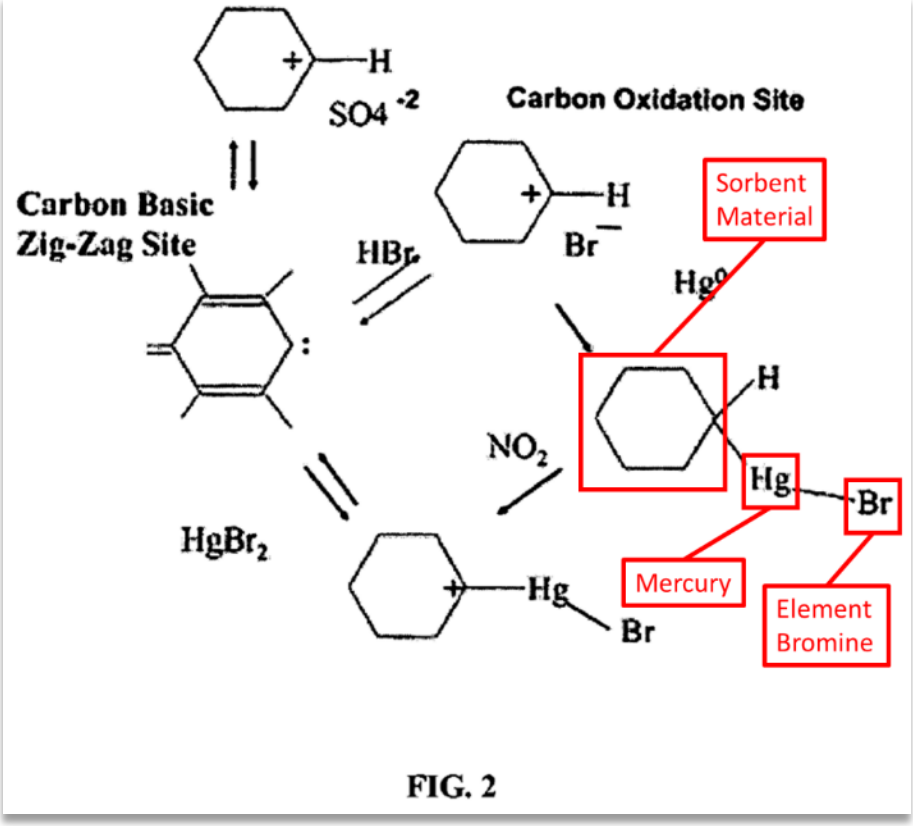


FIG. 2

The text in red was added above. Olson-646 explains that "hydrogen bromide reacts with the unsaturated structure of the activated carbon."[472] Olson-646 teaches that the reaction may take place at "a carbene species on the edge of the graphene sheet structures of the carbon."[473] 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."[474]

[472] EX1012 (Olson-646) ¶[0054].

[473] EX1012 (Olson-646) ¶[0054].

[474] 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.[475] Though more expensive, iodine can also be used, as well as other halogens or halides.[476]

286. 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.[477]

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

[476] EX1012 (Olson-646) ¶¶[0025], [0067], [0093].

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

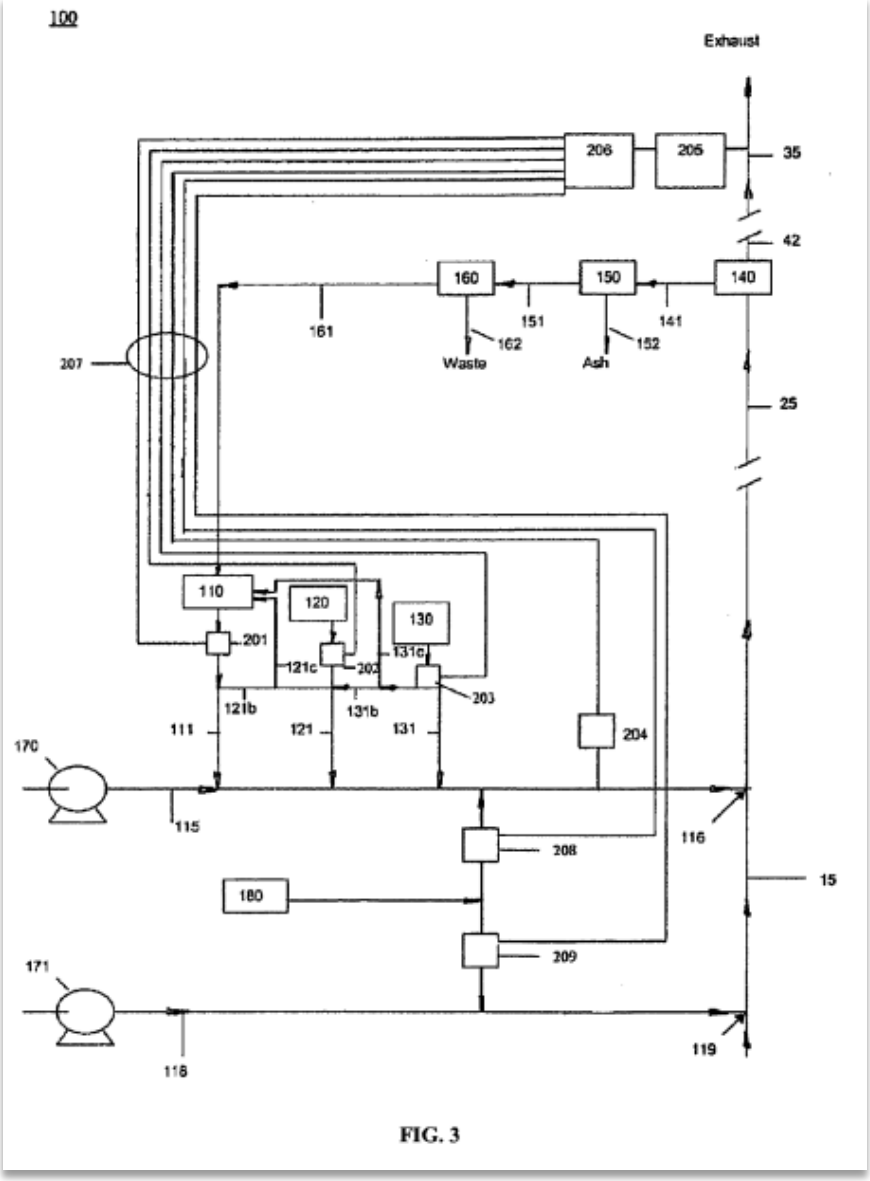


FIG. 3

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."[478]

[478] EX1012 (Olson-646) ¶[0056].

287. 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."[479] Olson-646 explains that a "promoted carbon sorbent and/or an optional alkali component is injected into contaminated flue gas stream 15."[480]

H. THE BALDREY REFERENCE [EX1015]

288. Exhibit 1015 ("Baldrey") is U.S. Patent Pub. No. 2011/0030592 which names Kenneth E. Baldrey, Sharon Sjostrom, Nina Bergan French, Michael Durham, Stephen Allen Johnson, John Wurster, and John Philip Corner as co-inventors and was assigned to ADA Environmental Solutions, LLC. Baldrey is entitled "Additives for Mercury Oxidation in Coal-Fired Power Plants."[481]

1. Prior-Art Status of the Baldrey Reference

289. I have been informed that Baldrey was filed on May 21, 2010 as U.S. Patent App. No. 12/785,184 and published on February 10, 2011 as U.S. Patent Publication No. 2011/0030592. As described above, the Challenged Claims of the

[479] EX1012 (Olson-646) ¶[0056].

[480] EX1012 (Olson-646) ¶[0061].

[481] EX1015(Baldrey).

Challenged Patent do not have priority support to the earlier-filed applications. Accordingly, I understand that Baldrey qualifies as prior art, as it was filed more than one year before the earliest priority date of the Challenged Patent.

2. Baldrey Is Analogous Art

290. Baldrey 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."[482] The specific problem faced by the inventors of the Challenged Patent was "a need for more economical and effective mercury removal technology."[483] So too, the field of endeavor of Baldrey relates to "additives for coal-fired power plants and particularly to additives for mercury removal," and the problem faced was "a need for an effective mercury control methodology" for "lower rank coals."[484]

[482] EX1001 ('370 Patent) at 1:41-45.

[483] EX1001 ('370 Patent) at 2:38-39.

[484] EX1015 (Baldrey) ¶¶ [0002], [0008].

3. Overview of the Disclosure of Baldrey

291. Figure 2 of Baldrey, reproduced below, depicts the coal combustion assembly described by Baldrey:[485]

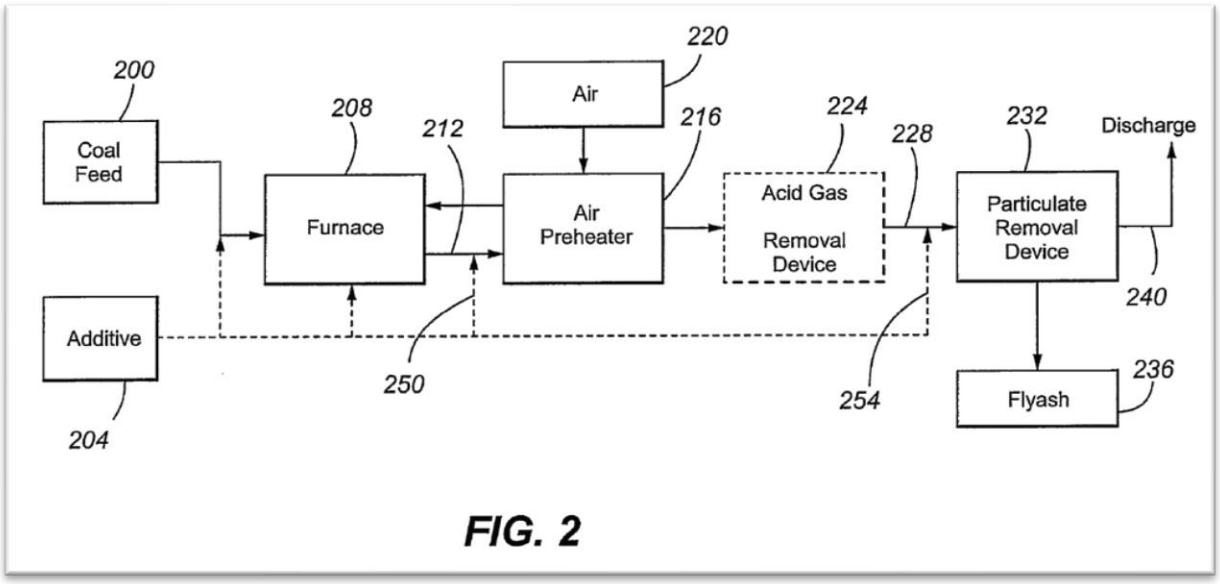


FIG. 2

Baldrey's Figure 2 depicts the process of adding the coal **200** to the furnace **218**, a combustion chamber, and thereby producing the mercury-containing flue gas **212**.[486] Baldrey teaches that an "additive [] can be combined and introduced with the coal feed 200 [or] injected into the furnace atmosphere independently of the coal feed 200," among other locations depicted in Figure 2.[487] Baldrey further discloses that

[485] EX1015 (Baldrey) ¶[0052], Fig. 2.

[486] EX1015 (Baldrey) ¶¶[0079-88].

[487] EX1015 (Baldrey) ¶[0089].

"[i]n a second formulation, the additive includes one or more additive metal catalysts or a precursor thereof and one or more diatomic halogens (e.g., Cl_2 and Br_2), interhalogen compounds (e.g., BrCl), and halide salts to act as elemental mercury oxidants."[488] Baldrey teaches that "[p]referred supplemental halide salts are calcium chloride ($CaCl_2$), iron (III) chloride ($FeCl_3$), copper (II) chloride ($CuCl_2$), magnesium bromide ($MgBr_2$), calcium bromide, sodium bromide, potassium iodide, and also the hydrated states of these halide salts."[489]

292. Baldrey discloses that "the additive of the present invention is believed to promote mercury oxidation and sorption by enrichment of transition metal catalysts in the fly ash or on suitable mercury sorbents that are injected and captured with the fly ash."[490] Baldrey teaches that the "oxidized mercury can [] bind to surface sites within the fly ash or to activated carbon or LOI carbon within the fly ash layer."[491] Baldrey explains that the result is that "[m]ost of the oxidized mercury

[488] EX1015 (Baldrey) ¶[0070].

[489] EX1015 (Baldrey) ¶[0070].

[490] EX1015 (Baldrey) ¶[0031].

[491] EX1015 (Baldrey) ¶[0069].

and excess halogens are absorbed by the fly ash and/or mercury sorbent of the third formulation and is therefore removed by the device 232."[492]

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

293. It is my opinion that Claims 1-8 and 10-18 would have been obvious over the combination of Vosteen589 and Starns (Ground A1). Claims 1-8, and 10-18 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.

A. REASONS TO COMBINE

294. 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

[492] EX1015 (Baldrey) ¶[0085].

references are directed towards the same goal (removing mercury from coal-combustion flue gas) and are interoperable with one another.

295. 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."[493] 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."[494] 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."[495] 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

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

[494] EX1005 (Vosteen589) ¶[0007].

[495] EX1005 (Vosteen589) ¶[0019].

the sorbent is "finely pulverulent slaked lime/activated carbon."[496] 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."[497] For the coal-fired power plants, Vosteen589 discloses that a "dry electrostatic precipitator (ESP) is used."[498]

296. Vosteen589 thus discloses that its invention is an improvement to the dry-emission control systems in particular, the very system that is the subject of Starns and Mass-EPA. Vosteen589 however does not fully disclose certain details about how to implement the dry-emission control system, although it does provide an exemplary sorbent (finely pulverulent slaked lime/activated 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

[496] EX1005 (Vosteen589) ¶[0019].

[497] EX1005 (Vosteen589) ¶[0019].

[498] EX1005 (Vosteen589) ¶[0034].

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 '370 Patent.[499] As explained above in Technology Background and State of the Art,[500] a POSITA would have readily understood how to add the activated-carbon sorbent to the system, namely by injection into the mercury-containing flue gas between the combustion chamber and the PCD (such as the ESP or fabric filter). Starns and Mass-EPA each provides these details of ACI to purify mercury-containing flue gas, including how sorbent injection rate affects mercury-removal rate, where to inject the sorbent, and how to remove it with an ESP. A POSITA 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)

297. 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

[499] EX1001 ('370 Patent) at 2:8-15, 7:41-48, 28:11-24.

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

Wisconsin Electric's Pleasant Prairie Power Plant."[501] 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.[502]

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

- **Injection of the activated carbon:** "injection equipment" that includes a "bulk-storage silo and twin blower/feeder trains ...."[503] The injection equipment at a full-scale coal-fired power plant is shown below, in Figure 2 of Starns:

[501] EX1008 (Starns) at 1.

[502] EX1008 (Starns) at 2.

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



- **Control of activated carbon injection (ACI):** "A PLC [programmable logic controller] is used to control system operation and adjust injection rates."[504] One of the "[p]rimary variables" to control how much mercury is removed is "injection concentration" of the sorbent.[505]

- **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 …."[506]

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

[505] 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).

[506] EX1008 (Starns) at 9.

299. Starns provides the details of ACI—what Starns describes as the "most mature retrofit technology available today"[507]—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.

300. A POSITA would have looked to Starns for practical applications of the discovery disclosed in Vosteen589 relating to the use of halogen-containing 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 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

[507] EX1008 (Starns) at 2.

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.

301. 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."[508] The particle control equipment in Starns is an electrostatic precipitator (ESP), and Starns recommends "using activated carbon injection upstream of an ESP."[509] A POSITA would have been motivated, as Starns suggests, to use activated carbon injection between the combustion chamber (furnace) and the ESP in Vosteen589.[510] The mercury-sorbent composition is eventually removed by standard and well-known particulate control devices, such as the electrostatic precipitators (ESPs) in Vosteen589 and in Starns.

[508] EX1008 (Starns) at 2.

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

[510] 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)

302. 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."[511] 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).[512]
>
> 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.[513]

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

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

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

303. 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.[514]
>
> 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.[515]

Vosteen589 also discloses activated carbon, including with lime.[516] Mass-EPA discloses "activated carbon injection" in numerous other places.[517]

304. 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."[518] Thus, a POSITA would have been motivated, with a reasonable

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

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

[516] EX1005 (Vosteen589) ¶[0019].

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

[518] 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.

305. 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"[519] 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.

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

[519] 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."[520] 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." [521] 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." [522]

307. 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."[523] 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

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

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

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

[523] 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

308. 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 render obvious the claims below of the Challenged Patent.

C. INDEPENDENT CLAIM 1

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

309. Vosteen589 discloses the preamble. The title of Vosteen589 is, "Process for removing mercury from flue gases."[524] Flue gas is an example of mercury-containing gas, and "removing mercury" refers to reducing the amount of mercury in a mercury-containing gas in order to reduce the mercury emissions. The mercury is reduced by separating it from the mercury-containing gas. 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

[524] EX1005 (Vosteen589) at Title.

example bituminous coal-fired or lignite-fired power stations.[525] Claim 1 of Vosteen589 also discloses the preamble, as shown in the highlighting below:[526]

> 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.[527]

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

310. In the combination of Vosteen589 with Starns (Ground A1), the combination still discloses the preamble, as the purpose of Starns is to help "coal-

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

[526] EX1005 (Vosteen589) at Claim 1.

[527] EX1005 (Vosteen589) at Claim 1.

fired power plants" comply with draft "mercury regulations" from the EPA and "to remove mercury."[528]

311. In the combination of Vosteen589 with Mass-EPA (Ground A2), the combination still discloses the preamble, as the purpose of Mass-EPA is to explain how controlling "mercury emissions from solid-fossil-fuel fired facilities" is indeed feasible. The Department plans, therefore, to proceed with the development of a proposed mercury emissions standard for power plants within six months of the date of this report."[529]

2. Claim 1: Element 1(a)—"combusting a mixture of coal and an additive in a combustion chamber, to form the mercury-containing gas, wherein the additive is chosen from halides, halogens, salts thereof, and combinations thereof;"

312. 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

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

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

consists of a slag-tap fired boiler …."[530] 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 1450ºC."[531] Vosteen589 describes his results in Figures 7 and 8 regarding the experiments conducted on "coal combustion (bituminous coal)."[532] This limitation is also disclosed in claim 1 of Vosteen589, highlighted below:[533]

> 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,

[530] EX1005 (Vosteen589) ¶[0034].

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

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

[533] EX1005 (Vosteen589) at Claim 1.

> 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.

313. 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."[534]

314. 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."[535]

315. Vosteen589 describes applying additives chosen from halides, halogens, salts thereof, and combinations thereof, including HBr (hydrogen bromide), bromine (Br_2), and bromide compounds (such as sodium bromide, NaBr),

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

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

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 halogen-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 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 ….[536]
>
> 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. [537]
>
> 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.[538]
>
> 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

[536] EX1005 (Vosteen589) ¶[0006].

[537] EX1005 (Vosteen589) ¶[0009].

[538] EX1005 (Vosteen589) ¶[0013].

> recirculated substream, in particular recirculated flue gas, recirculated ash and recirculated fly ash.[539]

Vosteen589 also describes that the halogen-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:

> 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. [540]

> [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. [541]

316. 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): [542]

[539] EX1005 (Vosteen589) ¶[0014].

[540] EX1005 (Vosteen589) ¶[0013].

[541] EX1005 (Vosteen589) ¶[0014].

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

> 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.
>
> 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.

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

317. 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).

318. Vosteen589 discloses a "dry emission control system" as part of the "flue gas emission control system," which he also refers to as "cleanup of the flue gas" or as "dry cleanup."[543] 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 . . . ."[544] The flue gas was formed as a result of combustion of coal in the combustion chamber.

319. 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."[545] The halogen-containing ingredients are used to oxidize mercury from its metallic (Hg) into its ionic form (such as $HgBr_2$),[546] because "the ionic

[543] 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").

[544] EX1005 (Vosteen589) ¶[0007].

[545] EX1005 (Vosteen589) ¶[0019].

[546] EX1005 (Vosteen589) ¶[0019].

mercury … is readily adsorbable to a range of adsorbents."[547] 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 mercury sorption stage."[548] 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,"[549] and provides as an exemplary sorbent "finely pulverulent slaked lime/activated carbon."[550]

320. 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

[547] EX1005 (Vosteen589) ¶[0007].

[548] EX1005 (Vosteen589) ¶[0019].

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

[550] EX1005 (Vosteen589) ¶[0019].

multistage cleanup for removing mercury from the flue gas, which cleanup comprises a wet scrubber and/or a dry cleanup."[551] Vosteen589 refers to "clean gas downstream of the wet and/or dry flue gas emission control system."[552] 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."[553] 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."[554] The "cleanup" and "removal" referred to by Vosteen589 in the passages above refer to separating the mercury-sorbent composition from the mercury-containing flue gas.

321. 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

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

[552] EX1005 (Vosteen589) ¶[0022].

[553] EX1005 (Vosteen589) ¶[0005].

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

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,[555] a POSITA would have readily understood how to add the activated-carbon sorbent to the system, namely by injection into the mercury-containing flue gas between the combustion chamber and the PCD (such as the ESP or fabric filter). Starns and Mass-EPA each provides these details, and a POSITA would have been motivated to combine Vosteen589 with Starns (Ground A1) and Vosteen589 with Starns (Ground A2), as discussed in the Reasons to Combine section.

i. Ground A1 (Combination of Vosteen589 with Starns)

322. 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."[556]

[555] State of the Art, §IX.C.

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

Starns provides "injection equipment" that includes a "bulk-storage silo and twin blower/feeder trains ...."[557] The silo is shown below:[558]



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

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

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

[559] EX1008 (Starns) at 9.

323. The particle control devices (PCD) in Starns includes an electrostatic precipitator (ESP), and Starns recommends "using activated carbon injection upstream of an ESP."[560] It is a mercury-sorbent composition that is removed by the ESP, 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."[561] 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.[562] Each of these were well-known components in coal-fired power plants to remove particulate matter (such as the mercury-sorbent composition in Vosteen589 and Starns), as I describe above in the Technology Background and State of the Art section ("Particulate Matter Emissions Controls"). Further, to be effective, the injection must happen after the combustion zone (where the mercury-containing flue gas is generated) and before the separation system (where the sorbent is removed). The mercury-sorbent composition is collected and separated from the

[560] EX1008 (Starns) at 20.

[561] EX1008 (Starns) at 2.

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

mercury-containing gas by particulate control devices, such as the electrostatic precipitators (ESPs) in Vosteen589 and in Starns, to form a cleaned gas.

ii. Ground A2 (Combination of Vosteen589 with Mass-EPA)

324. 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.[563]
>
> 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. [564]
>
> 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.[565]
>
> 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.[566]

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

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

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

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

A "powdered" activated carbon is a particulate sorbent material. Mass-EPA describes that the activated-carbon sorbent is injected downstream of the combustion chamber, in that it repeatedly refers to the activated-carbon injection as "post combustion pollution control."[567] 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).[568]

Mass-EPA explains that the activated carbon is "injected." Mass-EPA discloses "activated carbon injection" in numerous other places.[569]

325. 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)."[570] The "particulate-bound

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

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

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

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

form of mercury" refers to the mercury adsorbed onto the activated-carbon sorbent. Mass-EPA continues, "An ESP or a FF is always installed downstream of a semi-dry scrubber or dry injection point to remove the sorbent from the flue gas."[571] 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.[572] 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-sorbent composition 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.

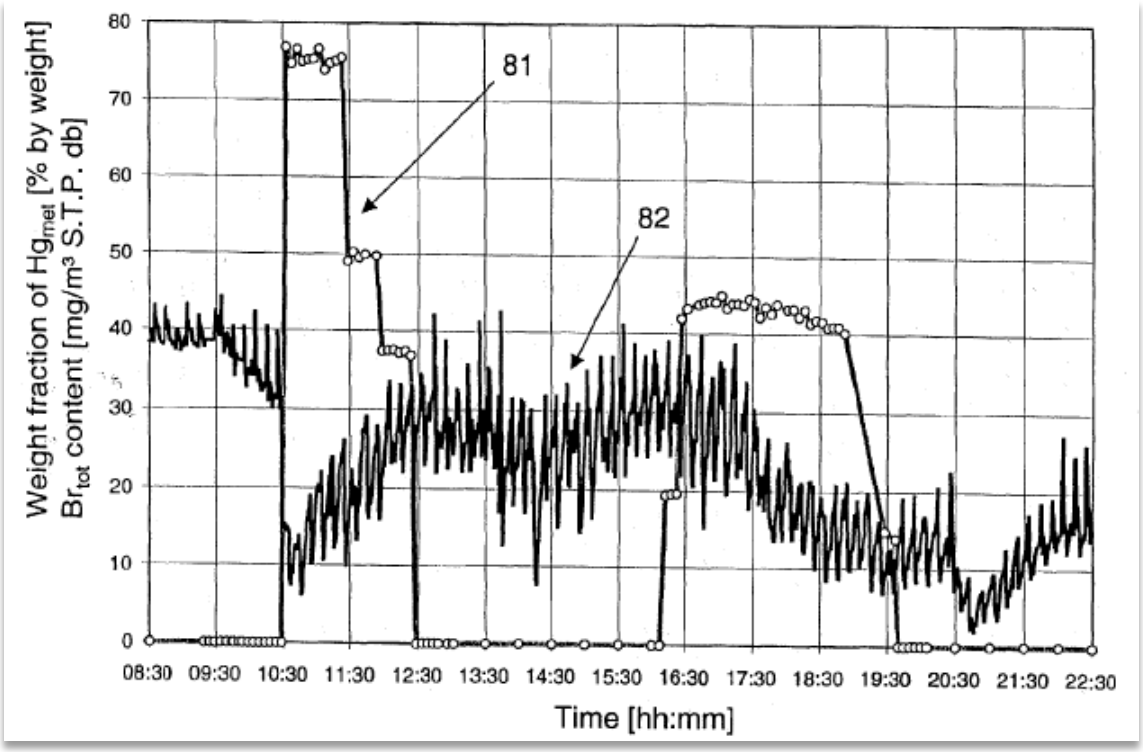
[571] EX1009 (Mass-EPA) at 27.

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

4. Claim 1: Element 1(c)—"wherein a weight ratio of the additive added to the coal, added to the combustion chamber, or a combination thereof, to an amount of the sorbent material added to the mercury-containing gas is from about 1:100 to about 30:100;"

326. This claim element is disclosed by the combinations of Vosteen589 with Starns (Ground A1) and Vosteen589 with Mass-EPA (Ground A2).

327. Vosteen589 describes in connection with Figure 8 (copied below), that he sought "to demonstrate the effect of bromine on mercury removal in a coal-fired power station of Bayer AG in Uerdingen."[573]



[573] EX1005 (Vosteen589) ¶[0046], Fig. 8.

In curve 82 above, Vosteen589 plots the ratio of elemental mercury (Hg_{met}) to the total mercury (Hg_{tot}, which is elemental + oxidized) as a function of time.[574] In Figure 8, Vosteen589 also plots "the total bromine content (Br_{tot}) in the boiler flue gas in mg/m^3 S.T.P. db (curve 81) as a function of time."[575] The units of mg/m^3 S.T.P. db refer to milligrams of the element bromine (Br) per cubic meter of mercury-containing flue gas, on a dry basis at standard temperature (25 ºC) and standard pressure (1 atm). Vosteen589 explains the amount of bromine added:

> [A]t 10:30, then the addition of bromine to the combustion chamber was also started (as aqueous NaBr solution). …. Curve 81 in FIG. 8 depicts the increase in Br content in the boiler flue gas induced by adding aqueous NaBr solution. At 10:30 the bromine content in the flue gas upstream of the ESP was initially increased by at least 75 mg/M^3 S.T.P. db and decreased again stepwise. At 16:10, there was a renewed increase in bromine content by approximately 43 mg/M^3 S.T.P. db.[576]

Thus, Vosteen589 discloses two values for the concentration of bromine in the flue gas: 43 and 75 mg/M^3 S.T.P. db. Vosteen589 also discloses "the flue gas volume flow rate" of $110x10^3$ m^3 S.T.P. db/hr.[577] I note that the quantity of Br in the flue gas equals the quantity of bromine-containing additive applied to the combustion

[574] EX1005 (Vosteen589) ¶[0031].

[575] EX1005 (Vosteen589) ¶[0031].

[576] EX1005 (Vosteen589) ¶[0048].

[577] EX1005 (Vosteen589) ¶[0048].

chamber and/or coal (e.g., as opposed to native halogens in the coal), as the Br concentration is near zero prior to the additive being applied.[578]

328. Vosteen589 also describes that activated carbon is used in its system,[579] but does not expressly state the injection rate of activated carbon into the system downstream of the combustion chamber. A person of ordinary skill in the art would have known to use, or at least start with as a first approximation, widely accepted values for injection rates of activated carbon. As described above,[580] it was routine in the industry to use injection rates of activated carbon of around 10 pounds/MMacf (million actual cubic feet of flue gas) to capture mercury.

329. This injection rate is further confirmed in Ground A1, as this is the value that Starns uses to obtain maximum mercury removal:

> Effective mercury removal between 40 – 50% was obtained at 1 lb/MMacf.
>
> Effective mercury removal between 50 – 60% was obtained at 3 lb/MMacf.
>
> Effective mercury removal between 60 – 70% was obtained at 10 lb/MMacf.[581]

[578] EX1005 (Vosteen589) Fig. 8.

[579] EX1005 (Vosteen589) ¶[0019].

[580] *See* Technology Background and State of the Art, § IX.C.5.

[581] EX1008 (Starns) at 20.

330. This injection rate is also confirmed in Ground A2, as Mass-EPA also discloses sorbent injection rates at 10 lbs/MMacf.[582]

331. Regarding Ground A1 and Ground A2, based on the data presented by Vosteen589 of 43 mg bromine per m^3 of flue gas S.T.P. db[583], and a standard and well-known injection rate of activated carbon of around 10 pounds/MMacf (as described in each of Starns and in Mass-EPA), a person of ordinary skill in the art would have used, or at least tried using, a mercury-containing gas that comprises about 17.3 – 22.3 grams of the additive per 100 grams of sorbent (depending on whether HBr, NaBr, or Br_2 is used), each of which is within the claimed range of 1-30 grams bromine per 100 grams sorbent. I explain my calculations below.

332. In order to determine a ratio of additive concentration in the flue gas to activated carbon in the flue gas, the concentrations must have the same units—such as grams per actual cubic feet (ACF) or pounds per million actual cubic feet (MACF). Vosteen589 provides the gas-phase concentration of Br in units of mg/m^3 Standard Temperature and Pressure (STP) dry basis (db). Activated-carbon injection concentrations were typically provided in pounds (lbs.) per million actual

[582] EX1009 (Mass-EPA) at 73 (Brayton Point testing); p. 12 (Chart 2, showing Gaston, Brayton Point, and Pleasant Prairie).

[583] EX1005 (Vosteen589) ¶[0048].

cubic feet (MACF) of flue gas, as in Starns and Mass-EPA. Converting between the two would have been a routine calculation at a power plant to a POSITA and would have involved such basic concepts as the ideal gas law (to convert concentrations between temperatures and pressures), which would have been taught in first semester undergraduate chemistry to a person of skill in the art.[584] Such unit conversion would have also involved basic engineering knowledge of a power-plant operation, such as a typical flue gas temperature, pressure, and moisture content. Each of these would have been well-known to a person of skill in the art.

333. A person of skill in the art would have known that a typical flue gas has approximately 10% water content by volume. As such, volume on an actual basis equals (volume on a dry basis) / 0.9. A person of ordinary skill in the art would have understood that ten percent is a nominal value for moisture in flue gas because moisture levels diminish for coals of progressively higher rank. It was known, for example, that lignite and subbituminous coals can produce flue gas with 15 % moisture or greater, and anthracites can produce as little as 5 % moisture or less.[585]

[584] *See* Technology Background and State of the Art ("Common Units of Measurement"), §IX.A.9.

[585] EX1027 (B&W: Steam) at 8-5 to 8-6.

For example, estimates for a low volatile bituminous coal gave 8.1 % moisture in flue gas.[586]

334. Regarding the second conversion, a person of skill in the art would have understood from the ideal gas law (PV = nRT) that the density of a gas is proportional to pressure and inversely proportional to temperature. A person of skill in the art would have learned from undergraduate chemistry that standard temperature and pressure (STP) refers to 25 ºC (298 K) and 1 atm, respectively, and would have known that a typical flue gas temperature where sorbent would be injected is 150 ºC (413 K) and also 1 atm of pressure. In fact, Starns (Ground A1) discloses a temperature of 290 ºF, which is 143 ºC (416 K).[587] Mass-EPA (Ground A2) also discloses "flue gas temperatures range from 284 to 320ºF (140 to 160°C)."[588] A person of ordinary skill in the art would have understood that this temperature is a typical value for sorbent injection downstream of an air preheater and upstream of an ESP or fabric filter. A POSITA would have known that air preheaters typically do not operate with outlet gas temperatures below the acid dew

[586] EX1005 (Vosteen589) ¶[0008] ("bituminous coal-fired or lignite-fired power stations").

[587] EX1008 (Starns) at 10.

[588] EX1009 (Mass-EPA) at 26.

points of sulfuric acid, which are given as 120 – 150°C.[589] Thus, a temperature of 416 Kelvin (143ºC) is used for the calculations, as this temperature is disclosed by Starns and within the range disclosed by Mass-EPA. Last, a person of ordinary skill in the art would have found in readily available tables of unit conversions that 1 m^3 = 35.3 ft^3.

335. Accordingly, 43 mg / m^3 S.T.P. db (as disclosed by Vosteen589, and which equals 0.043 g / m^3 S.T.P. db) and at a temperature of 416 K (the temperature of flue gas where the activated carbon is injected, as in Starns and Mass-EPA) converts to the following in terms of grams Br / million actual cubic feet.

$$\frac{0.043\ gBr}{1\ m^3_{STP.DB}} \times \left(\frac{0.9 m^3_{STP.DB}}{1.0 m^3_{STP}}\right) \times \left(\frac{298K\ std}{416K\ act}\right) \times \left(\frac{1 m^3}{35.3 ft^3}\right) \times \left(\frac{10^6 ACF}{1\ MACF}\right) = 785.3 \frac{g\ Br\ element}{MACF\ flue\ gas}$$

336. A person of ordinary skill in the art would have also been readily able to convert pounds activated carbon to grams activated carbon (and vice versa) through the well-known unit conversion that there are 453.592 grams per pound. Accordingly, at a typical activated-carbon injection rate of 10 pounds per MACF, as in Starns and in Mass-EPA, the injection rate of activated carbon would equal:

[589] EX1027 (B&W: Steam) at 19-11.

$$10\frac{pounds\ PAC}{MACF} \times \frac{453.592\ grams}{pound} = 4{,}536\frac{grams\ PAC}{MACF}$$

337. Dividing the two rates—the Br concentration of Vosteen589 (43 mg / m^3 S.T.P. db) with the activated carbon concentration of Starns and Mass-EPA (10 lb/MMacf)—provides a mercury-containing gas that comprises about 17.3 grams of the element bromine per 100 grams of activated-carbon sorbent. The exemplary bromine-containing additives in Vosteen589 include aqueous NaBr, aqueous HBr, and Br_2. Converting from the weight of elemental Br, to the weight of additive itself involves (i) multiplying by the ratio of molecular masses of additive to elemental Br (e.g., 102.89 grams of NaBr, 80.91 grams HBr, and 159.8 grams Br_2 each divided by 79.9 grams for Br) and (ii) dividing by the number of Br atoms in the additive (which is unity for NaBr and HBr).[590] These additives yield ratios of: 22.27 grams NaBr additive per 100 grams sorbent; 17.51 grams HBr additive per 100 grams sorbent; and 17.3 grams of Br_2 per 100 grams sorbent. All of these ratios fall within the claimed range of 1:100-30:100.

[590] No further scaling needs to be done when Br_2 is used as the additive, because Vosteen589 reports concentrations of elemental Br, and all Br comes from the additive.

338. And even if one were to use the highest sorbent injection rate tested in Chart 2 of Mass-EPA, which is 30 lb/MMacf,[591] the ratio of the element bromine to sorbent would still be 5.8. This would yield additives with ratios of: 7.47 grams NaBr additive per 100 grams sorbent; 5.87 grams HBr additive per 100 grams sorbent; and 5.8 grams of Br_2 per 100 grams sorbent. All of these ratios fall within the claimed range of 1:100-30:100.

339. And if one were to use the higher bromine concentration disclosed in Vosteen589 (75 mg/M^3 S.T.P. db)[592] with 10 lbs/MMacf sorbent, that would still provide a mercury-containing gas that comprises about 29.6 grams of the element bromine per 100 grams of activated-carbon sorbent. This corresponds to ratios of: 29.97 grams HBr per 100 grams sorbent; and 29.6 grams Br_2 per 100 grams sorbent. These ratios are also within the claimed range of 1:100-30:100.

340. It would have been obvious to try other ratios, such as by increasing the halogen concentration (while reducing the activated carbon injection), or decreasing the halogen concentration (while increasing the active carbon injection) as part of routine process optimization to achieve the desired mercury removal. Claim Element 1(c) is merely an attempt to claim a broad workable range for combining a

[591] EX1009 (Mass-EPA) at 12.

[592] EX1005 (Vosteen589) ¶[0048].

conventional halogen (e.g., bromine) being used in a conventional way with a conventional sorbent (to oxidize mercury and promote activated carbon). Nothing in the '370 Patent specification attributes significance to the claimed range, or establishes that the claimed range achieves unexpected results. The range presents nothing more than optimization of result-effective variables that would have been obvious to a POSITA. Patent Owner's expert in the Delaware litigation involving patents related to the '370 Patent stated that "power plants employing bromine additives and activated carbon would necessarily produce a sorbent that is 1 g to 30 g bromine per 100 g of activated carbon."[593] He further cited to this analysis for a claim that requires "the mercury-containing gas comprises about 1 g to about 30 g of the element bromine per 100 g of the sorbent."[594]

5. Claim 1: Element 1(d)—"contacting mercury in the mercury-containing gas with the sorbent material, to form a mercury-sorbent; and"

341. This claim element is disclosed by the combination of Vosteen589 with Starns (Ground A1) and Vosteen589 with Mass-EPA (Ground A2). The mercury in the flue gas is adsorbed, and thus contacted, with the sorbent to form a mercury-sorbent composition. As described above, the system works "based on the

[593] EX1092 (O'Keefe Report) at 153 (cl. 4).

[594] EX1092 (O'Keefe Report) at 154 (cl. 29).

adsorption of ionic mercury compounds."[595] The halogen-containing species are used to oxidize mercury from its metallic (Hg) into its ionic form (such as $HgBr_2$),[596] because "the ionic mercury … is readily adsorbable to a range of adsorbents."[597] Vosteen589 also refers to this as the "mercury sorption stage."[598] In order to be adsorbed onto the activated-carbon sorbent, the mercury must contact the sorbent.

342. Vosteen589 explains that the mercury forms a mercury-sorbent composition that comprises mercury, bromine, and activated carbon. Vosteen589 states regarding the dry emission control system, "Mercury bromide $HgBr_2$ adsorbs more strongly to dry sorbents than mercury chloride $HgCl_2$."[599] Also, the title of Vosteen589 is "Process for Removing Mercury from Flue Gases," and the way mercury gets removed from a flue gas, in a dry-sorbent system, is by contacting the sorbent (activated carbon) that is then removed.

343. This is also confirmed by Starns (Ground A1): through "the injection of sorbents such as powdered activated carbon (PAC) into the flue gas upstream of

[595] EX1005 (Vosteen589) ¶[0019].

[596] EX1005 (Vosteen589) ¶[0019].

[597] EX1005 (Vosteen589) ¶[0007].

[598] EX1005 (Vosteen589) ¶[0019].

[599] EX1005 (Vosteen589) ¶[0019].

the particle control equipment," the "gas-phase mercury in the flue gas contacts the sorbent and attaches to its surface."[600]

344. This is further confirmed by Mass-EPA (Ground A2), in that "[m]ass transfer refers to the ability of the sorbent particles to contact the Hg in the flue gas."[601]

6. Claim 1: Element 1(e)—"separating the mercury-sorbent from the mercury-containing gas."

345. This claim element is disclosed by Vosteen589. Vosteen589 discloses "removing mercury … from flue gases."[602] 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."[603] Vosteen589 refers to "clean gas downstream of the wet and/or dry flue gas emission control system."[604] This is because, as Vosteen589 discloses, an "object of the invention

[600] EX1008 (Starns) at 2 (Introduction).

[601] EX1009 (Mass-EPA) p. 21 n.25; see also EX1009 (Mass-EPA) p. 33 ("time available for the mercury to contact the AC [activated carbon] particle").

[602] EX1005 (Vosteen589) ¶[0005].

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

[604] EX1005 (Vosteen589) ¶[0022].

[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."[605] The "dry cleanup stage" and "dry sorbent" includes, for example, the activated-carbon sorbent that is separated by the ESP or other PCD devices, such as a fabric filter. For the coal-fired power plants, Vosteen589 discloses that a "dry electrostatic precipitator (ESP) is used."[606] The "cleanup" and "removal" referred to by Vosteen589 in the passages above refer to separating the mercury-sorbent composition from the mercury-containing flue gas, such as with the ESP. As described for Element 1(d), a POSITA would have known, or at least found it obvious that the sorbent is a contacted with the mercury after it is introduced into the mercury-containing gas.

346. This limitation is also disclosed by the combination of Vosteen589 with Starns (Ground A1): The particle control devices (PCD) in Starns includes an electrostatic precipitator (ESP), and Starns recommends "using activated carbon injection upstream of an ESP."[607] It is a mercury-sorbent composition that is removed, because through the "injection of sorbents such as powdered activated

[605] EX1005 (Vosteen589) ¶[0005].

[606] EX1005 (Vosteen589) ¶[0034].

[607] EX1008 (Starns) at 20.

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."[608] 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.[609] Each of these were well-known components in coal-fired power plants to remove particulate matter (such as the mercury-sorbent composition in Vosteen589 and Starns), as I describe above in the Technology Background and State of the Art section ("Particulate Matter Emissions Controls"). Further, to be effective, the injection must happen after the combustion zone (where the mercury-containing flue gas is generated) and before the separation system (where the sorbent is removed). The mercury-sorbent composition is separated from the mercury-containing gas by particulate control devices, such as the electrostatic precipitators (ESPs) in Vosteen589 and in Starns, to form a cleaned gas.

347. This limitation is also disclosed by the combination of Vosteen589 with Mass-EPA (Ground A2): "The particulate-bound form of mercury can be readily

[608] EX1008 (Starns) at 2.

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

captured in the particulate matter (PM) control devices, i.e., electrostatic precipitators (ESPs) and fabric filters (FFs)."[610] The "particulate-bound form of mercury" refers to the mercury adsorbed onto the activated-carbon sorbent, i.e., a mercury-sorbent composition. Mass-EPA continues, "An ESP or a FF is always installed downstream of a semi-dry scrubber or dry injection point to remove the sorbent from the flue gas."[611] 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.[612] Each of these were well-known components in coal-fired power plants to remove particulate matter (such as the mercury-sorbent composition in Vosteen589 and Mass-EPA), as I describe above in the Technology Background and State of the Art section ("Particulate Matter Emissions Controls"). Further, to be effective, the injection must happen after the combustion zone (where the mercury-containing flue gas is generated) and before the separation system (where the sorbent is removed). The mercury-sorbent composition is separated from the mercury-containing gas by particulate control

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

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

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

devices, such as the electrostatic precipitators (ESPs) and fabric filters in Vosteen589 and in Mass-EPA, to form a cleaned gas.

D. CLAIMS DEPENDING FROM CLAIM 1

1. Claim 2: "The method of claim 1, further comprising adding the additive to the coal before combusting the coal."

348. This claim is disclosed by Vosteen589 in Grounds 1-2. As I described above for Claim Element 1(a), the halogen-containing additive is added to the coal upstream of the combustion chamber.

2. Claim 3: "The method of claim 2, wherein the additive mixed with the coal is in a liquid."

349. This claim is disclosed by Vosteen589 in Grounds 1-2. As discussed for Claim Element 1(a), the halogen-containing ingredients (e.g., HBr, NaBr) are added to the coal as an "aqueous solution" (i.e., the halogen-containing ingredients are dissolved in water).[613] NaBr is a salt, and aqueous NaBr is a salt solution. As confirmed by Claim 4, which depends from Claim 3, a "liquid" can include "water" and a "salt solution," each of which are present in the aqueous additives of Vosteen589.

[613] EX1005 (Vosteen589) ¶¶[0009], [0013]-[0014], claim 2.

3. Claim 4: "The method of claim 3, wherein the liquid is a hydrocarbon, supercritical carbon dioxide, water, salt solution, or a combination thereof."

350. This claim is disclosed by Vosteen589. Vosteen589 discloses this limitation for the reasons discussed for Claim 3. As discussed above for Claim 3, the liquid contains water and is a salt solution.[614]

4. Claim 5: The method of claim 1, wherein carbocations in the activated carbon of the mercury-sorbent accept electrons from mercury atoms of the mercury-sorbent.

351. According to Patent Owner's expert in the Delaware litigation, this chemical reaction takes place between the activated carbon and mercury.[615]

5. Claim 6: "The method of claim 1, wherein the additive is substantially in vapor form in the mercury-containing gas."

352. Claim 6 would have been obvious over the combination of Vosteen589 in view of Starns (Ground A1) and Vosteen589 in view of Mass-EPA (Ground A2). As described for Claim 1, the combination of Vosteen589 in view of Starns (Ground A1) and the combination of Vosteen589 in view of Mass-EPA (Ground A2) each injects activated carbon into the mercury-containing flue gas. The boiling point of Br_2 is only 58.8ºC (it is a fuming liquid at room temperature), and the boiling point

[614] EX1005 (Vosteen589), ¶¶[0009], [0013]-[0014], claim 2.

[615] EX1092 (O'Keefe Report) p. 160 ('147 Patent Claim 1(c)).

of hydrogen bromide is -66.38 ºC (i.e., it is a gas at room temperature).[616] Each of these is well below the temperature of the mercury-containing flue gas. For the other species that Vosteen589 adds to the coal and/or combustion chamber (e.g., aqueous NaBr), at least a portion of the Br would have vaporized in the combustion chamber (upon the coal being fed to the combustion chamber) and reacted to form vapor-phase HBr. When bromine-containing species (e.g., HBr) and carbon come into contact with each other, the bromine acts as a promoter.[617] Vosteen589 confirms that the bromine-containing ingredients are present in the mercury-containing flue gas, as he describes "the mass ratio of bromine to mercury in the flue gas."[618]

353. Regarding Ground A1, Starns discloses typical flue gas temperatures of 290 ºF, which is 143 ºC.[619] Regarding Ground A2, the flue gas in Mass-EPA ranges from 284 to 320ºF (140-160ºC) after the air heater or 350-450ºC before the air heater.[620] In each of these configurations, the temperatures are well-above the limit at which the mercury-containing gas would be in the gas phase, and the halogen

[616] EX1036 (CRC Press: March 2005) at 4-53 and 4-65.

[617] *See* Technology Background and State of the Art, §§IX.C.3, IX.G.2.

[618] EX1005 (Vosteen589) at claim 5.

[619] EX1008 (Starns) at 10.

[620] EX1009 (Mass-EPA) at 26.

promoters (such as HBr and/or Br_2) would likewise be vaporized. Regarding both Ground A1 and Ground A2, the boiling point of water is around 100 ºC, so a POSITA would have understood, or at the very least found it obvious, that the mercury-containing flue gas (which also contains promoter (e.g., HBr and/or Br_2)) would be at a temperature well above the boiling point of water and remain in the gas phase. In each combination, the promoter (e.g., HBr and/or Br_2) would have remained in the vapor form as it is transported with the flue gas and eventually contacted the activated-carbon sorbent.[621]

6. Claim 7: "The method of claim 1, wherein the additive is chosen from Cl_2, HCl, sodium chloride, calcium chloride, and a combination thereof."

354. This claim is disclosed by Vosteen589. Vosteen589 discloses that a "chlorine compound and/or iodine compound can be fed … as a supplement to, or partial replacement of, the added bromine compound," and that the "process proceeds, in addition to the bromine compounds, in the presence of chlorine and/or iodine."[622] A POSITA would recognize that a "chlorine compound" and "iodine compound" refers to "Cl" and "I" bonded with another element, respectively, and that the terms by themselves ("chlorine" and "iodine") refer to Cl_2 and I_2,

[621] Patent Owner's expert agrees. EX1092 (O'Keefe Report) at 154, 170, 176; see also EX1095 (Olson) at 98:23-100:3, 231:3-9.

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

respectively. It was known that chlorides and bromides oxidize mercury.[623] Vosteen589 further discloses that molecular chlorine (Cl_2) would be used as the partial supplement for the additive, and used in combination with the bromine-containing additive:

> 1. Process for removing mercury from flue gases of high-temperature plants, in particular from power stations … 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 ….
>
> 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.
>
> 6. Process according to one of claims 1 to 5, characterized in that 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.[624]

355. A POSITA would have been motivated to apply widely-available and inexpensive chloride compounds, such as sodium chloride (NaCl, table salt) for the "chlorine compound" taught by Vosteen589, as Vosteen589 is already using an

[623] Technology Background and State of the Art, §§IX.A.1, IX.A.7, IX.C.3, IX.C.4, IX.G.2; *see also* EX1062 at 2-3, 10 ("screening tests of several oxidation additives including chloride compounds (e.g., sodium chloride, hydrogen chloride, calcium chloride").

[624] EX1005 (Vosteen589) at Claims 1, 2, 6.

analogous compound (NaBr, sodium bromide). It would have been obvious that the weight ratio of Element 1(c) (of additive to sorbent) would still be within "about 1:100 to about 30:100" because, according to Vosteen589, the chlorine compound acts as a "partial replacement" of the bromine compound. Further, contact among added halogens and activated carbon sorbents downstream of the combustion chamber is inevitable because once halogens appear in flue gas, they remain 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 fly ash, which hardly adsorb any halogen vapors at all under gas cleaning conditions. This is why nearly all of the halogen vapor in a combustion chamber will be available to contact activated carbon sorbents injected downstream. The 1:100-30:100 range presents nothing more than optimization of result-effective variables that would have been obvious to a POSITA, as discussed above for Element 1(c).

7. Claim 8: "The method of claim 1, wherein the additive is chosen from Br_2, HBr, sodium bromide, calcium bromide, and a combination thereof."

356. This claim is disclosed by Vosteen589. As discussed for Element 1(a), the halogen-containing ingredients include Br_2, HBr and sodium bromide (NaBr).[625]

[625] EX1005 (Vosteen589), ¶¶[0009], [0013]-[0014], cl. 1-2.

8. Claim 10: "The method of claim 1, wherein the additive is chosen from I_2, HI, sodium iodide, calcium iodide, potassium iodide, and combinations thereof."

357. This claim is disclosed by Vosteen589. Vosteen589 discloses that an "iodine compound can be fed … as a supplement to, or partial replacement of, the added bromine compound," and that the "process proceeds, in addition to the bromine compounds, in the presence of chlorine and/or iodine."[626] It would have been obvious that the weight ratio of Element 1(c) (of additive to sorbent) would still be within "about 1:100 to about 30:100" because, according to Vosteen589, the iodine compound acts as a "partial replacement" of the bromine compound. Further, contact among added halogens and activated carbon sorbents downstream of the combustion chamber is inevitable because once halogens appear in flue gas, they remain 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 fly ash, which hardly adsorb any halogen vapors at all under gas cleaning conditions. This is why nearly all of the halogen vapor in a combustion chamber will be available to contact activated carbon sorbents injected downstream. The 1:100-30:100 range presents nothing more than optimization of

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

"result-effective" variables that would have been obvious to a POSITA, as discussed above for Element 1(c).

358. A POSITA would have been motivated to use iodine-containing ingredients as a partial replacement for the bromine-containing ingredients when using coals with higher native-mercury content (or lower native-halogen content), for which additional mitigation may be needed to further reduce mercury emissions. Though Vosteen589 teaches that iodine compounds can be more expensive than corresponding bromine compounds (less "economical"), it also discloses that "[i]odine compounds oxidize mercury more effectively compared with bromine compounds."[627] Thus, for high-mercury applications, where additional mitigation is required, a POSITA would be motivated to include iodine compounds in the additive.

359. A POSITA would have been motivated, as a matter of routine experimentation, to apply widely-available iodine compounds, such as potassium iodine (KI) or sodium iodide (NaI), for the "iodine compound" taught by Vosteen589.[628] Potassium iodide and sodium iodide are salts, readily dissolvable in

[627] EX1005 (Vosteen589) ¶[0016].

[628] Technology Background and State of the Art, §§IX.A.1, IX.A.7, IX.C.3, IX.C.4, IX.G.2; *see also* EX1062 at 2-3, 10 ("screening tests of several oxidation

water, and able to applied in the same manner as the aqueous sodium bromide already disclosed in Vosteen589 as a coal additive.

9. Claim 11: "The method of claim 1, wherein the activated carbon is chosen from powdered activated carbon, granular activated carbon, carbon black, carbon fiber, aerogel carbon, pyrolysis char, and combinations thereof."

360. Claim 11 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). As described for Element 1(b), Vosteen589 discloses usage of activated carbon. Starns and Mass-EPA further describe the types of activated carbon to use.

361. 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."[629]

362. For Ground A2, Mass-EPA discusses powdered activated carbon (abbreviated as "PAC") throughout the reference, including how "one mercury-

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additives including chloride compounds (e.g., sodium chloride, hydrogen chloride, calcium chloride").

[629] EX1008 (Starns) at 2.

specific control technology (powdered activated carbon injection) has the potential for commercialization in the near future."[630]

10. Claim 12: "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."

363. Claim 12 would have been obvious over the combination of Vosteen589 in view of Starns (Ground A1) and Vosteen589 and Mass-EPA (Ground A2).

364. Regarding Ground A1 and Ground A2, Vosteen589 repeatedly discloses adding "lime" or "slaked lime" to the mercury-containing flue gas, including by mixing the lime with activated-carbon sorbent.[631] 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 in Technology Background and State of the Art,[632] 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

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

[631] EX1005 (Vosteen589) ¶[0019].

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

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.

365. With respect to Ground A1, Starns refers to "injection of sorbents such as powdered activated carbon (PAC) into the flue gas."[633] 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.

366. 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.[634]
>
> 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.[635]

[633] EX1008 (Starns) at 2.

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

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

> 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. [636]

The "sodium carbonate" (Na_2CO_3) 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.

11. Claim 13: "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."

367. Vosteen589 discloses this claim. Vosteen589 "ensured that a sufficient supply of sulphur dioxide [i.e., SO_2] for the inventive process was available."[637] 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.[638] The sulfur dioxide facilitates the bromine reacting with mercury.[639] A

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

[637] EX1005 (Vosteen589) ¶[0036].

[638] EX1005 (Vosteen589) ¶[0006].

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

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).

12. Claim 14: "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."

368. 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 bromine-containing ingredients and other halogens such as chlorine and iodine. Each of these are in addition to the halogens or halides being applied to the coal and combustion chamber.

369. Beyond adding the halogens or halides to the combustion chamber and/or coal, as discussed above, Vosteen589 discloses that halogens or halides are also provided at a downstream 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.[640]

This is a second point of addition of the halogens or halides, 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."[641] Hydrogen bromide (HBr) is an example of a hydrogen halide.

370. 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."[642] 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

[640] EX1005 (Vosteen589) ¶[0014].

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

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

various iodine compounds."[643] The "iodine" and "chlorine" are each halogens. These materials would contact the activated-carbon sorbent, which is also injected downstream of the combustion chamber.[644] Contact among added halogens and activated carbon sorbents downstream of the combustion chamber is inevitable because once halogens appear in flue gas, they remain 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 fly ash, which hardly adsorb any halogen vapors at all under gas cleaning conditions. This is why nearly all of the halogen vapor in a combustion chamber will be available to contact activated carbon sorbents injected downstream.

371. 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)."[645] The modified activated carbons "doped with" chlorine and iodine describes a sorbent material that has been contacted with chlorine and iodine (i.e., halogens).

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

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

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

13. Claim 15: "The method of claim 14, wherein the secondary component is chosen from halogens, halide salts, HI, HBr, HCl, and combinations thereof."

372. Vosteen589 and Mass-EPA disclose Claim 15 for the same reasons discussed above for Claim 14. The secondary components of hydrogen bromide (HBr, disclosed by Vosteen589), chlorine, bromine, and iodine (halogens), and sodium bromide and sodium chloride (halide salts) each satisfy this claim.

14. Claim 16: "The method of claim 14, wherein the secondary component is chosen from I_2, HI, and combinations thereof."

373. Vosteen589 discloses Claim 16 for the same reasons discussed above for Claim 14. As discussed for Claim 14, Vosteen589 discloses the addition of "iodine and/or an iodine compound."[646] 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).

15. Claim 18: "The method of claim 1, wherein the additive comprises a and b, b and c, a and c, or a, b, and c: a) I^- and/or I_2, b) Br^- and/or Br_2, c) Cl^- and/or Cl_2."

374. Vosteen589 discloses this claim. As discussed for Claim Element 1(a) and Claims 7 and 10, Vosteen589 discloses that "chlorine compound and/or iodine compound can be fed" as a "partial replacement of, the added bromine compound," and that the "process proceeds, in addition to the bromine compounds, in the

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

presence of chlorine and/or iodine."[647] As discussed for Claim Element 1(a) and Claims 7 and 10, the chlorine compound and iodine compound are a "partial replacement" for the bromine compound, the weight ratio of additive to sorbent would remain within the claimed range. Vosteen589 further teaches that "[p]referably, an aqueous solution of the compound is sprayed into one of the combustion chambers."[648] A POSITA would have understood that bromine, chlorine, and iodine compounds present in aqueous solutions (i.e., salt solutions) would dissociate such that the solution contains Br-, Cl-, and I- ions, respectively.

E. INDEPENDENT CLAIM 17

375. Claim 17 is nearly identical to Claims 1 and 18. There are only minor changes, as shown in the redline below:

[647] EX1005 (Vosteen589) ¶[0016].

[648] EX1005 (Vosteen589) ¶[0013].

~~1~~17. A method for separating mercury from a mercury-containing gas, the method comprising:

combusting ~~a mixture of~~ coal ~~and~~comprising an additive in a combustion chamber, ~~to form the mercury-containing gas,~~ wherein the additive is chosen from halides, halogens, salts thereof, and combinations thereof~~; [18.~~, to form the mercury-containing gas, wherein the additive comprises a and b, b and c, a and c, or a, b, and c:

a) I^- and/or I_2,

b) Br^- and/or Br_2,

c) Cl^- and/or Cl_2.~~]~~;

~~adding a particulate~~injecting a sorbent material comprising activated carbon into the mercury-containing gas, wherein a weight ratio of the additive added to the coal, added to the combustion chamber, or a combination thereof, to an amount of the sorbent material added to the mercury-containing gas is from about 1:100 to about 30:100;

contacting mercury in the mercury-containing gas with the sorbent material, to form a mercury-sorbent; and

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

Claim 17 is disclosed for the reasons described for Claims 1 and 18. The differences are discussed below.

1. Claim 17: Preamble—"A method for separating mercury from a mercury-containing gas, the method comprising:"

376. The language of Claim Element 17(Preamble) is identical to the language of Claim Element 1(Preamble). Accordingly, the explanation I provide above for Claim Element 1(Preamble) applies equally to Claim Element 17(Preamble).

2. Claim 17: Element 17(a)—"combusting coal comprising an additive in a combustion chamber, wherein the additive is chosen from halides, halogens, salts thereof, and combinations thereof, to form the mercury-containing gas, wherein the additive comprises a and b, b and c, a and c, or a, b, and c: a) I^- and/or I_2, b) Br^- and/or Br_2, c) Cl^- and/or Cl_2;"

377. The language of Claim Element 17(a) is nearly identical to the language of Claim Element 1(a) and Claim 18. Accordingly, the explanation I provide above for Claim Element 1(a) and Claim 18 applies equally to Claim Element 17(a). As discussed above for Claim Element 1(a), Vosteen589 discloses that the coal combusted in the combustion chamber comprises the additive.

3. Claim 17: Element 17(b)—"injecting a sorbent material comprising activated carbon into the mercury-containing gas,"

378. The language of Claim Element 17(b) is nearly identical to the language of Claim Element 1(b) except "adding" is replaced with "injecting" and "particulate" has been removed. As described above for Claim Element 1(b), Vosteen589 discloses injecting a sorbent material comprising activated carbon into the mercury-containing gas.

4. Claim 17: Element 17(c)—"wherein a weight ratio of the additive added to the coal, added to the combustion chamber, or a combination thereof, to an amount of the sorbent material added to the mercury-containing gas is from about 1:100 to about 30:100;"

379. The language of Claim Element 17(c) is identical to the language of Claim Element 1(c). Accordingly, the explanation I provide above for Claim Element 1(c) applies equally to Claim Element 17(c). When using multiple types of halogens (e.g., mixing iodine-containing chemicals, chlorine-containing chemicals, and bromine-containing chemicals), it would have been obvious for the weight ratios to remain within the 1:100 to 30:100 range, as I describe above for Claims 7, 10, and 18.

5. Claim 17: Element 17(d)—"contacting mercury in the mercury-containing gas with the sorbent material, to form a mercury-sorbent; and"

380. The language of Claim Element 17(d) is identical to the language of Claim Element 1(d). Accordingly, the explanation I provide above for Claim Element 1(d) applies equally to Claim Element 17(d).

6. Claim 17: Element 17(e)—"separating the mercury-sorbent from the mercury-containing gas."

381. The language of Claim Element 17(e) is identical to the language of Claim Element 1(e). Accordingly, the explanation I provide above for Claim Element 1(e) applies equally to Claim Element 17(e).

XIV. GROUND A3 AND GROUND A4: OBVIOUSNESS OVER DOWNS-BOILER IN VIEW OF STARNS [GROUND A3] AND DOWNS-BOILER IN VIEW OF MASS-EPA [GROUND A4]

382. It is my opinion that Claims 1-6, 8, and 11 would have been obvious over the combination of Downs-Boiler and Starns (Ground A3). Claims 1-6, 8, 11-12, and 14-15 would have been obvious over the combination of Downs-Boiler and Mass-EPA (Ground A4). Ground A3 and Ground A4 largely rely on the common disclosure of Downs-Boiler, with certain limitations disclosed by Starns (Ground A3) and by Mass-EPA (Ground A4) (in some cases, in addition to disclosure of those limitations already present in Downs-Boiler).

A. REASONS TO COMBINE

383. A person of ordinary skill in the art would have been motivated to combine Downs-Boiler with Starns (Ground A3) and Downs-Boiler with Mass-EPA (Ground A4), 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.

384. 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)."[649] 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.[650] Downs-Boiler also discloses that the mercury-sorbent composition would be removed by an electrostatic precipitator (ESP) or fabric filter.[651]

385. 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,[652] and Starns and Mass-EPA each supplies those details. In particular, as explained above in 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).

[649] EX1006 (Downs-Boiler) ¶[0025].

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

[651] EX1006 (Downs-Boiler) Figure 6; see also EX1006 (Downs-Boiler) Figures 4-5; EX1007 (Downs-Boiler-Provisional) Figures 4-6.

[652] 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 A3 (Combination of Downs-Boiler with Starns)

386. Like Downs-Boiler, Starns 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."[653] 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.[654]

387. Starns provides details as to how to supply activated carbon to the system and processes of Downs-Boiler:

- **Injection of the activated carbon:** "injection equipment" that includes a "bulk-storage silo and twin blower/feeder trains ...."[655] The injection

[653] EX1008 (Starns) at 1.

[654] EX1008 (Starns) at 2.

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

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."[656] One of the "[p]rimary variables" to control how much mercury is removed is "injection concentration" of the sorbent.[657]

- **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 …."[658]

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

[657] 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).

[658] EX1008 (Starns) at 9.

388. Starns provides the details of ACI—what Starns describes as the "most mature retrofit technology available today"[659]—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.

389. 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."[660] Downs-Boiler also discloses that this injected sorbent is powdered activated carbon.[661] However, Downs-Boiler does not fully disclose certain details regarding the specifics of how such an activated carbon sorbent might be injected in the Downs-Boiler system. Starns does disclose such details for an ACI system. As ACI was already a "mature" technology by the time of Starns, the combination of Downs-Boiler and Starns represents no more than combining prior art elements according to known methods to yield predictable

[659] EX1008 (Starns) at 2.

[660] EX1006 (Downs-Boiler) ¶[0025]

[661] EX1006 (Downs-Boiler) ¶[0025]

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.

390. 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."[662] The particle control equipment in Starns is an electrostatic precipitator (ESP), and Starns recommends "using activated carbon injection upstream of an ESP."[663] 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.[664] The mercury-sorbent composition is eventually removed by standard and well-known particulate control devices, such as the electrostatic precipitators (ESPs) in Downs-Boiler and in Starns.

[662] EX1008 (Starns) at 2.

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

[664] EX1006 (Downs-Boiler) Figure 6 (annotated; see also EX1006 (Downs-Boiler) Figures 4-5; EX1007 (Downs-Boiler-Provisional) Figures 4-6.

2. Ground A4 (Combination of Downs-Boiler with Mass-EPA)

391. Like Downs-Boiler, Mass-EPA 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."[665] 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).[666]
>
> 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.[667]

[665] EX1008 (Starns) at 1.

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

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

392. 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.[668]
>
> 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.[669]

Mass-EPA discloses "activated carbon injection" in numerous other places.[670]

393. 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."[671] 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.

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

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

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

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

394. 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"[672] 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.

395. 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

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

removal in the near future."[673] 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."[674] 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."[675]

396. 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."[676] 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.

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

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

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

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

B. DISCLOSURE AND TEACHINGS OF THE COMBINATIONS

397. It is my opinion that the combination of Downs-Boiler in view of Starns (Ground A3) and the combination of Downs-Boiler in view of Mass-EPA (Ground A4) each renders obvious the claims below of the Challenged Patent.

C. INDEPENDENT CLAIM 1

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

398. Downs-Boiler discloses the preamble. The title of Downs-Boiler is "Bromine Addition for the Improved Removal of Mercury from Flue Gas.[677] Flue gas is an example of a mercury-containing gas, and "removal of mercury" refers to reducing the amount of mercury in 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 oxidation of mercury, thereby enhancing the overall removal of mercury in downstream pollution control devices.[678]

[677] EX1006 (Downs-Boiler) at Title; EX1007 (Downs-Boiler-Provisional) at Title.

[678] EX1006 (Downs-Boiler) ¶[0007]; EX1007 (Downs-Boiler-Provisional) ¶[0013].

Claim 1 of Downs-Boiler also recites a similar preamble: "1. A method of removing a portion of the elemental mercury in a flue gas"[679] The reduction of mercury in the flue gas as described by Downs-Boiler is by separating the mercury along with a sorbent:[680]

> 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.

399. Downs-Boiler characterizes its disclosed "invention" as "a cost-effective method of removing elemental mercury from coal combustion flue gases."[681]

2. Claim 1: Element 1(a)—"combusting a mixture of coal and an additive in a combustion chamber, to form the mercury-containing gas, wherein the additive is chosen from halides, halogens, salts thereof, and combinations thereof;"

400. 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

[679] 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.").

[680] EX1006 (Downs-Boiler) ¶[0004]; EX1007 (Downs-Boiler-Provisional) ¶[005].

[681] EX1006 (Downs-Boiler) ¶[0018]; EX1007 (Downs-Boiler-Provisional) ¶[021].

source of anthropogenic mercury emissions in the United States."[682] 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:[683]

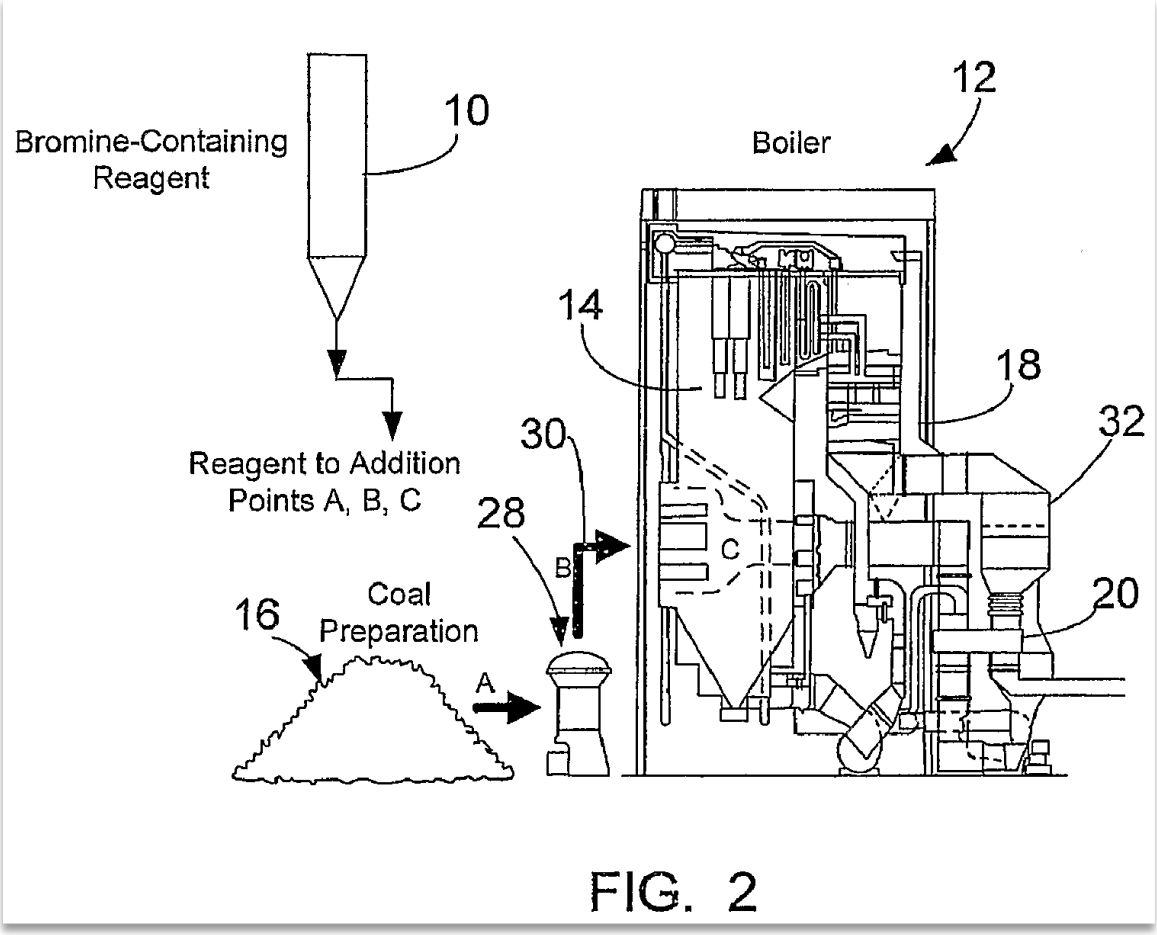


FIG. 2

[682] EX1006 (Downs-Boiler) ¶[0001]; see also EX1007 (Downs-Boiler-Provisional) ¶[002].

[683] 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.

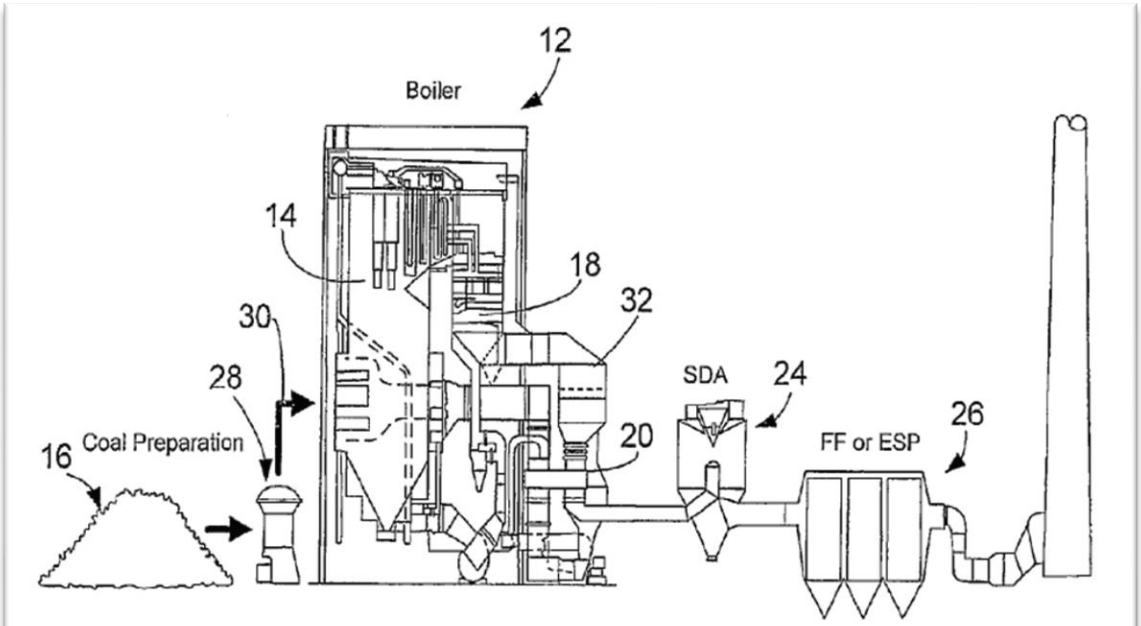

12
Boiler
14
18
32
30
28
SDA
24
26
20
FF or ESP
16
Coal Preparation

FIG. 4

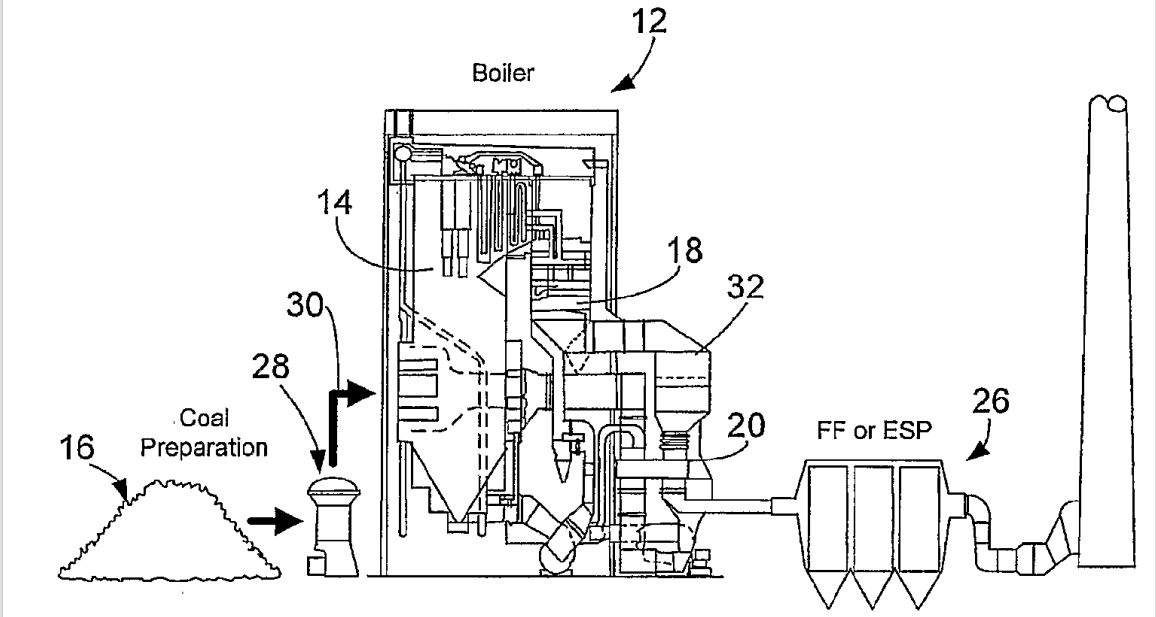

12
Boiler
14
18
32
30
28
Coal
Preparation
16
20
FF or ESP
26

FIG. 5

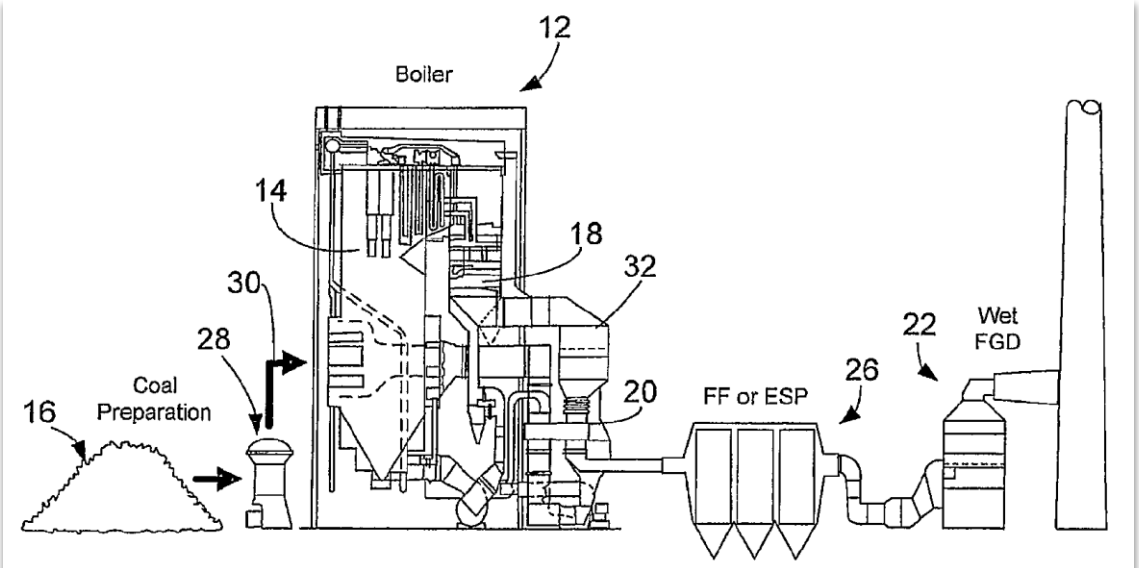


FIG. 6

401. 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:[684]

> 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.

402. Downs-Boiler describes combusting common ranks of coal used by the electric utility industry and, specifically, that "the coal-fired boiler fuel 16 may

[684] 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."[685] Finally, Downs-Boiler states that "[m]ercury appears in coal combustion flue gases in both solid and gas phases."[686] 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.

403. Downs-Boiler discloses halides, halogens, salts thereof, and combinations 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)."[687] Downs-Boiler also specifically discloses calcium bromide ($CaBr_2$) as another suitable bromide compound for use as the bromine-containing reagent.[688] These are examples of halides (HBr), halogens (Br_2), and salts thereof ($CaBr_2$).

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[685] EX1006 (Downs-Boiler) ¶[0020]; see also EX1007 (Downs-Boiler-Provisional) ¶[0023].

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

[687] EX1006 (Downs-Boiler) ¶[0021]; see also EX1007 (Downs-Boiler-Provisional) ¶[0024].

[688] EX1006 (Downs-Boiler) ¶[0018]-[0019]; see also EX1007 (Downs-Boiler-Provisional) ¶[0021-22].

404. 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."[689] 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."[690] 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 halides, halogens, and salts thereof has been added on the coal.

405. Downs-Boiler also discloses introduction of halides, halogens, salts thereof, and combinations thereof (i.e., the bromine-containing reagent) directly into the combustion chamber. Downs-Boiler teaches that a "bromine containing reagent

[689] EX1006 (Downs-Boiler) ¶[0015]; see also EX1006 (Downs-Boiler) ¶[0007]; EX1007 (Downs-Boiler-Provisional) ¶¶[009], [0018].

[690] EX1006 (Downs-Boiler) ¶[0019], Figure 2; see also EX1007 (Downs-Boiler-Provisional) ¶[0022], Figure 2.

10 is added to the boiler 12 combustion furnace 14, either directly or by premixing with the incoming coal 16."[691] 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."[692] 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."[693]

406. Downs-Boiler also 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 the additive is both on the coal and in the combustion chamber.

407. Downs-Boiler illustrates that the bromine-containing reagent may be mixed in at "addition points A, B, C" including "coal preparation" (point A), "the

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

[692] EX1006 (Downs-Boiler) ¶[0019]; see also EX1007 (Downs-Boiler-Provisional) ¶[0021].

[693] EX1006 (Downs-Boiler) ¶[0022]; see also EX1007 (Downs-Boiler-Provisional) ¶[0025].

pulverized coal conveying system 30" (point B) and "the boiler furnace 14" (point C).[694]

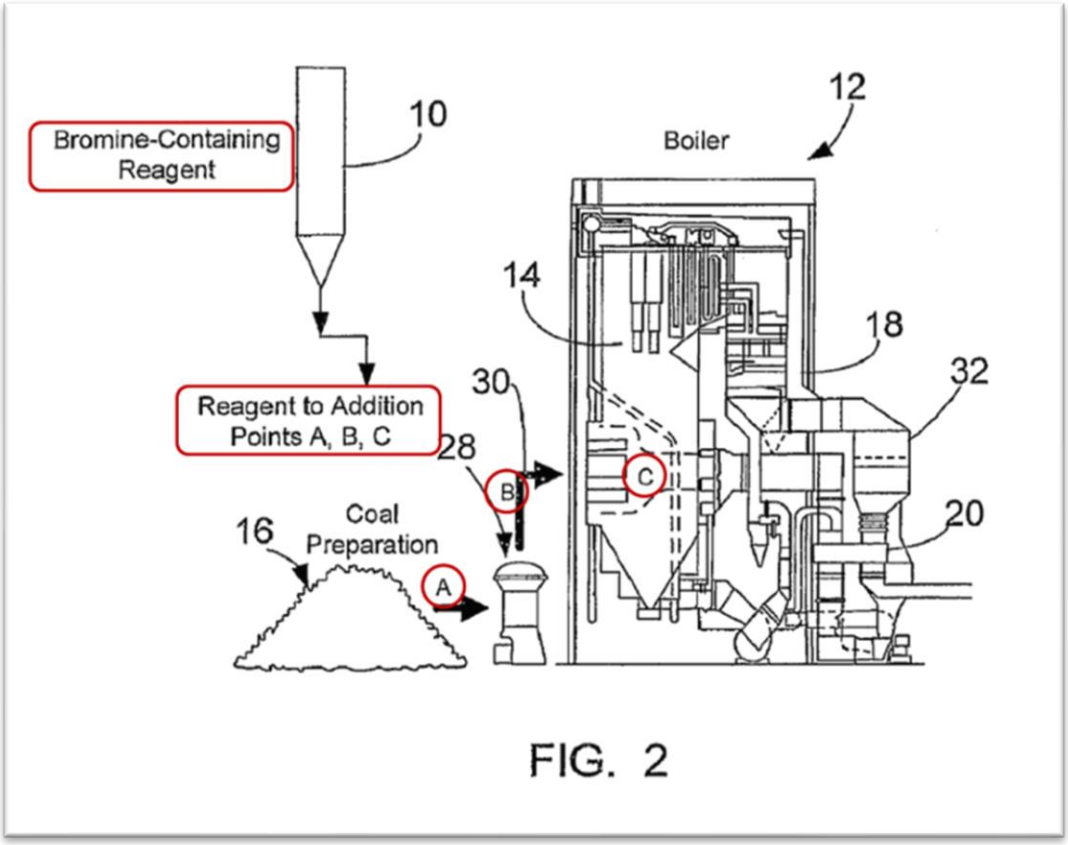


FIG. 2

Downs-Boiler does not restrict simultaneous introduction to each of points A, B, and C. Rather, as described above, Downs-Boiler invites, if not encourages, simultaneous introduction to each of points A, B, and C or some combination of A/B

[694] EX1006 (Downs-Boiler) ¶[0019], Figure 2 (annotated); see also EX1007 (Downs-Boiler-Provisional) ¶[0022], Figure 2.

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."[695]

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

408. 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-sorbent composition.

409. 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).[696] 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 injection process."[697] Downs-Boiler repeats in other places that the bromine-containing reagent saves costs by making more efficient use of the activated-carbon

[695] EX1006 (Downs-Boiler) ¶[0019]; see also EX1007 (Downs-Boiler-Provisional) ¶[0022].

[696] EX1006 (Downs-Boiler) ¶[0025]; see also EX1007 (Downs-Boiler-Provisional) ¶[0028].

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

sorbent material that is "inject[ed]."[698] 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."[699] 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.[700] 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. The activated-carbon sorbent is injected into a mercury-containing gas: "injection of a carbonaceous sorbent (e.g., powdered activated carbon, or PAC) into the flue gas upstream of the dust collector to adsorb vapor-phase mercury."[701]

410. In the context of conventional mercury removal by PAC injection, Downs-Boiler explains that adsorption (i.e., contact) of the mercury by the sorbent

[698] EX1006 (Downs-Boiler) ¶¶[0004], [0015], [0016], and [0025]; see also EX1007 (Downs-Boiler-Provisional) ¶¶[005], [0018], [0019], and [0028].

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

[700] EX1006 (Downs-Boiler) ¶¶[0012]-[0014] (discussing "downstream" with respect to the "boiler"); see also EX1007 (Downs-Boiler-Provisional) ¶¶[0014]-[0016].

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

occurs in the mercury-containing (flue) gas system (i.e., downstream of the combustion chamber):[702]

> 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.

411. Downs-Boiler recognizes that the sorbent "bond[s] with adsorbed mercury species" and that the strength of this bond is improved by halogens.[703] 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.[704] This increase in

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

[703] EX1006 (Downs-Boiler) ¶[0004]; EX1007 (Downs-Boiler-Provisional) ¶[005].

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

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."[705]

412. This claim limitation would be further obvious over Starns (Ground A3), which confirms that by "injection of sorbents such as powdered activated carbon (PAC) into the flue gas," the "gas-phase mercury in the flue gas contacts the sorbent and attaches to its surface."[706] A "powdered" sorbent is in particulate form.

413. This claim limitation would be further obvious over Mass-EPA (Ground A4), which Mass-EPA confirms that "sorbent particles … contact the Hg in the flue gas."[707] Mass-EPA further identifies "mercury to contact the AC [(activated carbon)] particle."[708]

4. Claim 1: Element 1(c)—"wherein a weight ratio of the additive added to the coal, added to the combustion chamber, or a combination thereof, to an amount of the sorbent material added to the mercury-containing gas is from about 1:100 to about 30:100;"

414. This claim element is obvious over the combinations of Downs-Boiler with Starns (Ground A3) and Downs-Boiler with Mass-EPA (Ground A4). Downs-

[705] EX1006 (Downs-Boiler) ¶[0016]; EX1007 (Downs-Boiler-Provisional) ¶[0019].

[706] EX1008 (Starns) at 2.

[707] EX1009 (Mass-EPA) at 21 n.25.

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

Boiler describes that bromine-containing reagent (e.g., HBr, Br_2, or aqueous solution of calcium bromide) was added to the coal to provide 375-1000 ppm equivalent Br increase in coal.[709] However, Downs-Boiler does not expressly state the gas-phase concentration of Br in the mercury-containing gas, and Downs-Boiler does not expressly state the injection rate of activated carbon into the system downstream of the combustion chamber. As described below, a POSITA would have been able to calculate and/or measure the gas-phase concentration of Br in the mercury-containing gas. Regarding the injection rate of activated carbon, as described above,[710] it was routine in the industry to use injection rates of activated carbon of around 10 pounds/MMacf (million actual cubic feet of flue gas) to capture mercury.

415. This injection rate is further confirmed in Ground A3, as this is the value that Starns uses to obtain maximum mercury removal:

> Effective mercury removal between 40 – 50% was obtained at 1 lb/MMacf.
>
> Effective mercury removal between 50 – 60% was obtained at 3 lb/MMacf.

[709] EX1006 (Downs-Boiler) ¶[0018], Figure 3 (annotated); see also EX1007 (Downs-Boiler-Provisional) ¶[0021], Figure 3.

[710] *See* Technology Background and State of the Art, IX.C.5.

> Effective mercury removal between 60 – 70% was obtained at 10 lb/MMacf.[711]

416. This injection rate is also confirmed in Ground A4, as Mass-EPA also discloses sorbent injection rates at 10 lbs/MMacf.[712]

417. Regarding Ground A3 and Ground A4, based on the data presented by Downs-Boiler of 375 ppm Br added to coal, and a standard and well-known injection rate of activated carbon of around 10 pounds/MMacf (as described in each of Starns and in Mass-EPA), a person of ordinary skill in the art would have used, or at least tried using, a mercury-containing gas that comprises about 20.4 grams of the element bromine per 100 grams of sorbent. I explain my calculations below.

418. In order to determine a ratio of bromine concentration in the flue gas to activated carbon in the flue gas, the concentrations must have the same units—such as grams per actual cubic feet (ACF) or pounds per million actual cubic feet (MACF). Downs-Boiler provides the concentration of bromine to coal, which can be converted to a concentration of bromine in the flue gas. Activated-carbon injection concentrations were typically provided in pounds (lbs.) per million actual cubic feet (MACF) of flue gas, as in Starns and Mass-EPA. Converting between the

[711] EX1008 (Starns) at 20.

[712] EX1009 (Mass-EPA) at 73 (Brayton Point testing); p. 12 (Chart 2, showing Gaston, Brayton Point, and Pleasant Prairie).

two would have been a routine calculation at a power plant to a POSITA and would have involved such basic concepts as the ideal gas law (to convert concentrations between temperatures and pressures), which was taught in first semester undergraduate chemistry to a person of skill in the art.[713] Such unit conversion would have also involved basic engineering knowledge of a power-plant operation, such as a typical flue gas temperature, pressure, and moisture content. Each of these would have been well-known to a person of skill in the art.

419. Downs-Boiler discloses usage of "western U.S. subbituminous coal," which is another name for Powder River Basin (PRB).[714] The concentration of Br in the mercury-containing gas is estimated for typical parameters for firing Powder River Basin (PRB) subbituminous coal in full-scale utility boilers beginning with the Br loading on coal. For a value of 375 ppm Br[715] on coal from Downs-Boiler, the equivalent concentration of Br in flue gas can be calculated as follows:

---

[713] Technology Background and State of the Art ("Common Units of Measurement"), §IX.A.9.

[714] EX1006 (Downs-Boiler) ¶[0017]; see also EX1007 (Downs-Boiler-Provisional) ¶[0020].

[715] EX1006 (Downs-Boiler) ¶[0018], Figure 3 (annotated); see also EX1007 (Downs-Boiler-Provisional) ¶[0021], Figure 3.

Downs-Boiler discloses the units of "ppm." A POSITA would have understood this to refer to ppm by weight, rather than on a molar basis, because the comparison is with respect to coal.

$$\left(\frac{375\ g\ Br}{10^6\ g\ coal}\right) = 3.75x10^{-4}\frac{g\ \ Br}{g\ coal}$$

$$3.75x10^{-4}\ \frac{g\ Br}{g\ coal} \times \left(\frac{1\ g\ coal}{10\ g\ flue\ gas}\right) = 3.75x10^{-5}\ \frac{gBr}{gflue\ gas}$$

I note that the ratio of 10 grams flue gas per gram coal is a nominal value for subbituminous coals fired at 15 – 20 % excess air, and representative of the typical firing practices at coal-fired utility boilers. (In other words, combustion of 1 gram of subbituminous coal can be expected to produce approximately 10 grams flue gas). The molecular weight of flue gas is typically between 28-32 grams per mole (depending on the type of coal and amount of excess air), because flue gas is primarily: molecular nitrogen (molecular weight of 28, from excess air), carbon dioxide (molecular weight of 44), water (molecular weight of 18), and excess oxygen (molecular weight of 32). Accordingly, a typical value for the molecular weight of flue gas is 30 g/mol.

$$3.75x10^{-5}\ \frac{g\ Br}{g\ flue\ gas} \times \left(30\ \frac{g\ flue\ gas}{mol\ flue\ gas}\right) = 1.12x10^{-3}\ \frac{g\ Br}{molf\ lue\ gas}$$

420. Regarding the second conversion, a person of ordinary skill in the art would have understood from the ideal gas law (PV = nRT) that the density of a gas is proportional to pressure and inversely proportional to temperature. A person of skill in the art would have learned from undergraduate chemistry that standard temperature and pressure (STP) refers to 25 ºC (298 K) and 1 atm, respectively, and would have known that a typical flue gas temperature where sorbent would be

injected is 150 ºC (413 K) and also 1 atm of pressure. In fact, Starns discloses a temperature of 290 ºF, which is 143 ºC (416 K).[716] Mass-EPA also discloses "flue gas temperatures range from 284 to 320ºF (140 to 160°C)."[717] A person of ordinary skill in the art would have understood that this temperature is a typical value for sorbent injection downstream of an air preheater and upstream of an ESP or fabric filter. A POSITA would have known that air preheaters typically do not operate with outlet gas temperatures below the acid dew points of sulfuric acid, which are given as 120 – 150 °C.[718] This dewpoint range restricts the outlet temperatures to somewhat hotter values like 150 °C. Thus, a temperature of 416 Kelvin (143ºC) is used for the calculations, as this temperature is disclosed by Starns and within the range disclosed by Mass-EPA.

$$1.12x10^{-3}\frac{gBr}{mol\ flue\ gas}\times\left(\frac{1\ atm}{(416\ K)\left(0.082058\frac{L\ atm}{mol\ K}\right)\left(\frac{1\ acf}{28.3\ L}\right)}\right)\left(\frac{10^6\ acf}{Macf}\right)$$
$$=929\frac{g\ Br}{Macf\ flue\ gas}$$

421. A person of ordinary skill in the art would have also been readily able to convert pounds activated carbon to grams activated carbon (and vice versa)

[716] EX1008 (Starns) at 10.

[717] EX1009 (Mass-EPA) at 26.

[718] EX1027 (B&W: Steam) at 19-11.

through the well-known unit conversion that there are 453.592 grams per pound. For an injection concentration of 10 lb PAC/MACF (as disclosed in Starns and in Mass-EPA), the concentration of PAC in the flue gas can be calculated in grams as:

$$10\frac{pounds\ PAC}{MACF}\times\frac{453.592\ grams}{pound}=4{,}536\frac{grams\ PAC}{MACF}$$

422. The estimated concentration of Br in flue gas is 929 g Br / MACF flue gas. For an injection concentration of 10 lb PAC/MACF, the concentration of PAC in the flue gas is 4,536 g PAC/MACF flue gas. Dividing the two rates—the bromine addition rate of Downs-Boiler with the activated carbon injection rate of Starns and Mass-EPA—provides a mercury-containing gas that comprises about 20.4 grams of the element bromine per 100 grams of activated-carbon sorbent.

423. Converting from grams of the element bromine in the gas to grams of the additive added to the coal and/or combustion chamber involves (i) multiplying by the ratio of molecular masses of additive to elemental Br (e.g., 199.89 grams of $CaBr_2$, 80.91 grams HBr, and 159.80 grams Br_2, each of which are divided by 79.9 grams for Br) and (ii) dividing by the number of Br atoms in the additive (which is 2 for $CaBr_2$ and Br_2 and 1 for HBr). These additives yield ratios of 25.5 grams additive per 100 grams sorbent when using $CaBr_2$, 20.6:100 when using HBr; and 20.4:100 when using Br_2.

424. And even if one were to use the highest sorbent injection rate tested in Chart 2 of Mass-EPA, which is 30 lb/MMacf,[719] the ratio of the element bromine to the sorbent injected would still be 6.8:100. In this circumstance, the additives yield ratios of 8.5 grams additive per 100 grams sorbent when using $CaBr_2$, 6.9 grams HBr per 100 grams sorbent; and 6.8 grams Br_2 per 100 grams sorbent.

425. It would have been obvious to try other ratios, such as by increasing the halogen concentration (while reducing the activated carbon injection), or decreasing the halogen concentration (while increasing the active carbon injection) as part of routine process optimization to achieve the desired mercury removal. Claim Element 1(c) is merely an attempt to claim a broad workable range for combining a conventional halogen (bromine) being used in a conventional way with a conventional sorbent (to oxidize mercury and promote activated carbon). Nothing in the '370 Patent specification attributes significance to the claimed range, or establishes that the claimed range achieves unexpected results. The range presents nothing more than optimization of result-effective variables that would have been obvious to a POSITA. Patent Owner's expert in the Delaware litigation involving patents related to the '370 Patent stated that "power plants employing bromine additives and activated carbon would necessarily produce a sorbent that is 1 g to 30

[719] EX1009 (Mass-EPA) at 12.

g bromine per 100 g of activated carbon."[720] He further cited to this analysis for a claim that requires "the mercury-containing gas comprises about 1 g to about 30 g of the element bromine per 100 g of the sorbent."[721]

5. Claim 1: Element 1(d)—"contacting mercury in the mercury-containing gas with the sorbent material, to form a mercury-sorbent; and"

426. Downs-Boiler discloses this claim element. 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):[722]

> injection of a carbonaceous sorbent (e.g., powdered activated carbon, or PAC) into the flue gas upstream of the dust collector to adsorb vapor-phase mercury. The sorbent, and its burden of adsorbed mercury, are subsequently removed from the flue gases in a downstream particulate collector. Adsorption is a technique that has often been successfully applied for the separation and removal of trace quantities of undesirable components.

The "sorbent, and its burden of adsorbed mercury" discloses a mercury-sorbent composition, because the "adsorbed mercury" is adsorbed onto sorbent. For this process, described by Downs-Boiler as taking place as part of a dry emission-control

[720] EX1092 (O'Keefe Report) at 153 (cl. 4).

[721] EX1092 (O'Keefe Report) at 154 (cl. 29).

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

system that further includes an electrostatic precipitator or fabric filter, the "adsorption" of mercury refers to a process by which atoms, ions, or molecules in a fluid (typically a gas) are bound to the surface of a sorbent, and thus by definition the sorbent is "contacting mercury in the mercury-containing gas," as per Claim Element 1(d).

427. Downs-Boiler recognizes that the sorbent "bond[s] with adsorbed mercury species" and that the strength of this bond is improved by halogens.[723] 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.[724] This increase in the fraction of particulate-bound mercury is explained as leading to a mercury-sorbent composition due to the increased "reactivity of oxidized mercury with PAC."[725]

428. Regarding Ground A3, Starns further verifies through the "injection of sorbents such as powdered activated carbon (PAC) into the flue gas upstream of the

[723] EX1006 (Downs-Boiler) ¶[0004]; EX1007 (Downs-Boiler-Provisional) ¶[005].

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

[725] EX1006 (Downs-Boiler) ¶[0016]; EX1007 (Downs-Boiler-Provisional) ¶[0019].

particle control equipment," the "gas-phase mercury in the flue gas contacts the sorbent and attaches to its surface."[726]

429. Regarding Ground A4, Mass-EPA further verifies that through activated-carbon injection, the "sorbent particles … contact the Hg in the flue gas."[727]

6. Claim 1: Element 1(e)—"separating the mercury-sorbent from the mercury-containing gas."

430. Downs-Boiler discloses this claim element. Downs-Boiler explains that the desired removal of mercury from the flue gas is by a separation of the mercury-sorbent composition from the mercury-containing gas. Separation of the mercury-sorbent composition, which includes the oxidized mercury adsorbed onto the PAC as discussed above regarding Claim Element 1(d), is removed from the mercury-containing gas by a particulate collector as a way to clean the flue gas:[728]

> 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.

[726] EX1008 (Starns) at 2.

[727] EX1009 (Mass-EPA) at 21 n.25. Page 33 also refers to "time available for the mercury to contact the AC [activated carbon] particle").

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

The "sorbent, and its burden of adsorbed mercury" refers to a sorbent contacted with the mercury, and it is "removed" by separating the mercury-sorbent composition from the mercury-containing gas to form a cleaned gas. Downs-Boiler illustrates a number of example particulate collection devices that may be used to separate the mercury-sorbent composition to produce a cleaned gas, each of which were well known to a POSITA. These particulate collectors include "electrostatic precipitators (ESP) or fabric filters (FF), sometimes called baghouses" that "provide high-efficiency removal of particulate-bound mercury."[729]

D. CLAIMS DEPENDING FROM CLAIM 1

1. Claim 2: "The method of claim 1, further comprising adding the additive to the coal before combusting the coal."

431. This claim is disclosed by Downs-Boiler. As I described above for Claim Element 1(a), the bromine-containing additive (e.g., Br_2, $CaBr_2$) is added to the coal upstream of the combustion chamber, including at "coal preparation" (point A) and "the pulverized coal conveying system 30" (point B).

[729] EX1006 (Downs-Boiler) ¶¶[0003], [0023], Figures 4-6; see also EX1007 (Downs-Boiler-Provisional) ¶¶ [004] [0026], Figures 4-6.

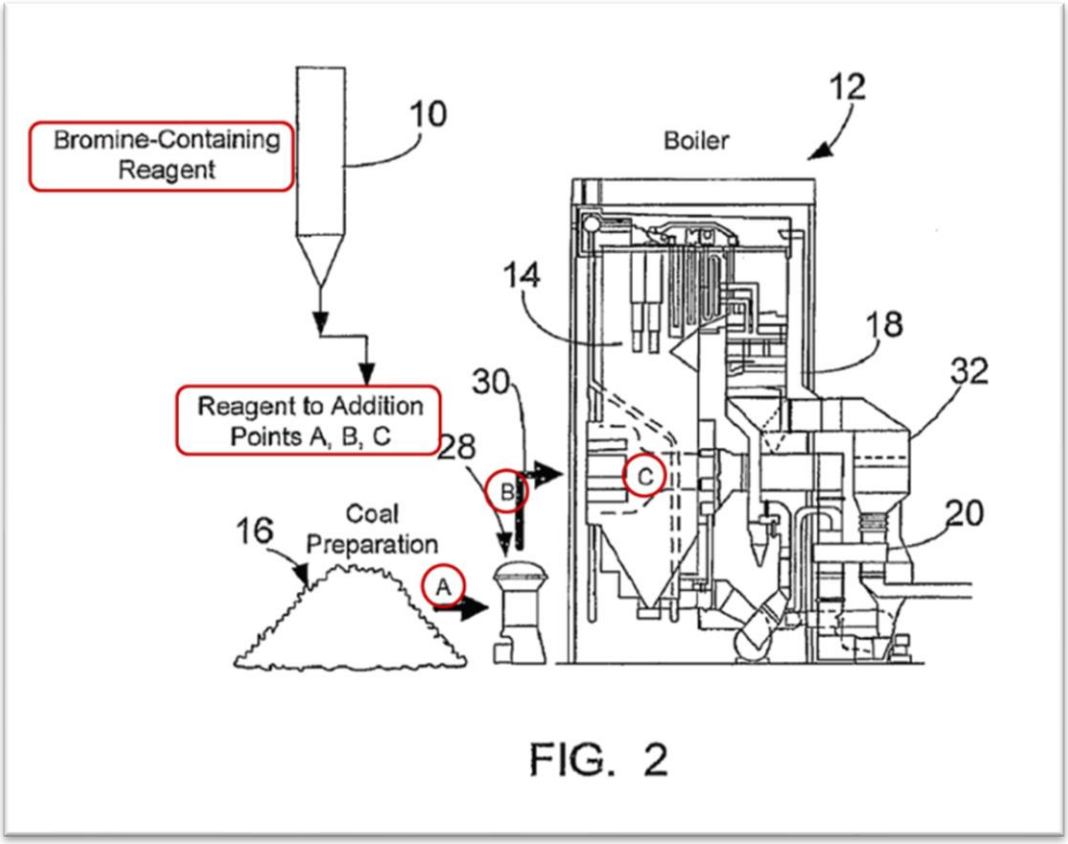


FIG. 2

2. Claim 3: "The method of claim 2, wherein the additive mixed with the coal is in a liquid."

432. This claim is disclosed by Downs-Boiler. As described for Claim Element 1(a), Downs-Boiler discloses mixing Br_2 and "an aqueous solution of calcium bromide ($CaBr_2$)" with the coal.[730] A POSITA would have known that Br_2 is a liquid at room temperature, and that the aqueous solution of calcium bromide is $CaBr_2$ dissolved in water (i.e., a liquid). $CaBr_2$ is a salt, and aqueous $CaBr_2$ is a salt

[730] EX1006 ¶¶[0018]-[0019], [0021]; EX1007 ¶¶[0021]-[0022], [0024].

solution. As confirmed by Claim 4, which depends from Claim 3, a "liquid" can include "water" and a "salt solution."

3. Claim 4: "The method of claim 3, wherein the liquid is a hydrocarbon, supercritical carbon dioxide, water, salt solution, or a combination thereof."

433. This claim is disclosed by Downs-Boiler. Downs-Boiler discloses this limitation for the reasons discussed for Claim 3. As discussed above for Claim 3, the liquid contains water and is a salt solution.

4. Claim 5: The method of claim 1, wherein carbocations in the activated carbon of the mercury-sorbent accept electrons from mercury atoms of the mercury-sorbent.

434. According to Patent Owner's expert in the Delaware litigation, this chemical reaction takes place between the activated carbon and mercury.[731]

5. Claim 6: "The method of claim 1, wherein the additive is substantially in vapor form in the mercury-containing gas."

435. Claim 6 would have been obvious over the combination of Downs-Boiler in view of Starns (Ground A3) and Downs-Boiler in view of Mass-EPA (Ground A4). Downs-Boiler discloses this claim.As discussed for Claim Element 1(a), Downs-Boiler discloses adding Br_2, HBr, or an "aqueous solution of calcium bromide" ($CaBr_2$) to the coal (Points A-B) and/or combustion chamber (Point C). Downs-Boiler explicitly discloses that the promoter (i.e., the bromine-containing

[731] EX1092 (O'Keefe Report) p. 160 ('147 Patent Claim 1c).

reagent) "may be fed to the boiler combustion zone 14 in gaseous, liquid, or solid form."[732] This is shown at Point C below:

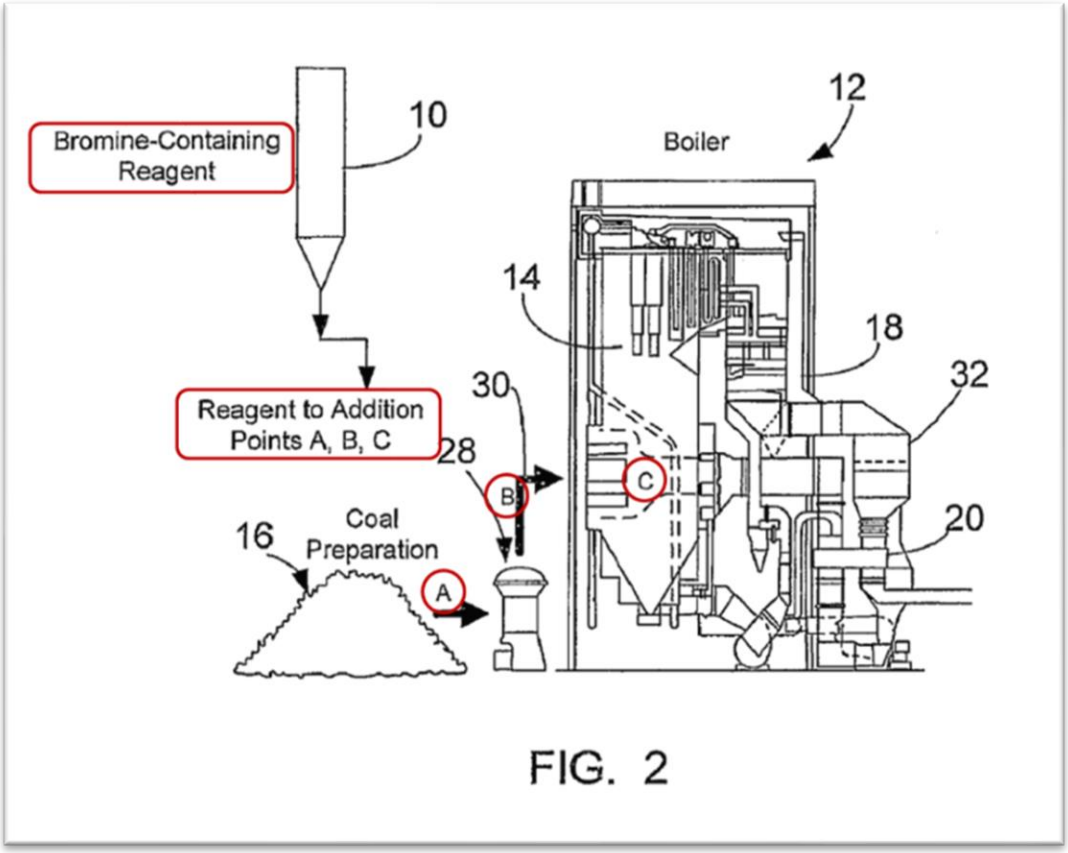


FIG. 2

Downs-Boiler also explicitly discloses that the promoter may be in the form of an "aqueous solution."[733]

[732] EX1006 (Downs-Boiler) ¶¶[0021]-[0022], Fig. 2; see also EX1007 (Downs-Boiler-Provisional) ¶[0025], Fig.2.

[733] EX1006 (Downs-Boiler) ¶¶[0018]-[0019]; see also EX1007 (Downs-Boiler-Provisional) ¶¶[0021]-[0022].

436. As described for Claim 1, Downs-Boiler discloses adding activated carbon into the mercury-containing flue gas. The boiling point of Br_2 is only 58.8ºC (it is a fuming liquid at room temperature), and the boiling point of hydrogen bromide is -66.38 ºC (i.e., it is a gas at room temperature).[734] Each of these is well below the temperature of the mercury-containing flue gas. For the other species that Downs-Boiler adds to the coal and/or combustion chamber, at least a portion of the Br would have vaporized in the combustion chamber and reacted to form vapor-phase HBr. When bromine-containing species (e.g., HBr) and carbon come into contact with each other, the bromine acts as a promoter.[735]

437. The boiling point of water is around 100 ºC, and a POSITA would have understood that the mercury-containing flue gas (which also contains the promoter (e.g., HBr and Br_2)) would be at a temperature well above the boiling point of water and remain in the gas phase. In each combination, the promoter (e.g., HBr and Br_2) would have remained in vapor form as it is transported with the flue gas and eventually contacted the activated-carbon sorbent.[736] Downs-Boiler confirms that bromine-containing species are present in the mercury-containing flue gas, as they

[734] EX1036 (CRC Press: March 2005) at 4-53 and 4-65.

[735] *See* Technology Background and State of the Art, §IX.C.3, §IX.G.2.

[736] Patent Owner's expert agrees. EX1092 (O'Keefe Report) at 154, 170, 176.

are responsible for "enhanc[ing] the removal of mercury across a PAC injection process."[737]

438. Regarding Ground A3, Starns discloses typical flue gas temperatures of 290 ºF, which is 143 ºC.[738] Regarding Ground A4, Mass-EPA discloses activated carbon injection upstream of ESPs and FFs fall into two classifications, coldside (CS) or hotside (HS), depending on whether they are installed after an air heater, where flue gas temperatures range from 284 to 320ºF (140 to 160°C), or before an air heater, where flue gas temperatures range from 662 to 842ºF (350 to 450°C)."[739] In each of these configurations, the temperatures are well-above the limit at which the mercury-containing gas would be in the gas phase, and the halogen promoters (such as HBr and Br_2) would likewise be vaporized. Regarding both Ground A3 and Ground A4, the boiling point of water is around 100 ºC, so a POSITA would have understood, or at the very least found it obvious, that the mercury-containing flue gas (which also contains the promoter (e.g., HBr and Br_2)) would be at a temperature well above the boiling point of water and remain in the gas phase. In each combination, the promoter (e.g., HBr and Br_2) would have remained in the vapor

[737] EX1006 (Downs-Boiler) ¶¶[0015]-[0016]; EX1007 (Downs-Boiler-Provisional) ¶¶[0018]-[0019].

[738] EX1008 (Starns) at 10.

[739] EX1009 (Mass-EPA) at 26.

form as it is transported with the flue gas and eventually contacted the activated-carbon sorbent.

6. Claim 8: "The method of claim 1, wherein the additive is chosen from Br_2, HBr, sodium bromide, calcium bromide, and a combination thereof."

439. This claim is disclosed by Downs-Boiler. As discussed for Claim Element 1(a), Downs-Boiler discloses that the additive can be chosen from Br_2, HBr, and/or an "aqueous solution of calcium bromide" ($CaBr_2$). 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)."[740] Downs-Boiler also specifically discloses calcium bromide ($CaBr_2$) as another suitable bromide compound for use as the bromine-containing reagent.[741]

7. Claim 11: "The method of claim 1, wherein the activated carbon is chosen from powdered activated carbon, granular activated carbon, carbon black, carbon fiber, aerogel carbon, pyrolysis char, and combinations thereof."

440. This limitation is disclosed by Downs-Boiler (Ground A3 and Ground A4). Downs-Boiler discloses the use of a "sorbent injection system" for the purpose of injecting a "carbonaceous sorbent" including at least "powdered activated carbon

[740] EX1006 (Downs-Boiler) ¶[0021]; see also EX1007 (Downs-Boiler-Provisional) ¶[0024].

[741] EX1006 (Downs-Boiler) ¶[0018]-[0019]; see also EX1007 (Downs-Boiler-Provisional) ¶[0021-22].

(PAC), carbons and chars produced from coal and other organic materials, and unburned carbon produced by the combustion process itself."[742]

441. For Ground A3, 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."[743]

442. For Ground A4, 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."[744]

8. Claim 12: "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."

443. Claim 12 would have been obvious over the combination of Downs-Boiler in view of Mass-EPA (Ground A4). With respect to Ground A4, Mass-EPA

[742] EX1006 (Downs-Boiler) ¶[0025]; see also EX1007 (Downs-Boiler-Provisional) ¶[0028].

[743] EX1008 (Starns) at 2.

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

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.[745]
>
> 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. [746]
>
> 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.[747]

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.

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

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

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

9. Claim 14: "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."

444. Claim 14 would have been obvious over the combination of Downs-Boiler in view of Mass-EPA (Ground A4). Mass-EPA discloses injecting "[m]odified activated carbons (i.e., doped with sulfur, iron, chlorine, and iodine)."[748] The modified activated carbons "doped with" chlorine and iodine renders obvious that the sorbent material would have been contacted with chlorine and iodine (i.e., halogens).

10. Claim 15: "The method of claim 14, wherein the secondary component is chosen from halogens, halide salts, HI, HBr, HCl, and combinations thereof."

445. The claim is obvious over the combination of Down-Boiler in view of Mass-EPA (Ground A4), which co-injects activated carbon "doped with" chlorine and iodine.[749] Both chlorine and iodine are halogens.

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

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

11. Claim 16: "The method of claim 14, wherein the secondary component is chosen from I_2, HI, and combinations thereof."

446. The claim is obvious over the combination of Downs-Boiler in view of Mass-EPA (Ground A4), which co-injects activated carbon "doped with" iodine.[750] A POSITA would recognize that "iodine" by itself refers to molecular iodine (I_2).

XV. GROUND A5 AND GROUND A6: OBVIOUSNESS OVER LISSIANSKI IN VIEW OF STARNS [GROUND A5] AND LISSIANSKI IN VIEW OF MASS-EPA [GROUND A6]

447. It is my opinion that Claims 1, 5-6, and 11 would have been obvious over the combination of Lissianski and Starns (Ground A5). Claims 1, 5-6, 11-12, and 14-15 would have been obvious over the combination of Lissianski and Mass-EPA (Ground A4). Ground A5 and Ground A6 largely rely on the common disclosure of Lissianski, with certain limitations disclosed by Starns (Ground A5) and by Mass-EPA (Ground A6) (in some cases, in addition to disclosure of those limitations already present in Lissianski).

A. REASONS TO COMBINE

448. A person of ordinary skill in the art would have been motivated to combine Lissianski with Starns (Ground A5) and Lissianski with Mass-EPA (Ground A6), and with reasonable expectation of success, because all three

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

references are directed towards the same goal (removing mercury from coal-combustion flue gas) and are interoperable and complimentary with one another.

449. As described more fully below, Lissianski discloses that some types of coal tend to have "low chlorine (Cl) content" natively, which results "in relatively high levels of elemental mercury in the flue gas from low rank coal."[751] Lissianski discloses a process for increasing the concentration of halogen-containing promoter (including HCl, HBr, and HI) in a mercury-containing gas, by supplying a "halogen agent" to the mercury-containing gas in the combustion chamber.[752]

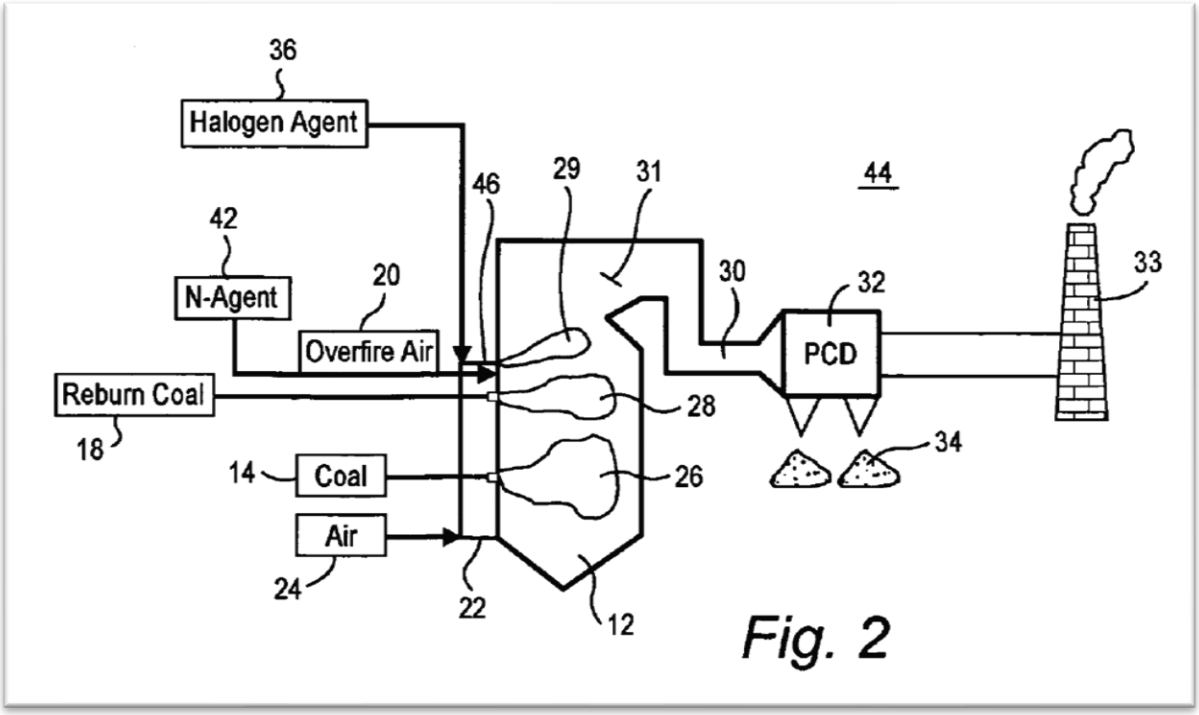


Fig. 2

[751] EX1014 (Lissianski) at 1:52-67.

[752] EX1014 (Lissianski) at at Fig. 2.

450. Lissianski teaches, among other configurations, injecting the halogen agent (e.g., NH_4Br, NH_4Cl, and/or NH_4I) along with the overfire air **20** into the furnace **12** as shown by Figure 2 above. Lissianski describes that the "[o]verfire air (OFA) is injected into the OFA burnout zone **29** to complete combustion."[753] Upon exposure to flue-gas temperatures, the NH_4Br, NH_4Cl, and NH_4I vaporize and decompose into HBr, HCl, and HI, respectively:

> It has been discovered that mercury removal can be significantly improved by injecting ammonium chloride (NH_4Cl), NH_4Br, or NH_4I into flue gas, especially in the flue gas from low-rank coals. The hot flue gas causes the additive to thermally decompose to form HCl, HBr or HI which results in more significant mercury oxidation.[754]

Lissianski further teaches injecting activated carbon directly into the mercury-containing flue gas.[755] As such, the halogen-containing promoter (e.g., HCl, HBr, and/or HI) in vapor form reacts with the injected activated carbon in the flue gas. Lissianski describes that an "increase in mercury oxidation allows for improved efficiency of mercury removal by activated carbon (AC) injection, wet flue gas desulfurization (FGD) systems, and other mercury control technologies."[756]

---

[753] EX1014 (Lissianski) at 4:9-10.

[754] EX1014 (Lissianski) at 3:42-48.

[755] EX1014 (Lissianski) at 3:20-23, 3:47-50.

[756] EX1014 (Lissianski) at 3:47-50; *see also* EX1014 (Lissianski) at claim 8.

451. More specifically, Lissianski discloses a method of reducing the emissions in flue gas by "adsorbing the oxidized mercury generated by the combustion of the coal with an adsorbent in the flue gas," and that the emission control system works because "oxidized mercury . . . is water soluble and is easily *adsorbed* on high carbon fly ash or activated carbon."[757] Lissianski uses halogen-containing species (such as NH_4Cl, NH_4Br, or NH_4I) to oxidize mercury because "[b]y increasing the fraction of oxidized mercury, the halogen additive increases the amount of mercury removal by activated carbon injection."[758]

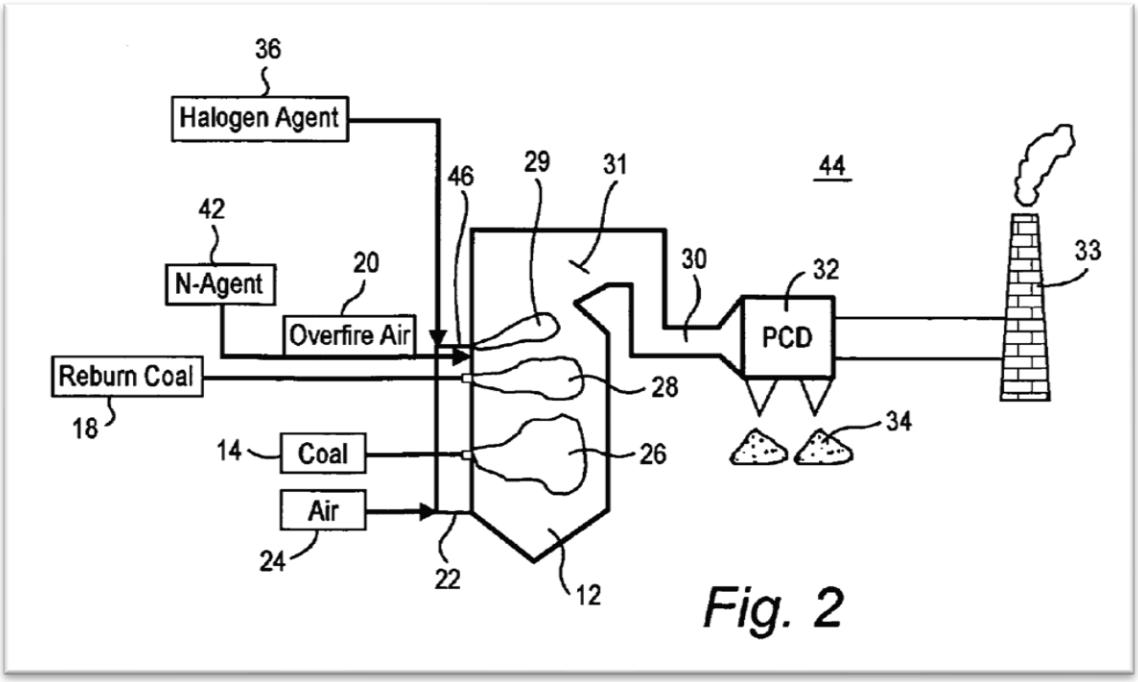
452. The process that Lissianski describes as being performed to remove mercury from the flue gas—"adsorption"—refers to a process by which adsorbate (e.g., atoms, ions, or molecules) in a fluid (typically a gas) are bound to the surface of a sorbent. In such adsorption processes, the adsorbate (e.g., mercury) is adhering to the sorbent (e.g., activated carbon), and the activated carbon is thus contacting mercury in the mercury-containing gas. Lissianski further discloses "collecting the adsorbent with the oxidized mercury in a combustion waste treatment system."[759] Lissianski describes that it was well known that "volatized mercury can be captured

[757] EX1014 (Lissianski) at Abstract, 1:35, 36.

[758] EX1014 (Lissianski) at 3:16-22.

[759] EX1014 (Lissianski) at 2:13-14.

by coal fly ash and removed via a particulate collection system."[760] Lissianski discloses such a particulate collection system as PCD **32**, as shown for example by Figure 2 below:[761]



453. Lissianski however does not fully disclose all the details about how to implement the activated carbon injection, 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, and Starns and Mass-EPA each supplies those

[760] EX1014 (Lissianski) at 1:15-17; *see* EX1014 (Lissianski) at 1:37-38.

[761] EX1014 (Lissianski) at 4:3-5. Figs. 1-3.

details. In particular, as explained above in Technology Background and State of the Art, a POSITA would have readily understood how to add the activated carbon sorbent to the system, namely by injection into the mercury-containing flue gas between the combustion chamber and the PCD (such as the ESP or fabric filter). Starns and Mass-EPA each provides these details, and a POSITA would have been motivated to combine Lissianski with Starns (Ground A3) and Lissianski with Mass-EPA (Ground A4).

1. Ground A5 (Combination of Lissianski with Starns)

454. Like Lissianski, 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."[762] Like Lissianski, 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.[763]

[762] EX1008 (Starns) at 1.

[763] EX1008 (Starns) at 2.

Starns provides details as to how to supply activated carbon to the system and processes of Lissianski:

- **Injection of the activated carbon:** an "injection equipment" that includes a "bulk-storage silo and twin blower/feeder trains ...."[764] 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."[765] One of the "[p]rimary variables" to control how much mercury is removed is "injection concentration" of the sorbent.[766]

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

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

[766] 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 …."[767]

455. Starns provides the details of ACI—what Starns describes as the "most mature retrofit technology available today"[768]—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 Lissianski.

456. As discussed above, Lissianski does not fully disclose all the details about how to implement the activated carbon injection system disclosed therein. Starns does disclose such details for an ACI system. As ACI was already a "mature" technology by the time of Starns, the combination of Lissianski 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 Lissianski) would yield the predictable results in the form of improved mercury removal.

[767] EX1008 (Starns) at 9.

[768] EX1008 (Starns) at 2.

457. A POSITA would have a reasonable expectation of success in combining Lissianski 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."[769] The participle control equipment in Starns is an electrostatic precipitator (ESP), and Starns recommends "using activated carbon injection upstream of an ESP."[770] A POSITA would have been motivated, as Starns suggests, to use activated carbon injection between the combustion chamber (furnace) in Lissianski and the ESP or fabric filter disclosed by Starns.[771] The mercury-sorbent composition is eventually removed by standard and well-known particulate control devices, such as the electrostatic precipitators (ESPs) and fabric filter disclosed in Starns, which are examples of the particle collection device (PCD) 32 of Lissianski.

2. Ground A6 (Combination of Lissianski with Mass-EPA)

458. Like Lissianski, Mass-EPA also pertains to systems for removing mercury from the flue gas of coal-combustion plants. The title of Mass-EPA is,

[769] EX1008 (Starns) at 2.

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

[771] EX1006 (Downs-Boiler) Figure 6 (annotated; see also EX1006 (Downs-Boiler) Figures 4-5; EX1007 (Downs-Boiler-Provisional) Figures 4-6.

"Evaluation of the Technological and Economic Feasibility of Controlling and Eliminating Mercury Emissions from the Combustion of Solid Fossil Fuel."[772] And like Lissianski, Mass-EPA discusses the use of sorbents and 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).[773]
>
> 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.[774]

459. 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

[772] EX1008 (Starns) at 1.

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

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

> there have been full-scale tests of this technology that have generated promising results.[775]
>
> 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. [776]

Mass-EPA discloses "activated carbon injection" in numerous other places.[777]

460. 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."[778] 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 Lissianski.

461. A POSITA would have looked to Mass-EPA for practical applications of the discovery disclosed in Lissianski relating to the use of halogen species added to the combustion chamber to improve the uptake of mercury on activated carbon sorbents. A POSITA would have used "injection" (as described by

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

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

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

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

Mass-EPA) as the method for introducing activated carbon sorbent (as described by both Lissianski and Mass-EPA) into the mercury-containing flue gas of Lissianski. As ACI was already "the most likely technology to be commercialized for mercury control"[779] by the time the Massachusetts EPA released its report in December 2002, the combination of Lissianski 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 Lissianski) would yield the predictable results in the form of improved mercury removal.

462. A POSITA would have a reasonable expectation of success in combining Lissianski with Mass-EPA because, as Mass-EPA described, activated carbon injection was the most likely candidate for near-term commercialization:

> 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).[780]

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

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

463. The technology was also mature, as "[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." [781] 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]

B. DISCLOSURE AND TEACHINGS OF THE COMBINATIONS

464. It is my opinion that the combination of Lissianski in view of Starns (Ground A5) and the combination of Lissianski in view of Mass-EPA (Ground A6) each renders obvious the claims below of the Challenged Patent.

C. INDEPENDENT CLAIM 1

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

465. Lissianski discloses the preamble. The title of Lissianski is, "Method for Removal of Mercury Emissions from Coal Combustion."[783] Specifically, Lissianski "relates to the combustion of coal and in particular to the reduction of mercury (Hg) and nitrogen oxides (NOx) on flue gas generated during coal

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

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

[783] EX1014 (Lissianski) at Title.

combustion."[784] Lissianski describes "[a] method to reduce emissions in flue gas" by "adsorbing the oxidized mercury generated by the combustion of the coal with an adsorbent in the flue gas, and collecting the adsorbent with the oxidized mercury in a combustion waste treatment system."[785] Flue gas is an example of a mercury-containing gas, and "reduc[ing] mercury" and "collecting" the mercury-sorbent composition refers to separating the mercury from a mercury-containing gas. Claim 1 of Lissianski also discloses the preamble, as shown in the emphasis below:[786]

> 1. ***A method to reduce emissions in flue gas*** due to combustion of coal in a combustion unit, said method comprising:
>
> a. combusting coal in a primary combustion zone of the combustion unit;
>
> b. ***releasing elemental mercury*** from the combustion ***into the flue gas***;
>
> c. injecting a halogen-containing additive into the flue gas, wherein the halogen-containing additive is selected from a group consisting of NH_4Br and NH_4I;
>
> d. oxidizing the elemental mercury with a halogen from the halogen-containing additive;

[784] EX1014 (Lissianski) at 1:6-8.

[785] EX1014 (Lissianski) at Abstract.

[786] EX1014 (Lissianski) at Claim 1.

> e. ***adsorbing the oxidized mercury*** generated by the combustion of the coal ***with an adsorbent in the flue gas***, and
>
> f. ***collecting the adsorbent with the mercury in a combustion waste treatment system***.

Thus, Lissianski itself discloses the preamble.

2. Claim 1: Element 1(a)—"combusting a mixture of coal and an additive in a combustion chamber, to form the mercury-containing gas, wherein the additive is chosen from halides, halogens, salts thereof, and combinations thereof;"

466. Lissianski discusses combusting coal to form the mercury-containing gas. For example, the title is, "Method for Removal of Mercury Emissions from Coal Combustion."[787] The term "flue gas" refers to mercury-containing gas. Lissianski refers to the combustion chamber as "furnace 12" or, alternatively, as "boiler 12."[788] Combustion chamber 12 is shown below in Figures 1-2.[789]

[787] EX1014 (Lissianski) at Title, Abstract ("A method to reduce emissions in flue gas due to combustion of coal in the combustion unit").

[788] EX1014 (Lissianski) at 1:1-6.

[789] EX1014 (Lissianski) at Figs. 1-2 (annotated);

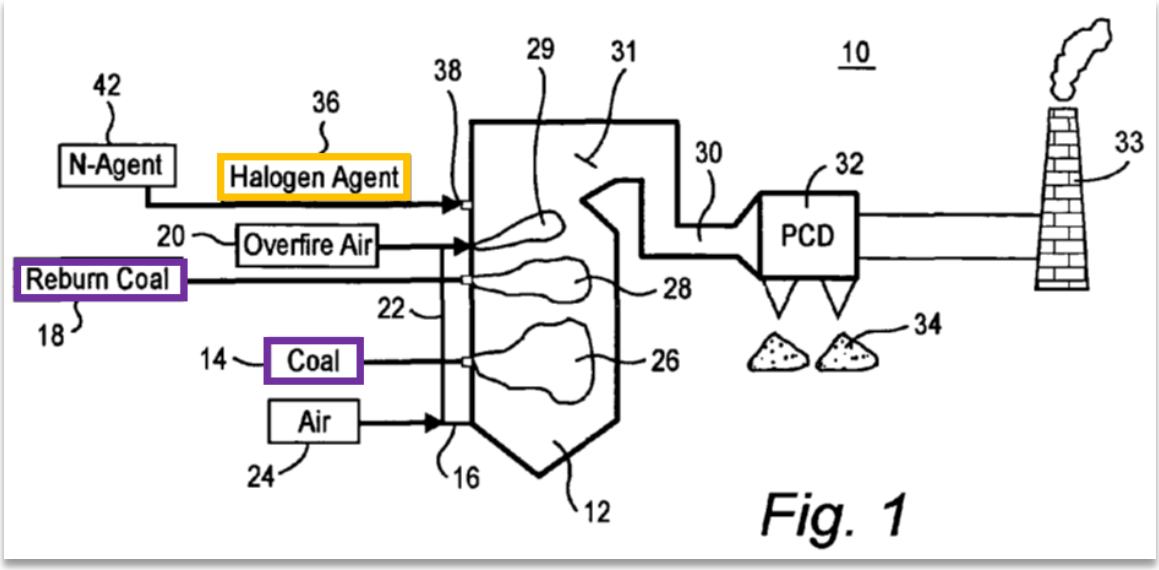


Fig. 1

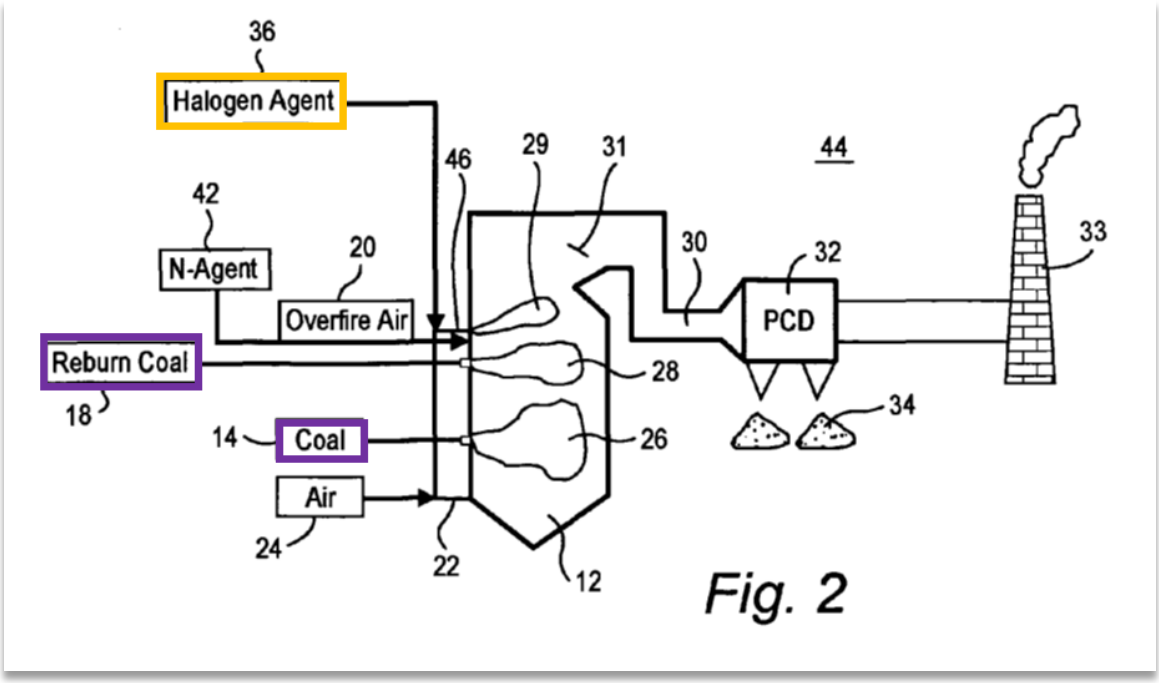


Fig. 2

467. Lissianski describes halide salts (referred to as "halogen agent" and annotated gold)—including NH_4Cl, NH_4Br, or NH_4I—into a combustion chamber

to help oxidize mercury.[790] Each of these are a salt that include a cation (NH_4) and anion (halides Cl, Br, and I). In the combustion chamber, the "hot flue gas causes the additive to thermally decompose to form HCl, HBr, or HI which results in more significant mercury oxidation."[791]

468. A POSITA would have recognized from Lissianski, or at least found it obvious, that the halogen agent is mixed with coal for combustion. In Figures 1 and 2 of Lissianski, a mixture of halogen agent (item 36, annotated gold) and coal (items 14 and 18, annotated purple) is combusted in combustion chamber 12. As shown in Figures 1 and 2, coal (annotated purple) is added to the combustion chamber in two places:

> Most of the coal is burned in a primary combustion zone 26 of the boiler 12. The remaining coal (or fuel) is injected downstream into the reburn zone 28 through the reburn injectors 18 to provide fuel-rich combustion in the reburn zone 28.[792]

A POSITA would have understood that burning coal in the reburn zone is a technique in which a portion of pulverized coal that is normally burnt as primary fuel is first partially burned and then injected into a second combustion zone, in the

[790] EX1014 (Lissianski) at Abstract, 4:14-29, Figs. 1-2.

[791] EX1014 (Lissianski) at 3:42-47.

[792] EX1014 (Lissianski) at 4:5-9; *see also* EX1014 (Lissianski) at 4:43-69 (discussing reburn system).

upper part of the boiler. This allows the reburn coal to react with unburned materials from the primary burn and associated NOx, and helps reduce overall NOx emissions from the power plant.

469. The halogen agent mixes with the primary coal and reburn coal, because the injectors are specifically designed to ensure thorough mixing between coal and additive:

> The halogen additive can be co-injected with air, recycled flue gas, nitrogen or another carrier gas to increase the penetration of the additive …

In either case, the halogen agent (additive) is in a mixture with coal.

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

470. Lissianski discloses "mercury removal by activated carbon injection."[793] Activated carbon is a particulate sorbent material. A POSITA would have understood, and at the very least found it obvious, that the active carbon injection occurs into the mercury-containing gas, downstream of the combustion chamber. For instance, a POSITA would have understood, as taught by Lissianski, that the activated carbon is used to adsorb mercury in the flue gas after that mercury

[793] EX1014 (Lissianski) at 3:21-22; *see* EX1014 (Lisskanski) at 3:45-49, cl. 7.

has been oxidized by the halogen additive.[794] A POSITA would have further understood, and at the very least found it obvious, that the activated carbon would have been injected at a later (cooler) point in the mercury-containing flue gas than the halogen additive, because a temperature of 1600-2300ºF where the halogen additive is added is above the flash point of activated carbon, and would combust the activated carbon (making it unavailable to adsorb anything).[795]

471. Thus, Lissianski discloses the need for a dry-emission control system that works using sorbent including activated carbon to collect the mercury. However, Lissianski 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,[796] a POSITA would have readily understood how to add the activated-carbon sorbent to the system, namely by injection into the mercury-containing flue gas between the combustion chamber and the PCD (such as the ESP or fabric filter). Starns and Mass-EPA each provides these details, and a POSITA would have been motivated

[794] EX1014 (Lissianski) at 3:42-49.

[795] EX1014 (Lissianski) at 4:17-19.

[796] State of the Art, §IX.C.

to combine Lissianski with Starns (Ground A5) and Lissianski with Starns (Ground A6), as discussed in the Reasons to Combine section.

i. Ground A5 (Combination of Lissianski with Starns)

472. 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."[797] Starns provides "injection equipment" that includes a "bulk-storage silo and twin blower/feeder trains ...."[798] The silo is shown below:[799]

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

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

[799] 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…."[800] A "powdered" activated carbon is a particulate sorbent material.

ii. Ground A6 (Combination of Lissianski with Mass-EPA)

473. 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

[800] EX1008 (Starns) at 9.

> there have been full-scale tests of this technology that have generated promising results.[801]
>
> 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. [802]
>
> 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.[803]
>
> 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.[804]

A "powdered" activated carbon is a particulate sorbent material. Mass-EPA describes that the activated-carbon sorbent is injected downstream of the combustion chamber, in that it repeatedly refers to the activated-carbon injection as "post combustion pollution control."[805] For example, Mass-EPA states:

> Post-combustion, flue gas technologies employ three basic methods to capture mercury:

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

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

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

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

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

> 1) capture of particulate-bound mercury in particulate matter control devices;
>
> 2) adsorption of elemental and oxidized mercury onto sorbents for subsequent capture in particulate matter control devices; and
>
> 3) removal of soluble oxidized mercury in wet scrubbers (including processes to convert elemental to oxidized mercury for subsequent capture in wet scrubbers).[806]

Mass-EPA explains that the activated carbon is "injected." Mass-EPA discloses "activated carbon injection" in numerous other places.[807]

4. Claim 1: Element 1(c)—"wherein a weight ratio of the additive added to the coal, added to the combustion chamber, or a combination thereof, to an amount of the sorbent material added to the mercury-containing gas is from about 1:100 to about 30:100;"

474. This claim element is disclosed by the combination of Lissianski with Starns (Ground A5) and the combination of Lissianski with Mass-EPA (Ground 6). Lissianski teaches supplying aqueous NH_4Br, NH_4I, or NH_4Cl into the combustion chamber.[808] A POSITA would have recognized that NH_4Br, NH_4I, and NH_4Cl were highly soluble in water, such that in aqueous solution, the ammonium iodide would have been present as NH_4^+ cations and I^- anions, the ammonium bromide would have

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

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

[808] EX1014 (Lissianski) at 3:59-60, 4:15-16, 4:37-40.

been present as NH_4^+ cations and Br^- anions, and the ammonium chloride would have been present as NH_4^+ cations and Cl^- anions. Lissianski discloses introducing the ammonium halide solutions into the combustion chamber at a temperature of 1600-2300 ºF.[809] At this temperature, the spray droplets simply evaporate to release the halogen species into the Hg containing gas.[810]

475. Lissianski discloses supplying such halogen additives into the mercury-containing gas to provide halogen concentrations in the flue gas of 0.3 ppm and 3 ppm (parts per million).[811] Lissianski discloses modeling at 0.3 and 3 ppm specifically for bromine and chlorine, respectively, though suggests the model also applies for the iodine-containing materials.[812] A POSITA would have understood based on the teaching of Lissianski that "bromine containing compounds are stronger oxidizing agents than are chlorine containing compounds" and that "iodine containing compounds" would "also [] be strong mercury oxidizing additives," and that such iodide compounds would be added in similar concentrations to bromine to

[809] EX1014 (Lissianski) at Abstract, 2:7-10, 3:51-57, 4:14-19.

[810] EX1014 (Lissianski) at 6:57-7:6.

[811] EX1014 (Lissianski) at 6:62-67.

[812] EX1014 (Lissianski) at 6:62-67.

achieve similar oxidation levels.[813] As I describe below, a POSITA would have been motivated to select the 3 ppm value for halogen-additive concentration, at least as a starting point.

476. Throughout the reference, Lissianski discusses the need to oxidize mercury.[814] Given that Lissianski states that he expects "the injection of chlorine or bromine in the amount of 3 ppm results in mercury oxidation at higher temperatures,"[815] a POSITA would have been motivated to choose the 3.0 ppm concentrations for the halogens. In general, and as shown in Lissianski's proposed model in Figure 9, injecting halogens at higher concentrations offsets the lack of Hg oxidation at hotter temperatures (i.e., as Hg tends to oxidize more at lower temperatures). In other words, the fraction of oxidized mercury (i.e., as compared to oxidized mercury plus elemental mercury) increases with increasing halogen concentration, but decreases with increasing temperature. Flue gas with Hg leaves furnaces at around 1000ºC (1800ºF)[816], and this temperature is otherwise too hot for Hg oxidation. Beyond the furnace exit, the flue gas cools as it moves through the

[813] EX1014 (Lissianski) at 6:57-7:6, 7:1-6, Fig. 9

[814] EX1014 (Lissianski) at Abstract, 1:14-51, 2:2-13, 3:12-50, 6:53-7:6, claim 1.

[815] EX1014 (Lissianski) at 6:62-64.

[816] EX1014 (Lissianski) at 3:51-58 (describing "flue gas temperatures in a range of 1600ºF … to 2300 ºF").

economizer heat exchanger and eventually reaches a temperature that sustains Hg oxidation. The temperature at which Hg oxidation becomes more favorable (as compared to remaining in elemental state) is determined by the rate of Hg oxidation and, in turn, this rate is directly proportional to the halogen-additive concentration. Since the initiation of Hg oxidation can be associated with a threshold value for the Hg oxidation rate, and since that rate is proportional to the additive concentration, higher additive concentrations will exceed the rate threshold at hotter temperatures than lower concentrations. In other words, higher additive concentrations sustain Hg oxidation at hotter temperatures than lower concentrations. Therefore, when presented with the 0.3 ppm option and 3 ppm option of Lissianski, a POSITA would have been led to select the 3 ppm halogen-additive concentration, at least as a starting point for further research.[817]

477. Lissianski describes that activated-carbon is used (as discussed for Element 1(b)), but Lissianski does not expressly state the injection rate of activated carbon into the system downstream of the combustion chamber. As described

[817] This 3 ppm concentration of halogen-containing additive represents the quantity of ammonium halide (e.g., NH_4Cl, NH_4Br, and/or NH_4I) added to the combustion chamber, because Lissianski discloses that its process is well-suited for coals with low native levels of halogens. EX1014, 1:53-67.

above,[818] it was routine in the industry to use injection rates of activated carbon of around 10 pounds/MMacf (million actual cubic feet of flue gas) to capture mercury.

478. This injection rate is further confirmed in Ground A5, as this is the value that Starns uses to obtain maximum mercury removal:

> Effective mercury removal between 40 – 50% was obtained at 1 lb/MMacf.
>
> Effective mercury removal between 50 – 60% was obtained at 3 lb/MMacf.
>
> Effective mercury removal between 60 – 70% was obtained at 10 lb/MMacf.[819]

This injection rate is also confirmed in Ground A6, as Mass-EPA also discloses sorbent injection rates at 10 lbs/MMacf.[820]

479. Regarding Ground A5 and Ground A6, based on the data presented by Lissianski of 3.0 ppm halogen agent in the flue gas, and a standard and well-known injection rate of activated carbon of 10 pounds/MMacf (as described in Starns and in Mass-EPA), a person of ordinary skill in the art would have used, or at least tried adding 7.9 grams ammonium iodide per 100 grams of sorbent, 5.4 grams ammonium

[818] *See* Technology Background and State of the Art, IX.C.5.

[819] EX1008 (Starns) at 20.

[820] EX1009 (Mass-EPA) at 73 (Brayton Point testing); p. 12 (Chart 2, showing Gaston, Brayton Point, and Pleasant Prairie).

bromide per 100 grams of sorbent, and/or 2.9 grams of ammonium chloride per 100 grams of activated carbon. I explain my calculations below.

480. In order to determine a ratio of halogen added to the coal and/or the combustion chamber to activated carbon sorbent in the flue gas, the concentrations must have the same units. Converting between ppm (rate of I, Br, and/or Cl addition, per Lissianski) and pounds/MACF[821] (sorbent injection rate, per Starns and Mass-EPA) would have been routine to a POSITA. In this case, converting both values to a grams/MACF basis is the most convenient for comparison, and requires the fewest assumptions (the only assumptions being the flue-gas pressure). Such a routine conversion of units would have involved such basic concepts as the ideal gas law (to convert concentrations between temperatures and pressures), which was taught in first semester undergraduate chemistry to a person of skill in the art. Such a unit conversion would have also involved basic engineering knowledge of a power-plant operation, such as a typical flue gas pressure. This would have been well-known to a POSITA.

481. A POSITA would have understood from the ideal gas law that the density of a gas is proportional to pressure and inversely proportional to temperature.

[821] "Mmacf" and "MACF" are used interchangeably, and the terms mean the same thing.

A POSITA would also have known that a typical flue gas temperature where sorbent would be injected is 290 ºF (416 K) and also 1 atm of pressure. Indeed, Starns teaches 290 ºF as the average injection temperature for the sorbent,[822] and Lissianski discloses this temperature.[823] Mass-EPA also discloses "flue gas temperatures range from 284 to 320ºF (140 to 160°C)."[824] Last, a POSITA would have found in readily available tables of unit conversions and/or basic chemistry books the following constants:

- 1 Actual Cubic Feet (ACF) = 1 ft^3 = 28.3168 L.
- 1 MACF = 10^6 ACF
- Universal gas constant (R) = 0.082058 (L*atm) / (mol*K)
- Molecular weight of NH_4I = 144.94 g/mol
- Molecular weight of NH_4Br = 97.94 g/mol
- Molecular weight of NH_4Cl = 53.49 g/mol

482. Based on the above constants and relationships, the concentration of activated carbon sorbent in the flue gas from Starns and Mass-EPA can be calculated in grams as:

[822] EX1008 (Starns) at 1.

[823] EX1014 (Lissianski) at Fig. 9.

[824] EX1009 (Mass-EPA) at 26.

$$\frac{10\ pounds\ PAC}{MACF} \times \frac{453.592\ grams}{pound} = 4{,}535.92 \frac{grams\ PAC}{MACF}$$

Further, the concentration of ammonium halide injected into the combustion chamber can be calculated as follows (for the example of ammonium iodide):

$$\frac{3.0\ mol\ I\ in\ flue\ gas}{10^6\ mol\ flue\ gas} \times \frac{1\ mol\ NH_4I\ added\ to\ chamber}{1\ mol\ I\ in\ flue\ gas} \times \left(\frac{144.94\ g\ NH_4I}{1\ mol\ NH_4I}\right)$$

$$= 4.34 \text{ x } 10^{-4} \frac{g\ NH_4I\ added\ to\ chamber}{mol\ flue\ gas}$$

Thus, for every 1 mole of mercury-containing flue gas, there were 4.34 x 10^{-4} grams of ammonium iodide added to the combustion chamber. A POSITA would have readily been able to convert the flue gas, described in Starns and Mass-EPA, from a molar basis (mol) to an actual volumetric basis (ACF) as follows:

$$\frac{ACF\ flue\ gas}{mol\ flue\ gas} = \frac{(416\ K) \times \left(0.082058 \frac{L\ atm}{mol\ K}\right) \times \frac{1 ACF}{28.3\ L}}{1\ atm}$$

$$= \frac{1.206\ ACF\ flue\ gas}{mol\ flue\ gas}$$

Combining the above equations to calculate the grams ammonium iodide per MACF flue gas:

$$4.34 \times\ 10^{-4} \frac{g\ NH4I}{mol\ flue\ gas} \times \frac{1\ mol\ flue\ gas}{1.206\ ACF} \times \frac{10^6 ACF}{MACF}$$

$$= 361\ \frac{g\ NH_4I\ added\ to\ chamber}{MACF\ flue\ gas}$$

483. Thus, when comparing the application rate of the ammonium iodide described by Lissianski (3.0 ppm NH_4I, which is 361 g NH_4I/MACF), and the

injection rate of the sorbent described by Starns (10 lb/MACF, which is 4,536 g/MACF), there are 7.9 grams of ammonium iodide (NH_4I) added to the combustion chamber per 100 grams of activated carbon sorbent injected into the flue gas. This is within the claimed ratio of 1:100 to 30:100.

484. Given a molecular weight for NH_4Br of 97.94 g/mol, and under the same circumstances described above, this ratio would be 5.4 grams of ammonium bromide (NH_4Br) per 100 grams of activated carbon. Likewise, given the molecular weight for NH_4Cl of 53.49 g/mol, the ratio would be 2.9 grams of ammonium chloride per 100 grams of activated carbon. Each of these numbers are within the claimed range of 1:100 to 30:100.

485. It would have been obvious to try other ratios, such as by increasing the halogen concentration (while reducing the activated carbon injection), or decreasing the halogen concentration (while increasing the active carbon injection) as part of routine process optimization to achieve the desired mercury removal. Claim Element 1(c) is merely an attempt to claim a broad workable range for combining a conventional halogen (bromine, iodine, chlorine) being used in a conventional way with a conventional sorbent (to oxidize mercury and promote activated carbon). Nothing in the ’370 Patent specification attributes significance to the claimed range, or establishes that the claimed range achieves unexpected results. The range presents nothing more than optimization of result-effective variables that would have

been obvious to a POSITA. Patent Owner's expert in the Delaware litigation involving patents related to the '370 Patent stated that "power plants employing bromine additives and activated carbon would necessarily produce a sorbent that is 1 g to 30 g bromine per 100 g of activated carbon."[825] He further cited to this analysis for a claim that requires "the mercury-containing gas comprises about 1 g to about 30 g of the element bromine per 100 g of the sorbent."[826]

5. Claim 1: Element 1(d)—"contacting mercury in the mercury-containing gas with the sorbent material, to form a mercury-sorbent; and"

486. Lissianski discloses this claim element. Lissianski discloses "adsorbing the oxidized mercury generated by the combustion of the coal with an adsorbent in the flue gas."[827] Lissianski further describes that "[o]xidized mercury … is water soluble and is easily adsorbed on high carbon fly ash or activated carbon."[828] The "adsorbing" process that Lissianski describes refers to a process by which adsorbate (e.g., atoms, ions, or molecules) in a fluid (typically a gas) are bound to the surface

[825] EX1092 (O'Keefe Report) at 153 (cl. 4).

[826] EX1092 (O'Keefe Report) at 154 (cl. 29).

[827] EX1014 (Lissianski) at 2:10-12.

[828] EX1014 (Lissianski) at 1:35-36.

of a sorbent, and thus by definition the sorbent is "contacting mercury in the mercury-containing gas" and forming a mercury-sorbent composition.

487. This is also confirmed by Starns (Ground A5): 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."[829]

488. This is further confirmed by Mass-EPA (Ground A6), in that "[m]ass transfer refers to the ability of the sorbent particles to contact the Hg in the flue gas."[830]

6. Claim 1: Element 1(e)—"separating the mercury-sorbent from the mercury-containing gas."

489. Lissianski discloses this claim element. Lissianski discloses "collecting the adsorbent with the oxidized mercury in a combustion waste treatment system."[831] Indeed, as described by Lissianski, it was well known that "volatized mercury can be captured by coal fly ash and removed via a particulate collection system."[832]

[829] EX1008 (Starns) at 2 (Introduction).

[830] EX1009 (Mass-EPA) p. 21 n.25; *see also* EX1009 (Mass-EPA) p. 33 ("time available for the mercury to contact the AC [activated carbon] particle").

[831] EX1014 (Lissianski) at 2:13-14.

[832] EX1014 (Lissianski) at 1:15-17; *see* EX1014 (Lissianski) at 1:37-38.

Lissianski discloses such a particulate collection system as PCD **32** in, for example, Figures 1-2 shown below.

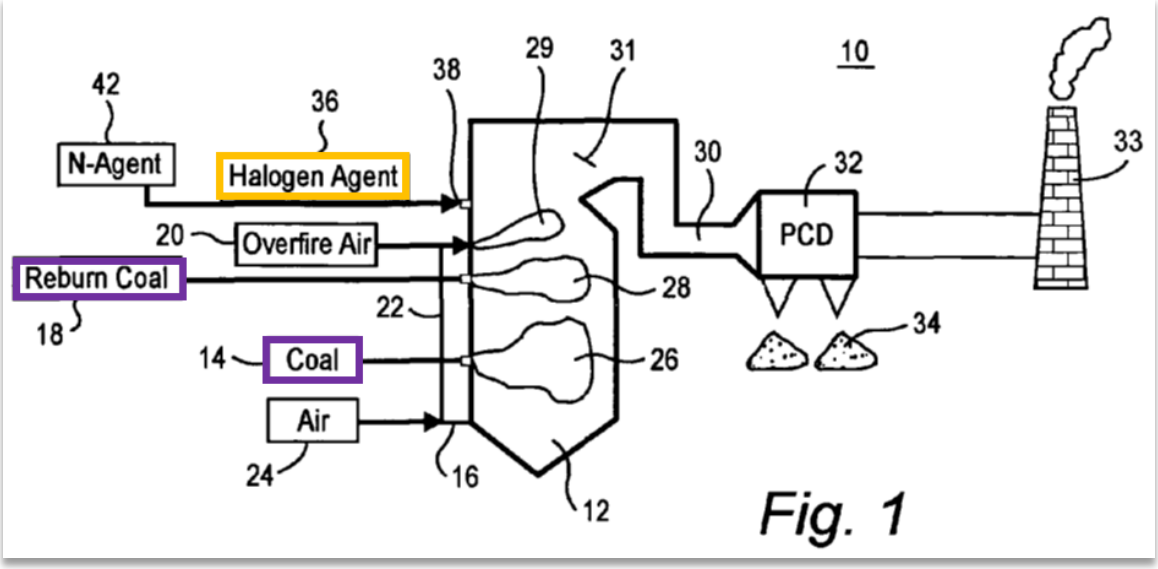


Fig. 1

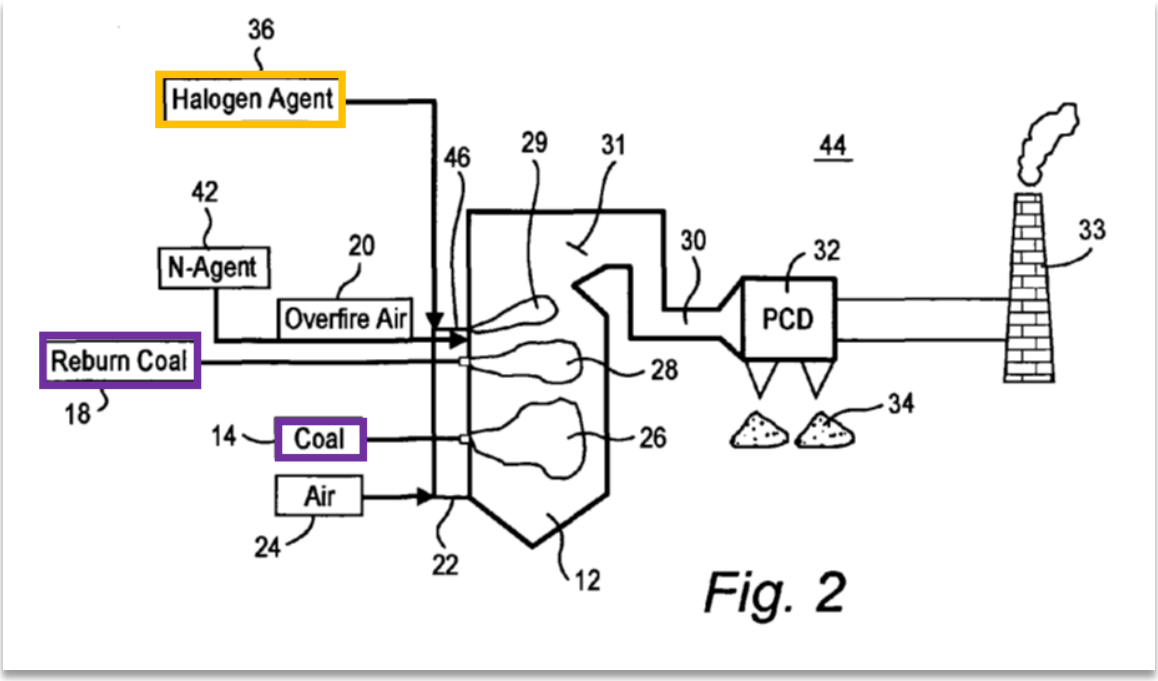


Fig. 2

490. This limitation is also disclosed by the combination of Lissianski with Starns (Ground A5): The particle control devices (PCD) in Starns includes an

electrostatic precipitator (ESP), and Starns recommends "using activated carbon injection upstream of an ESP."[833] It is a mercury-sorbent composition that is removed, because through the "injection of sorbents such as powdered activated carbon (PAC) into the flue gas upstream of the particle control equipment," the "gas-phase mercury in the flue gas contacts the sorbent and attaches to its surface."[834] A POSITA would have been motivated, as Starns suggests, to use activated carbon injection between the combustion chamber (furnace) of Lissianski and the ESP or fabric filter disclosed by Starns, which are examples of the particle collection device (PCD) 32 of Lissianski.[835] Each of these were well-known components in coal-fired power plants to remove particulate matter (such as the mercury-sorbent composition in Lissianski and Starns), as I describe above in the Technology Background and State of the Art section ("Particulate Matter Emissions Controls"). Further, to be effective, the injection must happen after the combustion zone (where the mercury-containing flue gas is generated) and before the separation system (where the sorbent is removed). The mercury-sorbent composition is separated from the mercury-

[833] EX1008 (Starns) at 20.

[834] EX1008 (Starns) at 2.

[835] EX1014 (Lissianski) at 4:3-5. Figs. 1-3.

containing gas by particulate control devices, such as the electrostatic precipitators (ESP) in Starns, to form a cleaned gas.

491. This limitation is also disclosed by the combination of Lissianski with Mass-EPA (Ground A6): "The particulate-bound form of mercury can be readily captured in the particulate matter (PM) control devices, i.e., electrostatic precipitators (ESPs) and fabric filters (FFs)."[836] The "particulate-bound form of mercury" refers to the mercury adsorbed onto the activated-carbon sorbent, i.e., a mercury-sorbent composition. Mass-EPA continues, "An ESP or a FF is always installed downstream of a semi-dry scrubber or dry injection point to remove the sorbent from the flue gas."[837] A POSITA would have been motivated, as Mass-EPA suggests, to use activated carbon injection between the combustion chamber (furnace) of Lissianski and the ESP or fabric filter in Mass-EPA, which are examples of the particle collection device (PCD) 32 of Lissianski.[838] Each of these were well-known components in coal-fired power plants to remove particulate matter (such as the mercury-sorbent composition in Lissianski and Mass-EPA), as I describe above in the Technology Background and State of the Art section ("Particulate Matter

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

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

[838] EX1014 (Lissianski) at 4:3-5. Figs. 1-3.

Emissions Controls"). Further, to be effective, the injection must happen after the combustion zone (where the mercury-containing flue gas is generated) and before the separation system (where the sorbent is removed). The mercury-sorbent composition is separated from the mercury-containing gas by particulate control devices, such as the electrostatic precipitators (ESP) and fabric filters and in Mass-EPA, to form a cleaned gas.

D. CLAIMS DEPENDING FROM CLAIM 1

1. Claim 5: The method of claim 1, wherein carbocations in the activated carbon of the mercury-sorbent accept electrons from mercury atoms of the mercury-sorbent.

492. According to Patent Owner's expert in the Delaware litigation, this chemical reaction takes place between the activated carbon and mercury.[839]

2. Claim 6: "The method of claim 1, wherein the additive is substantially in vapor form in the mercury-containing gas."

493. Claim 6 is disclosed by Lissianski. As discussed above for Claim Element 1(a), Lissianski discloses adding aqueous salt solutions of ammonium halides. Lissianski further discloses that "halogen containing additive is injected where the flue gas is in a temperature range of 1600 ºF to 2300 ºF."[840] At this high of a temperature, the ammonium halides "thermally decompose" in the "hot flue

[839] EX1092 (O'Keefe Report) p. 160 ('147 Patent Claim 1c)..

[840] EX1014 (Lissianski) at cl. 7, 4:17-19.

gas" and the additive is in vapor form.[841] Additive solutions containing NH_4 cations and halogen anions will vaporize at temperatures that are only slightly above the boiling point of water, which is very much cooler than Lissianski's injection location. Both ions will decompose in the vapor phase into even lighter species such as hydrohalides (HCl, HBr, HI), halogen atoms (Cl, Br, I), and molecular halogens (Cl_2, Br_2, I_2) and ammonia (NH_3) and other amine species (NH_2, NH). Due to their excessive volatilities, all of these smaller atoms and molecular fragments can only exist in the vapor phase at the temperatures of Lissianski's injection location.

3. Claim 11: "The method of claim 1, wherein the activated carbon is chosen from powdered activated carbon, granular activated carbon, carbon black, carbon fiber, aerogel carbon, pyrolysis char, and combinations thereof."

494. Claim 11 would have been obvious over the combination of Lissianski in view of Starns (Ground A5) and the combination of Vosteen589 and Mass-EPA (Ground A6). Lissianski discloses "activated carbon."[842] A POSITA would have understood that this is a shorter form of stating "powdered activated carbon."

495. For Ground A5, the activated carbon injected by Starns is "powdered activated carbon," which is also abbreviated as "PAC": "The most mature, retrofit

[841] EX1014 (Lissianski) at 3:42-47; EX1014 (Lissianski) at 4:23 ("mixing of the additive aqueous solution and flue gas").

[842] EX1014 (Lissianski) at 3:20-24, 3:47-50, cl. 7.

technology available today is the injection of sorbents such as powdered activated carbon (PAC) into the flue gas upstream of the particle control equipment."[843] For Ground A6, 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."[844]

4. Claim 12: "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."

496. Claim 12 would have been obvious over the combination of Lissianski in view of Mass-EPA (Ground A6). With respect to Ground A6, 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.[845]

[843] EX1008 (Starns) at 2.

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

[845] 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. [846]
>
> 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.[847]

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.

5. Claim 14: "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."

497. Claim 14 would have been obvious over the combination of Lissianski in view of Mass-EPA (Ground A6). Mass-EPA discloses injecting "[m]odified activated carbons (i.e., doped with sulfur, iron, chlorine, and iodine)."[848] The

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

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

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

modified activated carbons "doped with" chlorine and iodine renders obvious that the sorbent material that has been contacted with chlorine and iodine (i.e., halogens).

6. Claim 15: "The method of claim 14, wherein the secondary component is chosen from halogens, halide salts, HI, HBr, HCl, and combinations thereof."

498. The claim is obvious over the combination of Lissianski in view of Mass-EPA (Ground A6), which co-injects activated carbon "doped with" chlorine and iodine.[849] Both chlorine and iodine are halogens.

7. Claim 16: "The method of claim 14, wherein the secondary component is chosen from I_2, HI, and combinations thereof."

499. The claim is obvious over the combination of Lissianski in view of Mass-EPA (Ground A6), which co-injects activated carbon "doped with" chlorine and iodine.[850] A POSITA would recognize that "iodine" by itself refers to molecular iodine (I_2).

XVI. GROUND B1: ANTICIPATION BY BALDREY

500. Because the priority date of the '370 Patent is no earlier than April 2018, Baldrey (published 2011) qualifies as a prior art anticipatory reference.

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

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

A. INDEPENDENT CLAIM 1

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

501. The preamble is disclosed by Baldrey. Baldrey relates to "additives for coal-fired power plants and particularly to additives for mercury removal."[851] Baldrey discloses that "the additive of the present invention is believed to promote mercury oxidation and sorption by enrichment of transition metal catalysts in the fly ash or on suitable mercury sorbents that are injected and captured with the fly ash."[852] Baldrey teaches that the "oxidized mercury can [] bind to surface sites within the fly ash or to activated carbon or LOI carbon within the fly ash layer."[853] Baldrey explains that the result is that "[m]ost of the oxidized mercury and excess halogens are absorbed by the fly ash and/or mercury sorbent of the third formulation and is therefore removed by the device 232."[854] Baldrey's method for separating mercury from a mercury-containing gas is shown in Figure 2 below:[855]

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[851] EX1015 (Baldrey), ¶[0002]; *see also* EX1015 (Baldrey), ¶¶[0031], [0069] (separating mercury by "bind[ing] it to surface sites" of "suitable mercury sorbents").

[852] EX1015 (Baldrey), ¶[0031].

[853] EX1015 (Baldrey), ¶[0069].

[854] EX1015 (Baldrey), ¶[0085].

[855] EX1015 (Baldrey) at Fig. 2.

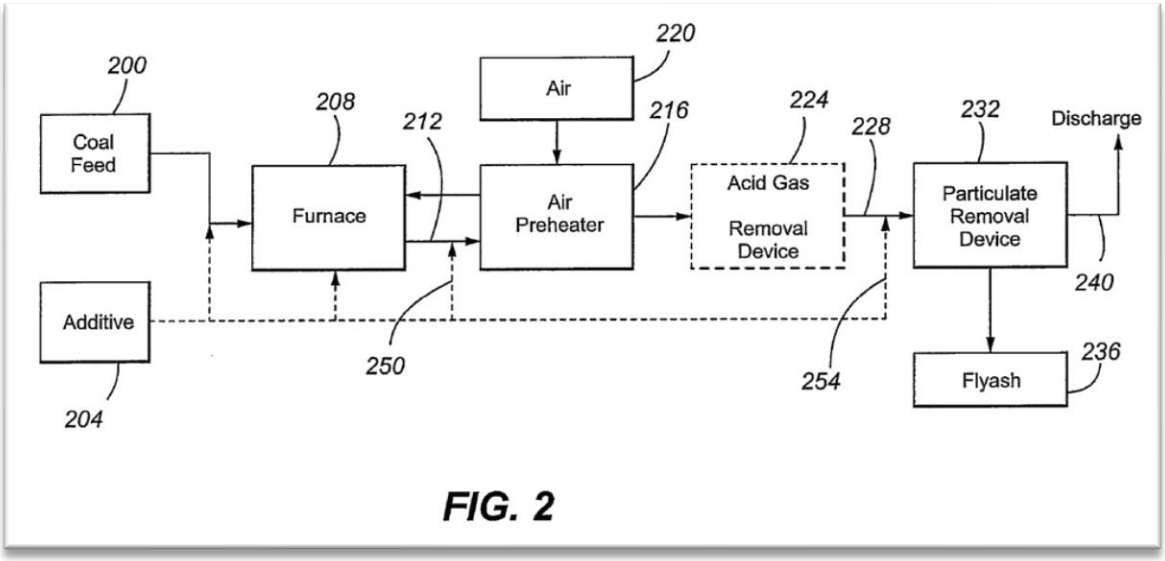


FIG. 2

2. Claim 1: Element 1(a)—"combusting a mixture of coal and an additive in a combustion chamber, to form the mercury-containing gas, wherein the additive is chosen from halides, halogens, salts thereof, and combinations thereof;"

502. Claim Element 1(a) is disclosed by Baldrey. Baldrey explains that "[m]ercury in coal is vaporized in the combustion zone and exits the high temperature region of the boiler entirely as Hg^0."[856] Baldrey depicts the process of adding the coal **200** to the furnace **218**, a combustion chamber, and thereby combusting coal to form mercury-containing flue gas **212**:[857]

[856] EX1015 (Baldrey), ¶[0004].

[857] EX1015 (Baldrey) at Fig.2; *see also* EX1015 (Baldrey), ¶¶[0079]-[0088].

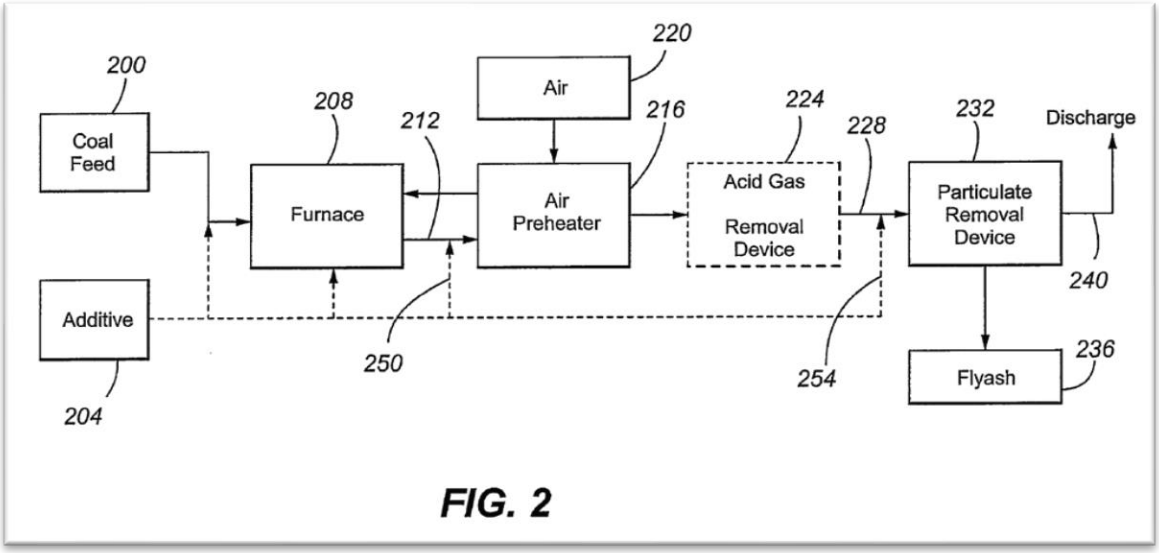


FIG. 2

503. As shown above in Figure 2 and below in Figure 3, Baldrey also discloses mixing the coal ("Coal Feed 200") with an additive ("Additive 204") before the coal enters the combustion chamber and/or in the combustion chamber itself.[858]

[858] EX1015 (Baldrey) at Figs. 2-3; *see also* EX1015 (Baldrey), ¶[0089], cl. 29 ("coal feed is contacted with the added halogen-containing compound before introduction of the coal feed to the furnace").

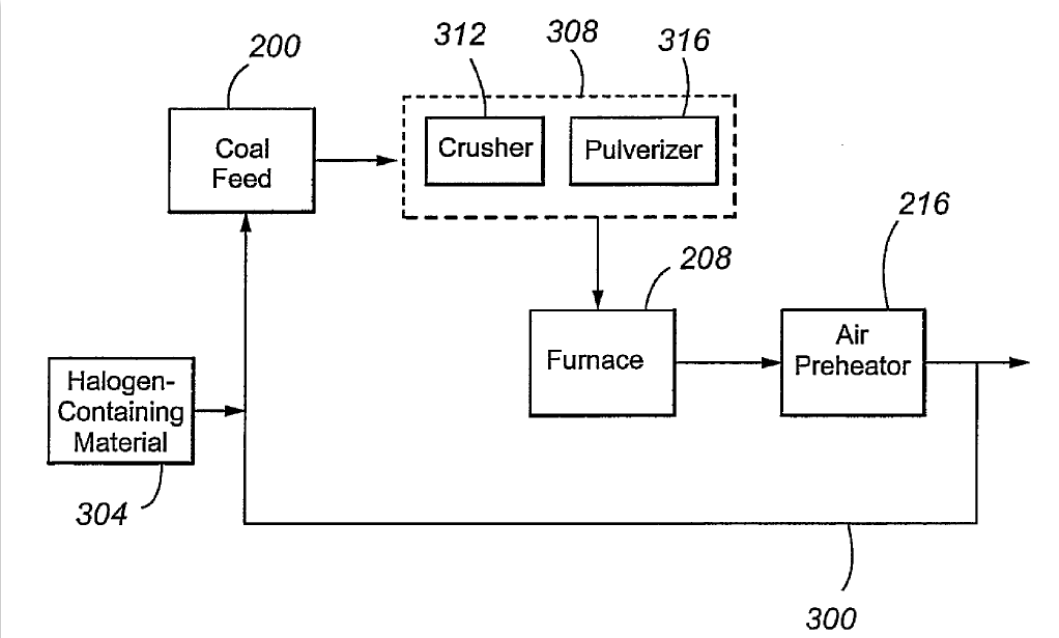


FIG. 3

Baldrey discloses that "the additive includes … one or more diatomic halogens (e.g., Cl_2 and Br_2), interhalogen compounds (e.g., BrCl), and halide salts to act as elemental mercury oxidants."[859] Baldrey identifies several other chlorine-containing, bromine-containing, and iodine-containing salts:

> Preferred supplemental halide salts are calcium chloride ($CaCl_2$), iron (III) chloride ($FeCl_3$), copper (II) chloride ($CuCl_2$), magnesium bromide ($MgBr_2$), calcium bromide, sodium bromide, potassium iodide, and also the hydrated states of these halide salts.[860]

[859] EX1015 (Baldrey), ¶[0070]; *see also* EX1015 (Baldrey), ¶¶[0006], [0096].

[860] EX1015 (Baldrey), ¶[0070].

Baldrey further teaches that "[s]upplemental halogen addition" occurs "either with the coal or downstream in the mercury-oxidation region."[861]

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

504. Claim Element 1(b) is disclosed by Baldrey. Baldrey discloses "activated carbon injection into coal-fired flue ducts."[862] The activated-carbon sorbent is added to the mercury-containing gas, downstream of the combustion chamber, "at either of locations 250 and 254 for plants with no FGD scrubbing or at location 254 for plants with SDA followed by particulate control device (FF or cold-side ESP)," as shown in Figure 2 below:[863]

[861] EX1015 (Baldrey), ¶[0031].

[862] EX1015 (Baldrey), ¶¶[0071]; *see also* EX1015 (Baldrey), ¶¶[0068]-[0069], [0097], [0105]-[0106] (further disclosure of "activated carbon").

[863] EX1015 (Baldrey), ¶[0106], Fig. 2.

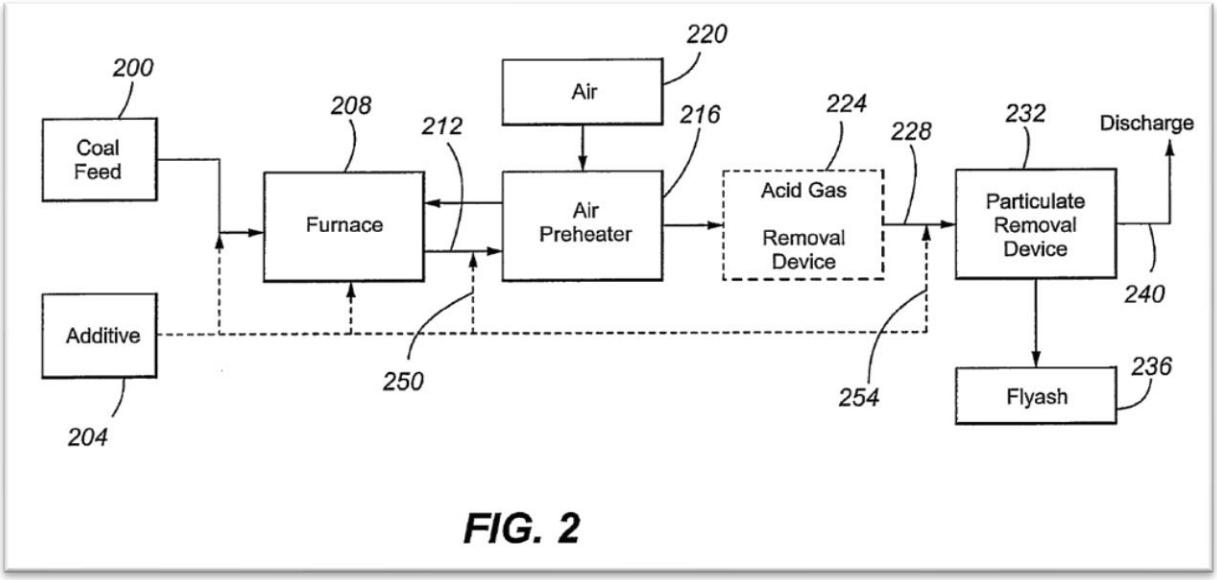


FIG. 2

4. Claim 1: Element 1(c)—"wherein a weight ratio of the additive added to the coal, added to the combustion chamber, or a combination thereof, to an amount of the sorbent material added to the mercury-containing gas is from about 1:100 to about 30:100;"

505. Baldrey discloses this claim element.

506. Baldrey describes the amount of halogens and halides that should be present as a weight percentage of the additive (i.e., how much halogens and halides are used, as compared to other components such as metal catalysts). Baldrey discloses that "the amounts of the additive metal and halogen in the additive depend on the natively occurring amounts of mercury, additive metal, and halogen in the coal," and that "[i]n the second formulation, the additive contains preferably . . . from about 0.1 to about 50 wt. % halogen, more preferably from about 0.5 to about 10 wt. % halogen, and even more preferably from about 0.5 to about 5.0 wt. %

halogen."[864] Baldrey further teaches that "[h]igher HCl concentrations are undesirable due to concerns with excessive corrosion of internal boiler tube and downstream duct structures" and that "it is desirable to maintain the concentration of HCl to a level less than that creating undesirable fouling or corrosion."[865] A person of ordinary skill would understand that such concerns also apply to other similarly corrosive halogen compounds in the flue gas, such as HBr and HI. A person of ordinary skill would have sought to optimize the concentration of the halogen in the additive to achieve the desired mercury removal in the flue without introduction of excess halogens. As such, a person of ordinary skill would have first selected the lower end of the preferred range of the halogen concentration in the additive disclosed by Baldrey (i.e., 0.5 wt. % halogen in the additive). The 0.5 wt % (fraction of halogens and halides within the total additive) is a data point expressly disclosed by Baldrey.

507. Baldrey also discusses the amount of total additive that should be used. Baldrey discloses that "the additive of the first and second formulations are preferably introduced at a concentration of from about 0.3 to about 100 lbs

[864] EX1015 (Baldrey), ¶[0073]. I note that Baldrey uses the term "additive" to refer to a mixture of "one or more additive metal catalysts" and halogen-containing materials (e.g., "Cl_2 and Br_2 … [and] halide salts"). EX1015 (Baldrey), ¶[0070].

[865] EX1015 (Baldrey), ¶¶[0095], [0097].

additive/Mmacf in the flue gas or in an amount ranging from about 0.1 to about 3.0% by weight of the coal feed 200, with from about 0.5 to about 1.5% being preferred."[866] Baldrey's additive is designed to lower Hg emissions by containing halogens that promote Hg oxidation and thereby enhance Hg capture on activated carbon sorbents. But this is not its only purpose. The additive is also designed to control slag viscosity in cyclone-fired furnaces by containing selected iron compounds. Since these furnaces manage slag loadings of 5 – 15 % of the coal feed, and since Hg in coal is in the ppb-range, the additive must contain much more iron than halogens. This is why, for most additive formulations, the upper additive concentration of 100 lbs additive/Mmacf will be required (of which only a small percentage by weight is halogen, such as 0.5% halogens), instead of the much lower amount needed to exclusively regulate Hg emissions. Given this disparity, a person of skill in the art would have first implemented Baldrey's disclosed additive concentration of 100 lbs additive/Mmacf, and then reduced the concentration based on tendencies in the performance. The data point of 100 pounds total additive per Mmacf of flue gas is a data point expressly disclosed by Baldrey.

508. Baldrey also discloses that sorbent is introduced as a dry powder into the flue gas upstream of the particulate control

[866] EX1015 (Baldrey), ¶[0075].

device at a concentration of from about 0.1 to about 10.0 lbs sorbent/Mmacf in the flue gas."[867] A POSITA would have started with 10 pounds sorbent / Mmacf in the flue gas, because this was a widely reported value for sorbent concentrations.[868]

509. Based on three data points expressly disclosed by Baldrey, a POSITA would have been able to readily determine the weight ratio of the additive added to the coal or combustion chamber, as compared to the weight of sorbent added to the mercury-containing gas. These data points are: (i) weight ratio of halogens in the additive; (ii) weight ratio of additive in the flue gas; and (iii) weight ratio of sorbent in the flue gas. In order to determine a ratio of halogen-containing additive added to the coal and/or the combustion chamber to activated carbon sorbent in the flue gas, the concentrations must have the same units. Converting between these units as shown below would have been routine to a POSITA.

510. Based on the above disclosed concentrations, the concentration of halogen added to the coal and/or the combustion chamber can be calculated as follows:

$$\frac{0.5\ pounds\ Halogen}{100\ pounds\ Additive} \times \frac{100\ pounds\ Additive}{MMACF\ Flue\ Gas} = \frac{0.5\ pounds\ Halogen}{MMACF\ Flue\ Gas}$$

[867] EX1015 (Baldrey) ¶[0075].

[868] *See* Technology Background and State of the Art, IX.C.5.

Using the disclosed sorbent injection rate of 10 lbs sorbent/Mmacf discussed above, the weight ratio of the halogen added to the coal and/or the combustion chamber to the sorbent injected into the mercury-containing gas can then be calculated as follows:

$$\frac{0.5\ pounds\ Halogen}{MMACF\ Flue\ Gas} / \frac{10\ pounds\ Sorbent}{MMACF\ Flue\ Gas}$$

$$= 0.05\ \frac{pounds\ halogen\ additive}{pounds\ Sorbent}$$

Thus, there are 5 pounds halogen additive for every 100 pounds sorbent.

511. Thus, when comparing the application rate of the halogen additive described by Baldrey (0.5 lb Halogen/Mmacf), and the injection rate of the sorbent described by Baldrey (10 lb Sorbent/Mmacf), there are 5 pounds of halogen additive added to the coal and/or combustion chamber per 100 pounds of activated carbon sorbent injected into the flue gas. These numbers are within the range of from about 1 to about 30 pounds halogen additive per 100 pounds of the sorbent material injected into the flue gas recited in Claim Element 1(c). Thus, Baldrey discloses wherein a weight ratio of the additive added to the coal, added to the combustion chamber, or a combination thereof, to an amount of the sorbent material added to the mercury-containing gas is from about 1:100 to about 30:100.

512. Even if an intermediate value for the preferred halogen range of 2.5 wt. % halogen in the additive were selected, the weight ratio of 25:100 halogen to sorbent would still disclose the range claimed by Claim Element 1(c).

513. Patent Owner's expert in the Delaware litigation involving patents related to the '370 Patent stated that "power plants employing bromine additives and activated carbon would necessarily produce a sorbent that is 1 g to 30 g bromine per 100 g of activated carbon."[869] He further cited to this analysis for a claim that requires "the mercury-containing gas comprises about 1 g to about 30 g of the element bromine per 100 g of the sorbent."[870]

5. Claim 1: Element 1(d)—"contacting mercury in the mercury-containing gas with the sorbent material, to form a mercury-sorbent; and"

514. Claim Element 1(d) is disclosed by Baldrey. Baldrey discloses that "oxidized mercury can [] bind to surface sites within the fly ash or to activated carbon or LOI carbon within the fly ash layer," and "[o]xidation and capture of the oxidized mercury are [] accomplished at the surface of the injected sorbent, generally

[869] EX1092 (O'Keefe Report) at 153(cl. 4).

[870] EX1092 (O'Keefe Report) at 154 (cl. 29).

powdered activated carbon."[871] To "bind" and "capture" the mercury at the surface of the sorbent requires contacting the mercury with the sorbent.

6. Claim 1: Element 1(e)—"separating the mercury-sorbent from the mercury-containing gas."

515. Claim Element 1(e) is disclosed by Baldrey. Baldrey discloses that "flue gas 228 is next passed through a particulate removal device 232, such as a fabric filter baghouse or cold-side electrostatic precipitator, to remove preferably most and more preferably substantially all of the particles, particularly fly ash 236 and sorbent (if any), in the flue gas."[872] The result is that "[m]ost of the oxidized mercury and excess halogens are absorbed by the fly ash and/or mercury sorbent of the third formulation and is therefore removed by the device 232."[873] Baldrey further teaches that "[t]he sorbent is co-precipitated with fly ash in an ESP or co-deposited onto the ash filter cake in a baghouse."[874] Baldrey depicts this process below:[875]

[871] EX1015 (Baldrey), ¶¶[0069], [0071].

[872] EX1015 (Baldrey), ¶[0085].

[873] EX1015 (Baldrey), ¶[0085].

[874] EX1015 (Baldrey), ¶[0071].

[875] EX1015 (Baldrey) at Fig. 2.

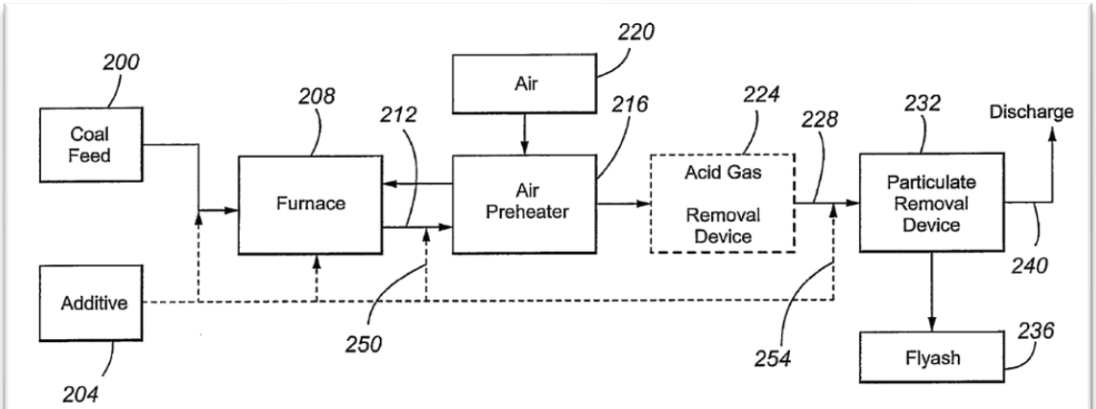


FIG. 2

B. CLAIMS DEPENDING FROM CLAIM 1

1. Claim 2: "The method of claim 1, further comprising adding the additive to the coal before combusting the coal."

516. Claim 2 is disclosed by Baldrey. As discussed for Claim Element 1(a) (and shown in Figure 2), the halogen-containing additive (204) is added to the coal (200) upstream of the combustion chamber (208).[876]

[876] EX1015 (Baldrey) at Fig. 2; *see also* EX1015 (Baldrey) ¶¶[0093], [0111], Fig. 3.

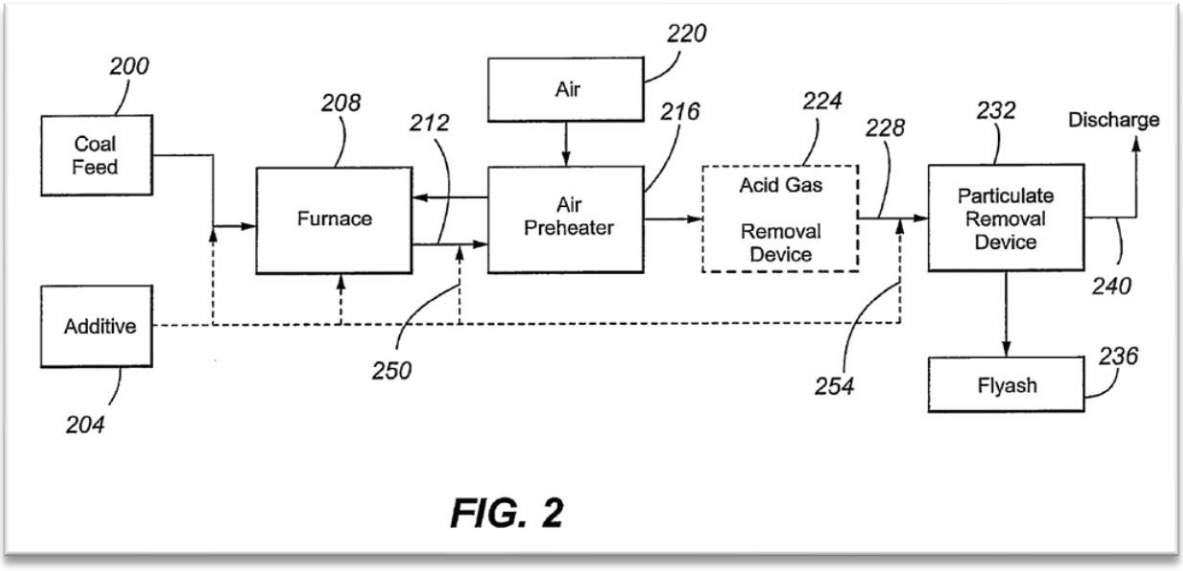


FIG. 2

This can be seen above where the additive arrow (dotted) combined with the coal feed arrow (solid). Baldrey further states that "coal feed is contacted with the added halogen-containing compound before introduction of the coal feed to the furnace."[877]

2. Claim 3: "The method of claim 2, wherein the additive mixed with the coal is in a liquid."

517. Claim 3 is disclosed by Baldrey. As discussed for Element 1(a), the additive includes halide salt solutions, such as "calcium chloride ($CaCl_2$), … magnesium bromide ($MgBr_2$), calcium bromide, sodium bromide, [and] potassium iodide."[878] Baldrey further teaches that "addition of the additive to the coal feed **200** or direct injection of the additive **200**, as a powdered solid or liquid

[877] EX1015 (Baldrey) at claim 29.

[878] EX1015 (Baldrey) at ¶[0070].

atomized solution containing the additive into the boiler via overfire air (OFA) ports, are preferred options," and also that "the halogen-containing material **304**, and optionally metal, is sprayed, in liquid form, into the redirected flue gas **300**," which then contacts "the coal feed **200**."[879] A liquid atomized solution of halide salt is salt solution.

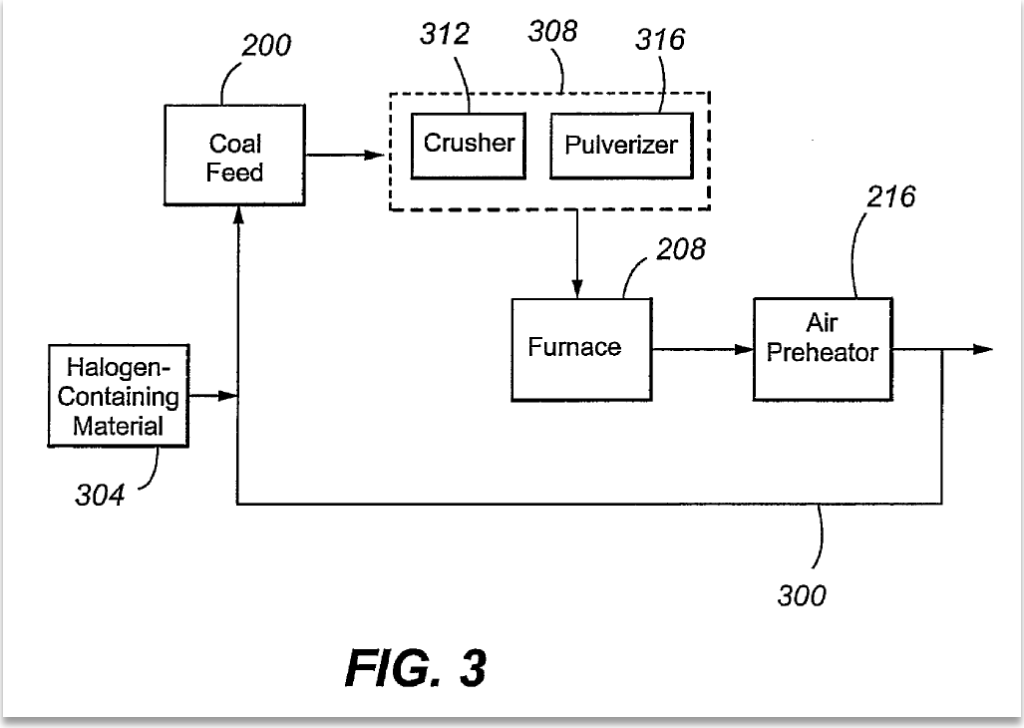


FIG. 3

3. Claim 4: "The method of claim 3, wherein the liquid is a hydrocarbon, supercritical carbon dioxide, water, salt solution, or a combination thereof."

518. Claim 4 is disclosed by Baldrey. As discussed above for Claim 3, the additive can be "in liquid form" which includes halide salt solutions.

[879] EX1015 (Baldrey) ¶¶[0093], [0111], Fig. 3.

4. Claim 6: "The method of claim 1, wherein the additive is substantially in vapor form in the mercury-containing gas."

519. Claim 6 is disclosed by Baldrey. Baldrey discloses that "[w]hen the coal feed is combusted, the halogen enters the vapor phase."[880] Baldrey further describes that the halogen-containing additive is in the vapor phase at the temperature in the flue gas:

> In the region upstream of location **250** and downstream of the furnace **208**, the flue gas or duct temperature ranges from about 470 to about 250° C. (880 to 480° F.), and the halogens are present primarily in the form of the hydrogen species, HCl, HBr and HI. Conversion of the hydrogen species to a mixture of vapor HCl, HBr, and HI, respectively, are substantially complete in the zone downstream of the economizer section.[881]

For example, Baldrey discloses that the additive may include "one or more diatomic halogens (e.g., Cl_2 and Br_2)."[882] The boiling point of Br_2 is only 58.8ºC (it is a fuming liquid at room temperature), and Cl_2 is a gas at room temperature, each of which are well below the temperatures disclosed by Baldrey.[883] Baldrey further

[880] EX1015 (Baldrey), ¶[0038].

[881] EX1015 (Baldrey), ¶[0101].

[882] EX1015 (Baldrey), ¶[0070].

[883] EX1036 (CRC Press: March 2005) at 4-53 and 6-86.

teaches that "at least most of the selected additive component decomposes into a vapor-phase element in the flue gas."[884]

5. Claim 7: "The method of claim 1, wherein the additive is chosen from Cl_2, HCl, sodium chloride, calcium chloride, and a combination thereof."

520. Claim 7 is disclosed by Baldrey. As discussed above for Element 1(a), Baldrey discloses that the additive includes "one or more diatomic halogens (e.g., Cl_2 and Br_2), interhalogen compounds (e.g., BrCl), and halide salts …. Preferred supplemental halide salts are calcium chloride ($CaCl_2$), … calcium bromide, sodium bromide, potassium iodide, and also the hydrated states of these halide salts."[885]

6. Claim 8: "The method of claim 1, wherein the additive is chosen from Br_2, HBr, sodium bromide, calcium bromide, and a combination thereof."

521. Claim 8 is disclosed by Baldrey. As discussed above for Element 1(a), Baldrey discloses that the additive includes "one or more diatomic halogens (e.g., Cl_2 and Br_2), interhalogen compounds (e.g., BrCl), and halide salts …. Preferred supplemental halide salts are calcium chloride ($CaCl_2$), … calcium bromide, sodium bromide, potassium iodide, and also the hydrated states of these halide salts.[886]

[884] EX1015 (Baldrey), ¶¶[0108]-[0109].

[885] EX1015 (Baldrey), ¶[0070].

[886] EX1015 (Baldrey), ¶[0070].

7. Claim 10: "The method of claim 1, wherein the additive is chosen from I_2, HI, sodium iodide, calcium iodide, potassium iodide, and combinations thereof."

522. Claim 10 is disclosed by Baldrey. As discussed above for Element 1(a), Baldrey discloses that the additive includes "one or more diatomic halogens (e.g., Cl_2 and Br_2), interhalogen compounds (e.g., BrCl), and halide salts …. Preferred supplemental halide salts are calcium chloride ($CaCl_2$), … calcium bromide, sodium bromide, potassium iodide, and also the hydrated states of these halide salts."[887]

8. Claim 11: "The method of claim 1, wherein the activated carbon is chosen from powdered activated carbon, granular activated carbon, carbon black, carbon fiber, aerogel carbon, pyrolysis char, and combinations thereof."

523. Claim 11 is disclosed by Baldrey. Baldrey discloses that "injected sorbent" is "generally powdered activated carbon."[888]

9. Claim 13: "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."

524. Claim 13 is disclosed by Baldrey. Baldrey discloses that the "additive comprises … sulfur" at quantities of up to 0.1% or 0.5%.[889] The chemical formula

[887] EX1015 (Baldrey), ¶[0070].

[888] EX1015 (Baldrey), ¶[0071]; *see also* EX1015 (Baldrey), ¶[0097].

[889] EX1015 (Baldrey), cls. 4, 6, 36, ¶[0019].

for sulfur is "S." Baldrey also discloses that SO_2 (sulfur dioxide) is present in the mercury-containing gas with the sorbent:

> The majority of coal chlorine forms HCl in the flue gas since the formation of elemental or diatomic chlorine is limited due to other dominant flue gas species including water vapor, sulfur dioxide (SO_2), nitrogen oxides (NOx) and sulfur trioxide (SO_3).[890]

The SO_2 is formed within the combustion chamber during coal combustion, with highest concentration at the exit of the combustion chamber. The contact with the activated-carbon sorbent is inevitable, regardless of whether the sorbent is injected upstream or downstream of the SDA (**224**).[891]

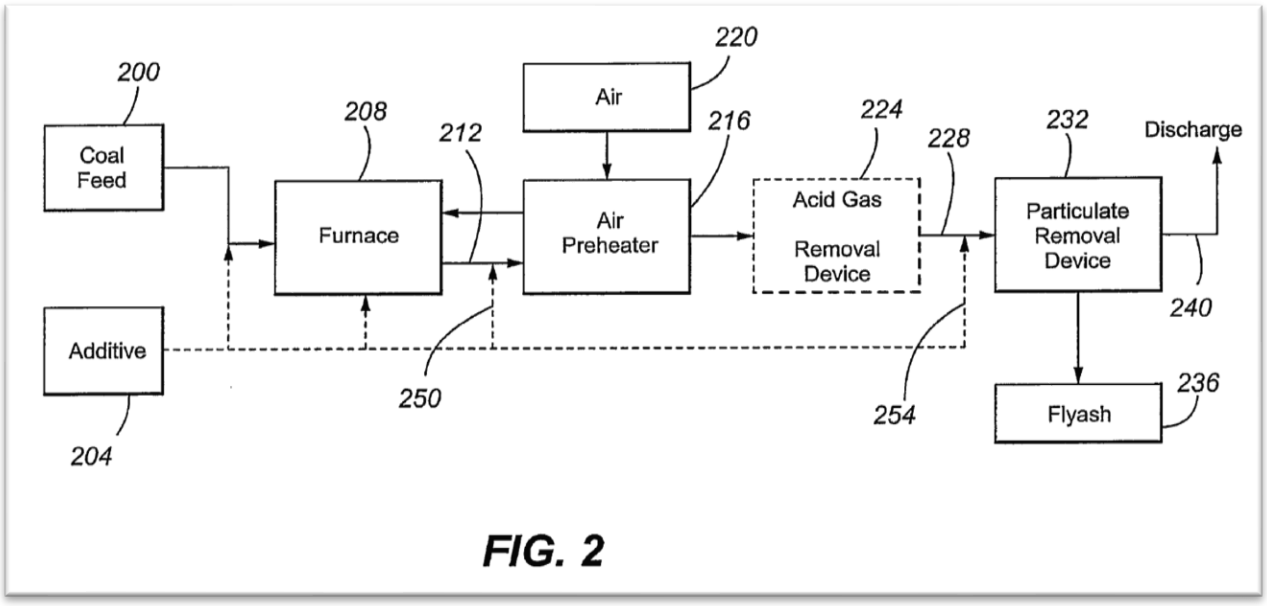


FIG. 2

[890] EX1015 (Baldrey), ¶[0004].

[891] EX1015 (Baldrey), Fig. 2; *see also* EX1015 (Baldrey), ¶¶[0103]-[0106] (describing injection before and after SDA **224**).

Thus, the sulfur (from the additive) and the SO_2 (from coal combustion) contacts the sorbent material in the mercury-containing gas.

10. Claim 14: "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."

525. Claim 14 is disclosed by Baldrey. As discussed for Claim Element 1(a), the additives of Baldrey include one or more "diatomic halogens" (e.g., Br_2 or Cl_2).[892] These halogens also qualify as a secondary component. As shown in Figure 2 below, Baldrey teaches that halogen-containing additives (item 204) can be applied not only to the coal and combustion chamber, but also to the sorbent in mercury-containing gas "at either of locations 250 and 254 for plants with no FGD scrubbing or at location 254 for plants with SDA followed by particulate control device (FF or cold-side ESP)."[893]

[892] EX1015 (Baldrey) ¶[0070].

[893] EX1015 (Baldrey) ¶[0106], Fig. 2; *see also* EX1015 (Baldrey) ¶[0168] ("the different components of the additive can be added to the coal feed **and/or** flue gas").

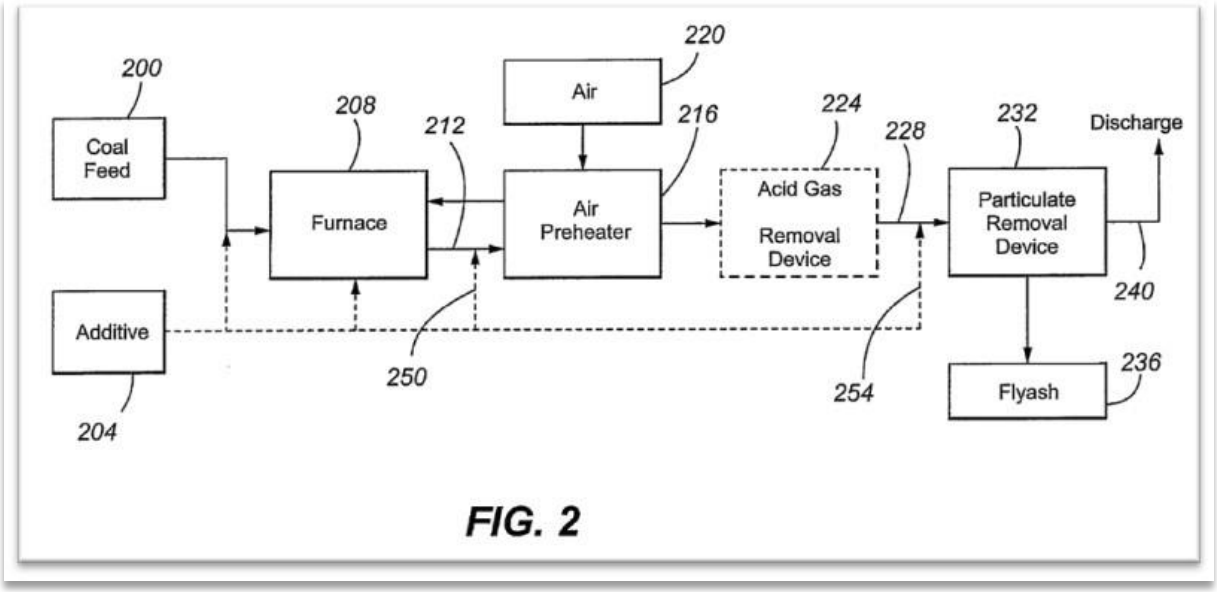


FIG. 2

Baldrey further teaches injecting halogen-containing additives "into the flue gas upstream of the particulate control device" at which temperatures "the halogens are present primarily in the form of the hydrogen species, HCl, HBr and HI."[894] These vapor phase hydrogen halides (i.e., HI, HBr, HCl) in the flue gas contact and "enrich" the sorbent material added to the flue gas.[895]

[894] EX1015 (Baldrey) ¶[0101].

[895] EX1015 (Baldrey) ¶[0031].

11. Claim 15: "The method of claim 14, wherein the secondary component is chosen from halogens, halide salts, HI, HBr, HCl, and combinations thereof."

526. Claim 15 is disclosed by Baldrey for the reasons discussed for Claim 14. Baldrey discloses injecting halogen containing additives into the flue gas, which include Br_2, Cl_2, HI, HBr, and HCl.[896]

12. Claim 16: "The method of claim 14, wherein the secondary component is chosen from I_2, HI, and combinations thereof."

527. Claim 16 is disclosed by Baldrey for the reasons discussed above for Claim 14. Baldrey discloses injecting halogen containing additives into the flue gas, which include HI.[897]

13. Claim 18: "The method of claim 1, wherein the additive comprises a and b, b and c, a and c, or a, b, and c: a) I^- and/or I_2, b) Br^- and/or Br_2, c) Cl^- and/or Cl_2."

528. Claim 18 is disclosed by Baldrey. As discussed for Element 1(a) and Claims 7 and 10, Baldrey discloses that "[i]n a second formulation, the additive includes **one or more** additive metal catalysts or a precursor thereof and <u>one or more</u>

[896] EX1015 (Baldrey) ¶[0101]; *see also* EX1015 (Baldrey) ¶[0168] ("the different components of the additive can be added to the coal feed **<u>and/or</u>** flue gas")..

[897] EX1015 (Baldrey) ¶[0101]; *see also* EX1015 (Baldrey) ¶[0168] ("the different components of the additive can be added to the coal feed **<u>and/or</u>** flue gas").

diatomic halogens (e.g., Cl_2 and Br_2), interhalogen compounds (e.g., BrCl), and halide salts to act as elemental mercury oxidants."[898]

C. INDEPENDENT CLAIM 17

529. Claim 17 is nearly identical to Claims 1 and 18, with minor changes, as shown in the redline below:

~~1~~17. A method for separating mercury from a mercury-containing gas, the method comprising:

combusting ~~a mixture of~~ coal ~~and~~comprising an additive in a combustion chamber, ~~to form the mercury-containing gas,~~ wherein the additive is chosen from halides, halogens, salts thereof, and combinations thereof~~; [18.~~, to form the mercury-containing gas, wherein the additive comprises a and b, b and c, a and c, or a, b, and c:

a) I^- and/or I_2,

b) Br^- and/or Br_2,

c) Cl^- and/or Cl_2~~.]~~;

~~adding a particulate~~injecting a sorbent material comprising activated carbon into the mercury-containing gas, wherein a weight ratio of the additive added to the coal, added to the combustion chamber, or a combination thereof, to an amount of the sorbent material added to the mercury-containing gas is from about 1:100 to about 30:100;

contacting mercury in the mercury-containing gas with the sorbent material, to form a mercury-sorbent; and

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

Claim 17 is disclosed for the reasons described for Claims 1 and 18. The differences are discussed below.

[898] EX1015 (Baldrey), ¶[0070].

1. Claim 17: Preamble—"A method for separating mercury from a mercury-containing gas, the method comprising:"

530. The language of Claim Element 17(Preamble) is identical to the language of Claim Element 1(Preamble). Accordingly, the explanation I provide above for Claim Element 1(Preamble) applies equally to Claim Element 17(Preamble).

2. Claim 17: Element 17(a)—"combusting coal comprising an additive in a combustion chamber, wherein the additive is chosen from halides, halogens, salts thereof, and combinations thereof, to form the mercury-containing gas, wherein the additive comprises a and b, b and c, a and c, or a, b, and c: a) I^- and/or I_2, b) Br^- and/or Br_2, c) Cl^- and/or Cl_2;"

531. The language of Claim Element 17(a) is nearly identical to the language of Claim Element 1(a) and Claim 18. Accordingly, the explanation I provide above for Claim Element 1(a) and Claim 18 applies equally to Claim Element 17(a). As discussed above for Claim Element 1(a) and for Claims 7 and 10, Baldrey discloses that the coal combusted in the combustion chamber comprises the additive, including the claimed combinations of halogens.

3. Claim 17: Element 17(b)—"injecting a sorbent material comprising activated carbon into the mercury-containing gas,"

532. The language of Claim Element 17(b) is nearly identical to the language of Claim Element 1(b) except "adding" is replaced with "injecting" and "particulate"

has been removed. As described above for Claim Element 1(b), Baldrey discloses injecting a sorbent material comprising activated carbon into the mercury-containing gas.

4. Claim 17: Element 17(c)—"wherein a weight ratio of the additive added to the coal, added to the combustion chamber, or a combination thereof, to an amount of the sorbent material added to the mercury-containing gas is from about 1:100 to about 30:100;"

533. The language of Claim Element 17(c) is identical to the language of Claim Element 1(c). Accordingly, the explanation I provide above for Claim Element 1(c) applies equally to Claim Element 17(c).

5. Claim 17: Element 17(d)—"contacting mercury in the mercury-containing gas with the sorbent material, to form a mercury-sorbent; and"

534. The language of Claim Element 17(d) is identical to the language of Claim Element 1(d). Accordingly, the explanation I provide above for Claim Element 1(d) applies equally to Claim Element 17(d).

6. Claim 17: Element 17(e)—"separating the mercury-sorbent from the mercury-containing gas."

535. The language of Claim Element 17(e) is identical to the language of Claim Element 1(e). Accordingly, the explanation I provide above for Claim Element 1(e) applies equally to Claim Element 17(e).

XVII. GROUND B2: OBVIOUSNESS OVER BALDREY IN VIEW OF OLSON-646

536. It is my opinion that claims 1-18 would have been obvious over the combination of Baldrey and Olson-646 (Ground B2). In the subsections below, I discuss the reasons to combine Baldrey with Olson-646, followed by the disclosure of Baldrey and Olson-646.

A. REASONS TO COMBINE

537. A person of ordinary skill in the art would have been motivated to look to Olson-646 to provide certain implementational details regarding the system disclosed in Baldrey, such as the ratios of halogen promoter to activated-carbon sorbent and further processes that take place downstream of the combustion chamber (such as location of sorbent injection). Baldrey 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, how those halogens react with the PAC. Thus, a person of skill in the art would have been motivated to combine Baldrey and Olson-646, and have a reasonable expectation of success in applying the teachings of Olson-646 to Baldrey, 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 Baldrey is "Additives for Mercury Oxidation in Coal-Fired Power Plants."[899] Similarly, the title of Olson-646 is "Sorbents for the Oxidation and Removal of Mercury."[900]

538. Baldrey describes removing mercury from flue gas of coal-fired power plants using halogen addition and sorbent injection as detailed below.

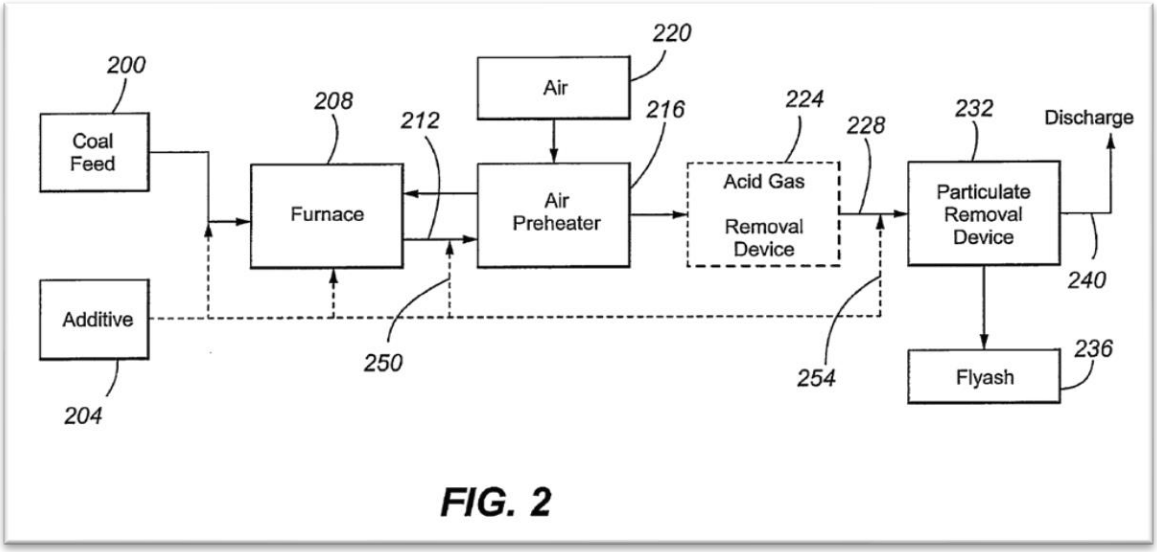


FIG. 2

Baldrey describes that "the additive of the present invention is believed to promote mercury oxidation and sorption by enrichment of transition metal catalysts in the fly ash or on suitable mercury sorbents that are injected and captured with the fly ash."[901] Baldrey teaches that the "oxidized mercury can [] bind to surface sites within

[899]EX1015(Baldrey) at 1 (Title).

[900] EX1012 (Olson-646) at 1 (Title).

[901] EX1015 (Baldrey) ¶[0031].

the fly ash or to activated carbon or LOI carbon within the fly ash layer."[902] Baldrey explains that the result is that "[m]ost of the oxidized mercury and excess halogens are absorbed by the fly ash and/or mercury sorbent of the third formulation and is therefore removed by the device 232."[903]

539. Baldrey provides overall process descriptions and diagrams and highlights the improved results of halogens used in combination with activated-carbon sorbents. To the extent that Baldrey does not expressly describe some implementation details associated with the PAC sorbent and reactions taking place when these chemicals are injected as described in Baldrey, a person of skill in the art would have looked to the Olson-646 reference for guidance on implementation details, such as a proposed reaction mechanism between sorbent, mercury, and halogen. Olson-646 describes using a conventional halogen (e.g., bromine, chlorine, iodine) in a conventional way (as a promoter) to increase the effectiveness of a conventional sorbent (activated carbon) to capture mercury from coal flue gas. Olson-646 teaches embodiments that upon contact with the sorbent, "the halogen/halide promoter is in gaseous or vapor form."[904] A person of ordinary skill

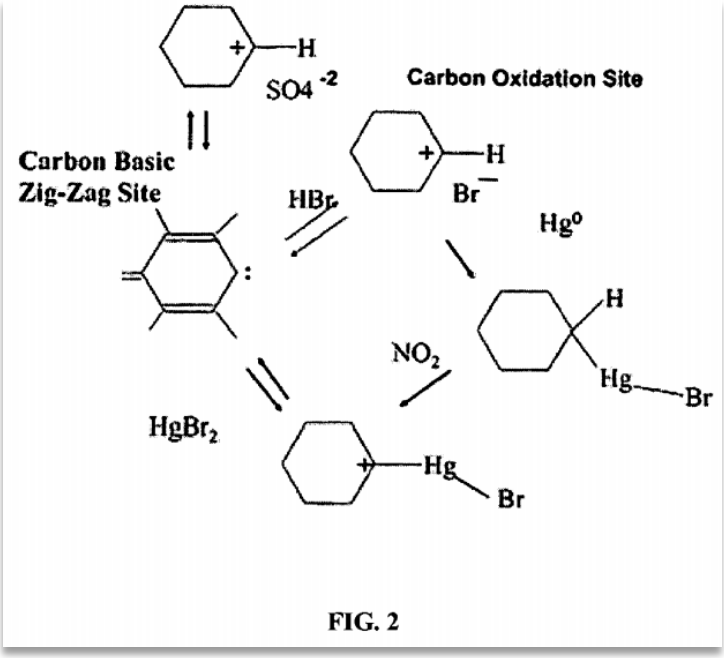
[902] EX1015 (Baldrey) ¶[0069].

[903] EX1015 (Baldrey) ¶[0085].

[904] EX1012 (Olson-646) ¶[0066].

in the art would also look to Olson-646 for additional discussion of the ratios of bromine promoter to activated-carbon sorbent, further processes that take place downstream of the combustion chamber (such as location of sorbent injection), and the underlying chemistry already theorized to take place by the processes disclosed in Baldrey.

540. Figure 2 of Olson-646, reproduced below, shows "a theory developed from scientific evidence to explain the nature of the promoting compounds."[905]



Olson-646 explains that "hydrogen bromide reacts with the unsaturated structure of the activated carbon."[906] Olson-646 teaches that the reaction may take place at "a

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

[906] EX1012 (Olson-646) ¶[0054].

carbene species on the edge of the graphene sheet structures of the carbon."[907] 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."[908] Figure 2 of Olson-646 shows that the complex includes the activated-carbon sorbent, the halogen, and the element mercury. Olson-646 further explains that "secondary component(s) may preferably comprise iodine or other halogens, hydrohalides, including without limitation HI," and that "[h]alogen treatment resulted in higher-activity carbons because the halide anions (especially bromide and iodide) were effective in promoting the oxidation by stabilizing the developing positive charge on the mercury in the transition state for oxidation."[909] Thus, a POSITA would have been motivated to apply the teachings of Olson-646 to Baldrey because it would have provided well-known details regarding the chemicals and associated reactions that would have been used in the system of Baldrey for mercury control from coal flue gas.

[907] EX1012 (Olson-646) ¶[0054].

[908] EX1012 (Olson-646) ¶[0054].

[909] EX1012 (Olson-646) ¶¶[0067], [0073].

541. 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 using halogen compounds as promoters and mercury sorbents (activated carbon).

542. Looking to the implementation details provided in the Olson-646 reference to understand the chemicals and reactions taking place in Baldrey, would have been nothing more than using known results of one process in a known way to improve a similar process. Further, the implementation details provided in Olson-646 are simply proposed workable ranges (such as concentration ratios), which were conventional and known in the art, and would have been selected, or at least tried, as part of routine process optimization by a POSITA applying the teachings of Baldrey.

B. DISCLOSURE AND TEACHINGS OF THE COMBINATIONS

543. It is my opinion that the combination of Baldrey in view of Olson-646 (Ground B2) renders obvious the claims below of the Challenged Patent. Elements and claims not mentioned below are disclosed or rendered obvious for the reasons stated above in Ground B1.

C. INDEPENDENT CLAIM 1

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

544. In addition to the reasons I discussed for Ground B1, this limitation is further obvious over Olson-646. Olson-646 describes "[a] promoted activated-carbon sorbent … that is highly effective for the removal of mercury from flue gas streams."[910] Olson-646 further describes that activated carbon "is injected into [the] contaminated flue gas stream."[911]

2. Claim 1: Element 1(c)—"wherein a weight ratio of the additive added to the coal, added to the combustion chamber, or a combination thereof, to an amount of the sorbent material added to the mercury-containing gas is from about 1:100 to about 30:100;"

545. This claim would have further been obvious over Baldrey. As discussed for Ground B1, Baldrey discloses ranges for the additive concentration in coal and ranges for the sorbent concentration in the flue gas. Values within that range meet this claim limitation for the reasons described in Ground B1. It would have been obvious to a POSITA to try other ratios, such as by increasing halogen concentration (while reducing activated-carbon injection rates), or decreasing

[910] EX1012 (Olson-646), Abstract.

[911] EX1012 (Olson-646), ¶¶[0043], [0061].

halogen concentration (while increasing active-carbon injection) as part of routine process optimization to achieve the desired mercury removal.

546. Claim Element 1(c) is merely an attempt to claim a workable range for combinations of conventional halogen (bromine, chlorine, iodine) being used in a conventional way (to oxidize mercury and promote activated carbon) with a conventional sorbent (activated carbon). Nothing in the '370 Patent specification attributes significance to the claimed range or establishes that the claimed range achieves unexpected results. The range presents nothing more than optimization of result-effective variables that would have been obvious to a POSITA. Patent Owner's expert in the Delaware litigation involving patents related to the '370 Patent stated that "power plants employing bromine additives and activated carbon would necessarily produce a sorbent that is 1 g to 30 g bromine per 100 g of activated carbon."[912] He further cited to this analysis for a claim that requires "the mercury-containing gas comprises about 1 g to about 30 g of the element bromine per 100 g of the sorbent."[913]

547. This limitation is also obvious over Olson-646, which repeatedly discusses the ratio of halogen/halide promoter to sorbent: "the promoter is added at

[912] EX1092 (O'Keefe Report) at 153 (cl. 4).

[913] EX1092 (O'Keefe Report) at 154 (cl. 29).

from about 1 to about 30 grams per 100 grams of activated carbon."[914] A POSITA would have understood that the promoter concentration in the coal is near zero prior to the additive being applied, such that the quantity of promoter in the flue gas equals the promoter applied to the combustion chamber and/or coal in Baldrey.[915]

3. Claim 1: Element 1(d)—"contacting mercury in the mercury-containing gas with the sorbent material, to form a mercury-sorbent; and"

548. In addition to the reasons I discussed for Ground B1, this limitation is further obvious over Olson-646. Olson-646 explains that a "promoted carbon sorbent and/or an optional alkali component is injected into contaminated flue gas stream 15."[916] The "contaminated flue gas stream" refers to a stream of mercury-containing gas. Olson-646 explains that "[t]he halogen/halide . . . contacts and reacts with the base activated carbon prior to injection point 116."[917]

549. Olson-646 describes that mercury contacts the activated carbon in the flue gas. Indeed, Olson-646 discloses a promoted activated-carbon sorbent "that

[914] EX1012 (Olson-646), ¶¶[0023], [0027], cls. 3, 17, 37, 47.

[915] EX1015 (Baldrey), ¶[0004] (discussing "low rank coals with … low chlorine and bromine contents").

[916] EX1012 (Olson-646) ¶[0061].

[917] EX1012 (Olson-646) ¶[0062].

capture[s] mercury via mercury-sorbent surface reactions,"[918] Olson-646 further describes "AC mercury binding sites" (i.e., sites where mercury contacts the sorbent)[919] and shows this mercury-sorbent composition in Figure 2 (annotated below).[920]

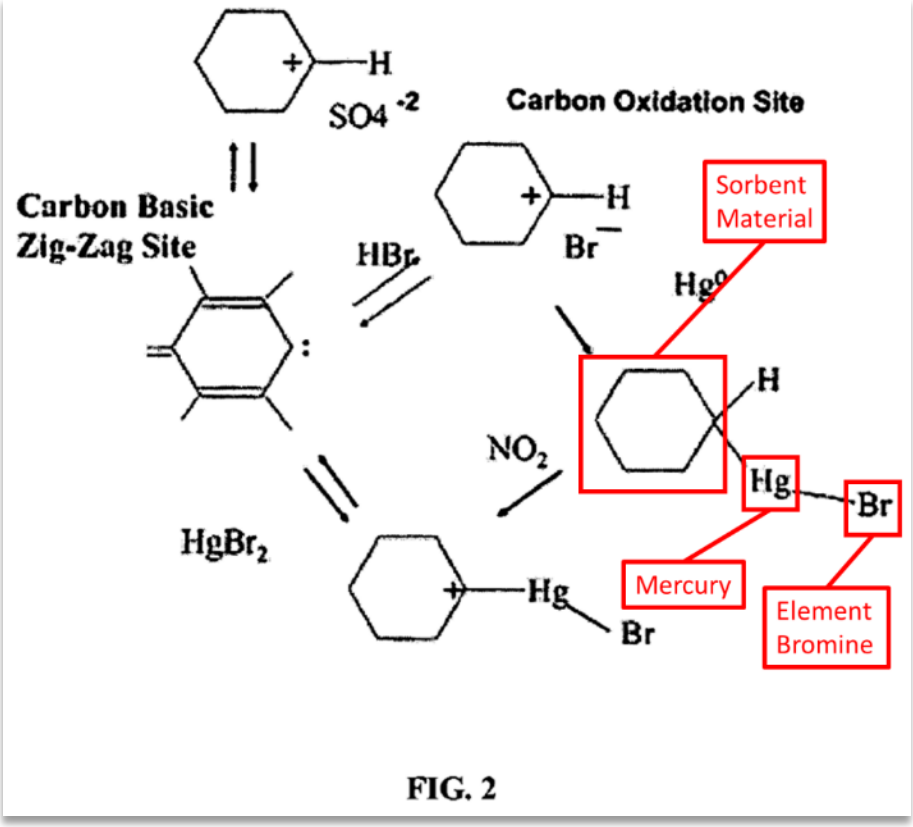


FIG. 2

Thus, Olson-646 discloses "contacting mercury in the mercury-containing gas with the sorbent material, to form a mercury-sorbent.".

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[918] EX1012 (Olson-646) ¶[0043]; see also EX1012 (Olson-646) at Abstract.

[919] EX1012 (Olson-646) ¶[0128].

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

4. Claim 1: Element 1(e)—"separating the mercury-sorbent from the mercury-containing gas."

550. In addition to the reasons I discussed for Ground B1, this limitation is further obvious over Olson-646, which discloses a particulate separator, such as an ESP or fabric filter.[921] As described for Element 1(d), a POSITA would have known, or at least found it obvious, that the sorbent is contacted with mercury after it is introduced into the mercury-containing gas.

D. CLAIMS DEPENDING FROM CLAIM 1

1. Claim 5: The method of claim 1, wherein carbocations in the activated carbon of the mercury-sorbent accept electrons from mercury atoms of the mercury-sorbent.

551. This claim limitation presents a proposed model of the chemistry already taking place when halogen-containing promoters contact activated-carbon sorbent. It is disclosed near-verbatim in Olson-646:

> [0093] According to our model, adding the bromine from the bromine reagent or a proton from a hydrogen halide acid to a basic carbene site on the carbon edge structure forms a carbocation that accepts electrons from the neutral mercury atom forming the oxidized mercury species that is bound to the sorbent surface. The reactive site may also generate reactive bromine radicals or carbon radicals at the active sites on the carbon. Thus, the activated carbon serves to stabilize the bromine, yet provides a highly reactive bromine-containing reagent that can oxidize the mercury and promote its capture on the activated carbon. The sorbent that contains bromine is expected to be more reactive

[921] EX1012 (Olson-646) ¶[0059].

> than the corresponding sorbent containing chlorine and much less expensive than the sorbent containing iodine.[922]

2. Claim 6: "The method of claim 1, wherein the additive is substantially in vapor form in the mercury-containing gas."

552. In addition to the reasons I discussed for Ground B1, Claim 6 is further obvious over Olson-646. Olson-646 teaches "the halogen/halide promoter is in gaseous or vapor form" that comprises "gaseous HBr or Br_2."[923] Furthermore, when heated, the halogen compounds of Baldrey would react to form the gas-phase promoters called for by Olson-646:

> The supplemental halide salts will decompose at combustion forming primarily HCl or HBr or HI and then further forming some fraction of diatomic chlorine, bromine or iodine in the cooling flue gases.[924]

[922] EX1012 (Olson-646) ¶[0093]

[923] EX1012 (Olson-646) ¶[0066].

[924] EX1015 (Baldrey) ¶[0096]; *see also* EX1015 (Baldrey) ¶[0004]; EX1095 (Olson Dep. Tr.) at 98:23-100:3, 231:3-9.

3. Claim 9: "The method of claim 1, wherein the additive is chosen from PBr_3, SCl_2, and a combination thereof."

553. Claim 9 would have been obvious over Baldrey in view of Olson-646. Olson-646 describes that "the halogen or halide promoter . . . may preferably comprise. . . PBr_3 or SCl_2."[925]

4. Claim 12: "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."

554. Claim 12 would have been obvious over Baldrey in view of Olson-646. Olson-646 teaches "adding an optional alkali component."[926] Olson-646 further discloses "co-injecting an optional alkaline material" into the mercury-containing gas (i.e., along with the sorbent), "including without limitation alkaline and alkaline earth components."[927] Claims 31 and 40 of Olson-646 further disclose "co-injecting an optional alkaline component into the mercury containing flue gas stream."[928] Olson-646 teaches that the alkaline component is used "to improve the efficiency of

[925] EX1012 (Olson-646), ¶[0052]; *see also* EX1012 (Olson-646), ¶¶[0067], [0132]-[0133]; *see* EX1012 (Olson-646), ¶¶[0023], [0037].

[926] EX1012 (Olson-646) ¶[0017].

[927] EX1012 (Olson-646) ¶[0026] *see also* EX1012 (Olson-646) ¶¶[0040]-[0041] (activated-carbon sorbent with "co-injected alkali material").

[928] EX1012 (Olson-646) at claims 31, 40.

mercury capture by capturing oxidized mercury and/or capturing gaseous components that might otherwise reduce sorbent capacity."[929] 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, along with the activated-carbon sorbent, as Olson-646 teaches that its use "improve[s] the efficiency of mercury capture."[930]

555. Olson-646 further teaches that the alkaline component can "includ[e] without limitation alkaline and alkaline earth components," including "lime."[931] Olson-646 further discloses that "the optional alkaline material may preferably comprise calcium oxide, sodium carbonate, and the like, as are known in the art."[932] 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."

[929] EX1012 (Olson-646) ¶[0026].

[930] EX1012 (Olson-646) ¶¶[0026], [0127].

[931] EX1012 (Olson-646) ¶ [0026].

[932] EX1012 (Olson-646) ¶ [0026].

5. Claim 13: "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."

556. In addition to the reasons I discussed for Ground B1, Claim 13 is further obvious over 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."[933] A POSITA would have been motivated to add these components, because Olson-646 states that they "stabilize" the mercury binding to activated carbon.[934]

6. Claim 14: "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."

557. Claim 14 would have been obvious over Baldrey in view of Olson-646. In addition to the reasons I discussed for this claim in Ground B1, Olson-646 repeatedly refers to a "secondary component."[935] Olson-646 provides more detail of injecting a secondary component into flue gas in Figure 3, reproduced below.[936]

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[933] EX1012 (Olson-646) ¶[0017]; *see also* ¶¶[0021], [0025], cls. 12, 14, 28-29, 44.

[934] EX1012 (Olson-646) ¶[0074].

[935] EX1012 (Olson-646) ¶¶[0011], [0014], [0015], [0017], cls. 4-8, 11, 24-27, 38-43.

[936] EX1012 (Olson-646) ¶[0056], Figure 3.

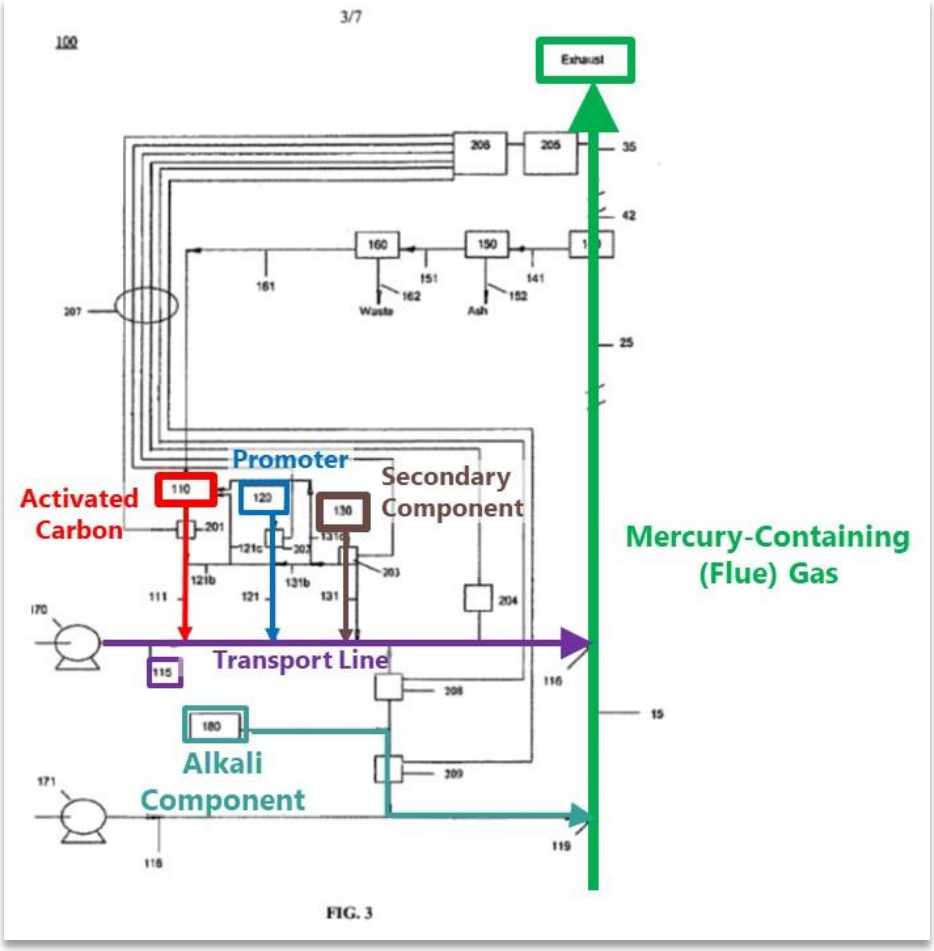


Figure 3 of Olson-646 shows a schematic of "mercury control system 100 comprising preparation of promoted carbon sorbents," which includes "an optional secondary component reservoir 130, and an optional akali [*sic*] component reservoir 180."[937] Specifically, Olson-646 teaches that "the optional secondary component may be contacted and react directly in transport line 115 via line 131, or optionally

[937] EX1012 (Olson-646) ¶[0056].

as described above with respect to the halogen/halide, via lines 131b and 131c."[938] 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.[939]

558. Olson-646 teaches that in certain embodiments, the "optional secondary component compris[es] a halogen or a hydrohalide."[940] Olson-646 explains that these secondary components are added "such that the reactivity and mercury capacity of the sorbent are enhanced," by reacting with SOx to minimize

[938] EX1012 (Olson-646) ¶[0063].

[939] EX1012 (Olson-646) ¶[0128].

[940] EX1012 (Olson-646) ¶[0014]; *see also* EX1012 (Olson-646) at Claim 4.

competition with mercury for active binding sites on activated-carbon sorbent.[941] A POSITA would have desired 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."[942]

559. As previously discussed, Baldrey teaches injecting halogen-containing additives "into the flue gas upstream of the particulate control device."[943] Thus, a POSITA would have had a reasonable expectation of success in adding the optional secondary component of Olson-646 to the location of Baldrey's injection of halogen-containing additives into the flue gas as they are described in both references as functioning to "enrich" or "enhance" the sorbent. [944]

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[941] EX1012 (Olson-646) ¶¶[0014], [0128]; *see also* EX1012 (Olson-646) at Claim 4; EX1015 (Baldrey) ¶[0031].

[942] EX1012 (Olson-646) ¶[0011].

[943] EX1015 (Baldrey) ¶[0101].

[944] EX1012 (Olson-646) ¶¶[0014], [0128]; *see also* EX1012 (Olson-646) at Claim 4.

560. In addition, Olson discloses embodiments wherein "the optional secondary component is selected from the group consisting of Group V halides, Group VI halides, HI, HBr, HCl, and combinations thereof."[945] 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."[946]

7. Claim 15: "The method of claim 14, wherein the secondary component is chosen from halogens, halide salts, HI, HBr, HCl, and combinations thereof."

561. Claim 15 would have been obvious over Baldrey in view of Olson-646 for the reasons discussed for this claim in Ground 1 and above for Claim 14. In addition to the reasons I discussed for this claim in Ground B1, Olson-646 also discloses wherein the secondary component is "selected from the group consisting of Group V halides, Group VI halides, HI, HBr, HCl, and combinations thereof."[947]

[945] EX1012 (Olson-646) ¶¶[0017], [0067]; *see also* EX1012 (Olson-646) at Claim 7.

[946] EX1012 (Olson-646) ¶[0025]; *see also* EX1012 (Olson-646) at Claim 39.

[947] EX1012 (Olson-646) ¶¶[0017], [0067]; *see also* EX1012 (Olson-646) at Claim 7.

8. Claim 16: "The method of claim 14, wherein the secondary component is chosen from I_2, HI, and combinations thereof."

562. Claim 16 would have been obvious over Baldrey in view of Olson-646 for the reasons discussed above for this claim in Ground 1 and above for Claim 14. In addition to the reasons I discussed for this claim in Ground B1, Olson-646 discloses the "secondary component is selected from the group consisting of … HI."[948]

E. OTHER CLAIMS

563. Claims 2-4, 7-8, 10-11, and 17-18 are obvious for the reasons described above in Ground B1.

XVIII. GROUND B3: OBVIOUSNESS OVER SJOSTROM IN VIEW OF OLSON-646

564. It is my opinion that claims 1-18 would have been obvious over the combination of Sjostrom and Olson-646 (Ground B3). 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

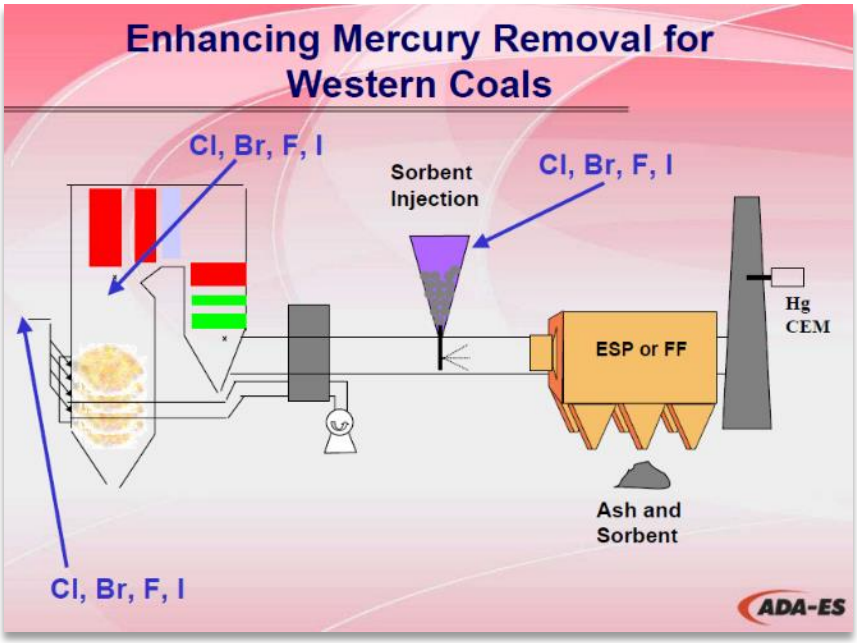
565. A person of ordinary skill in the art would have been motivated to combine Sjostrom with Olson-646, and have a reasonable expectation of success in

[948] EX1012 (Olson-646) ¶[0017]; *see also* ¶¶[0067], [0074] (similar).

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 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 halogen-containing (e.g., "Br") species to use, the ratios of halogen 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."[949] Similarly, the title of Olson is "Sorbents for the Oxidation and Removal of Mercury."[950]

566. 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.[951]



Sjostrom demonstrates that activated-carbon sorbent injection was a well-known way of treating mercury emissions in flue gas.[952] Sjostrom also teaches that halogen-

[949] EX1010 (Sjostrom) at 1 (Title).

[950] EX1012 (Olson-646) at 1 (Title).

[951] EX1010 (Sjostrom) at 4.

[952] EX1010 (Sjostrom) at 10-11.

containing chemicals (e.g., "Cl," "Br," and "I") may be injected at multiple locations.[953] 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.[954]

567. 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 (e.g., 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.

568. A POSITA would have been motivated, with a reasonable expectation of success, to add HBr or Br_2 into the combustion chamber of Sjostrom (e.g., Location 2), because it would have been a simple substitution of one known element (e.g., the "Br" in Sjostrom at the location specified by Sjostrom) for another known element (e.g., Br_2 or HBr of Olson-646) to improve a known device (activated-carbon sorbent in Sjostrom and Olson-646) and obtain predictable results (e.g., more

[953] EX1010 (Sjostrom) at 4.

[954] EX1010 (Sjostrom) at 16.

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."[955] 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.

569. 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."[956]

[955] EX1012 (Olson-646) ¶[0066].

[956] EX1012 (Olson-646) ¶[0054], Figure 2; *see also* ¶¶[0033], [0073].

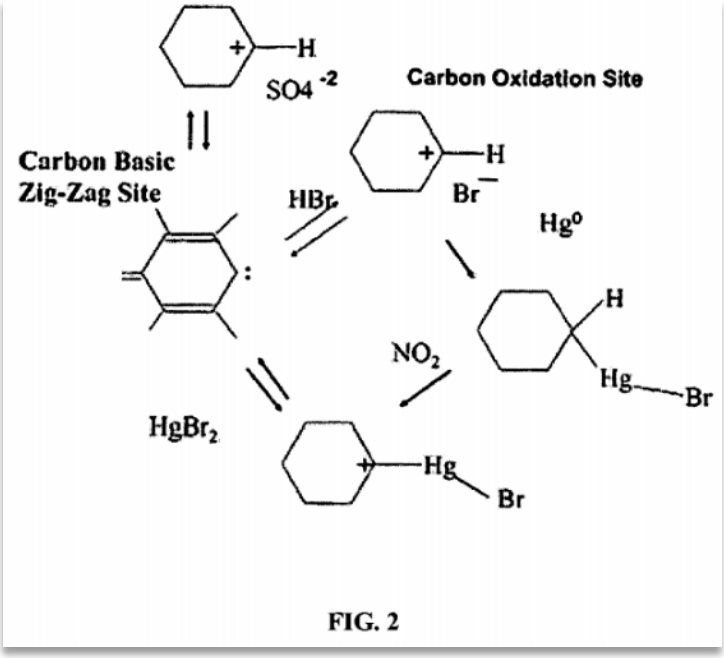


FIG. 2

Olson-646 explains that "hydrogen bromide reacts with the unsaturated structure of the activated carbon."[957] Olson-646 teaches that the reaction may take place at "a carbene species on the edge of the graphene sheet structures of the carbon."[958] 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."[959] 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

[957] EX1012 (Olson-646) ¶[0054].

[958] EX1012 (Olson-646) ¶[0054].

[959] 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.

570. 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).[960] Sjostrom describes mercury removal testing performed using "DARCO FGD" sorbent.[961] Likewise, Olson-646 teaches the use of "powdered activated carbon" such as "NORIT Darco FGD."[962]

571. 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.

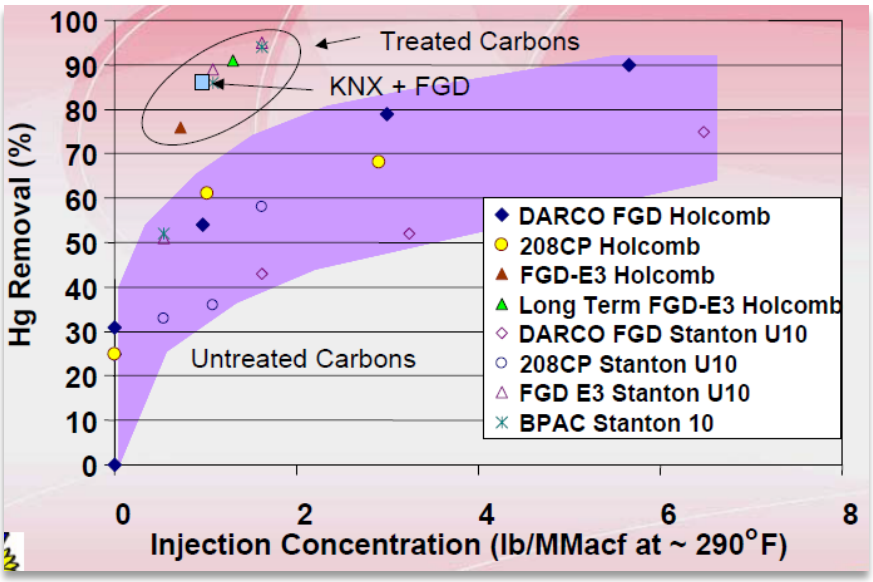
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[960] EX1010 (Sjostrom) at 15, 16; EX1012 (Olson-646) ¶¶[0035], [0036], [0039], [0040], [0095], [0100], [0126]

[961] EX1010 (Sjostrom) at 15, 16.

[962] 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).[963]



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."[964]

572. Looking to the implementation details provided in the Olson-646 reference to understand the chemicals and reactions taking place in Sjostrom, would

[963] EX1010 (Sjostrom) at 16.

[964] 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

573. It is my opinion that the combination of Sjostrom in view of Olson-646 (Ground B3) renders obvious the claims below of the Challenged Patent.

C. INDEPENDENT CLAIM 1

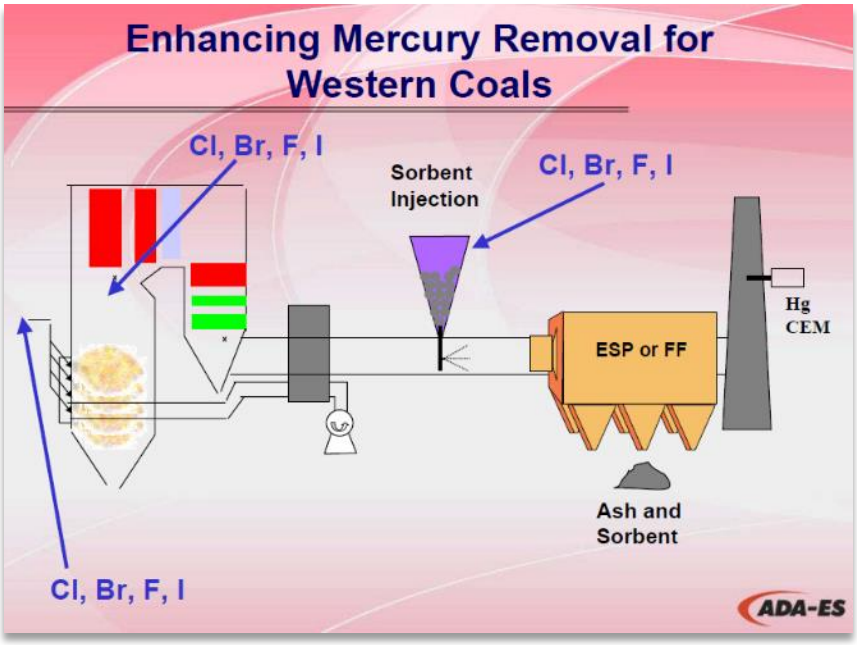
1. Claim 1: Preamble—"A method for separating mercury from a mercury-containing gas, the method comprising"

574. The preamble is disclosed by Sjostrom. Sjostrom teaches separating mercury from a mercury-containing gas. The title of Sjostrom is "Full Scale Evaluations of Mercury Control Technologies with PRB Coals."[965] Specifically, Sjostrom described various mercury control tests conducted at several coal-fired power plants.[966] Sjostrom described testing mercury removal from flue gas of coal-

[965] EX1010 (Sjostrom) at 1.

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

fired power plants involving sorbent injection and halogen addition, as detailed below.[967]



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.[968] 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

[967] EX1010 (Sjostrom) at 4.

[968] EX1010 (Sjostrom) at 8, 15-17, 20, and 21.

ESP or FF to remove such solid materials.[969] The pile removed from the ESP or FF is labeled "Ash and Sorbent," which also contains mercury that was removed from the flue gas.

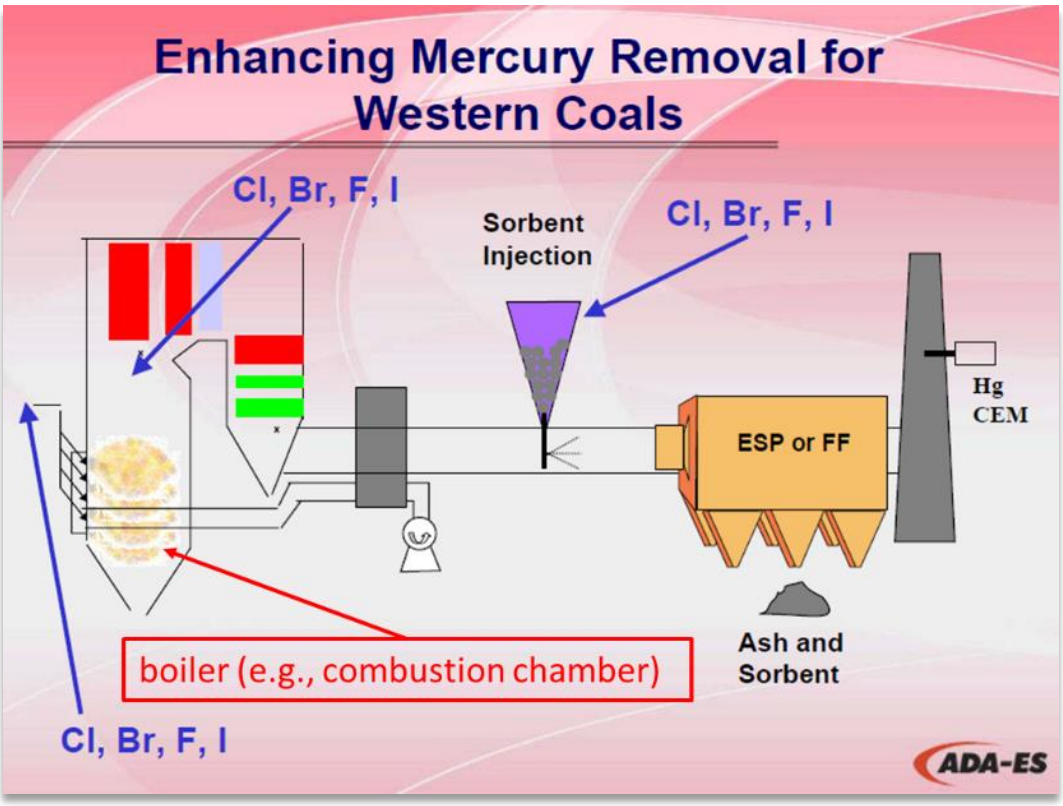
2. Claim 1: Element 1(a)—"combusting a mixture of coal and an additive in a combustion chamber, to form the mercury-containing gas, wherein the additive is chosen from halides, halogens, salts thereof, and combinations thereof;"

575. This limitation is disclosed by Sjostrom. This limitation is also obvious over Sjostrom in view of Olson-646. As discussed above, Sjostrom described various mercury control tests conducted at coal-fired power plants.[970] 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.[971]

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

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

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



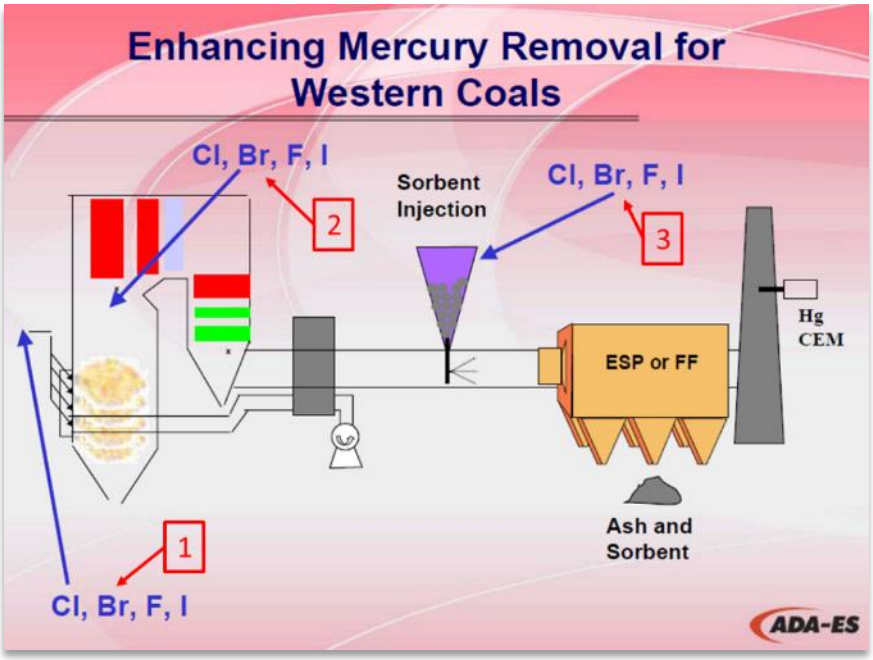
A POSITA would have understood that this unit was a boiler/furnace based on the image used to represent the unit in the drawing, which was a common and routine way to represent a coal-combustion chamber (boiler/furnace). Sjostrom explains that at the time of testing, two of the coal-fired power plants combusted PRB (Powder River Basin) coal having a mercury content of "0.04 – 0.1 ppm-dry."[972] Relying only on existing equipment at these plants, Sjostrom shows that the outlet mercury content of the flue gas was 11.2 μg/dncm.[973] Thus, Sjostrom discloses

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

[973] EX1010 (Sjostrom) at 3.

combusting coal in a combustion chamber (e.g., boiler/furnace) to form a mercury containing flue gas stream.

576. Sjostrom, as the annotated figure below shows, renders obvious the addition of halides, halogens, salts thereof, and combinations thereof in at least three locations throughout the coal-combustion process.[974]



Location 1 of Sjostrom renders obvious injecting halides, halogens, salts thereof, and combinations thereof upstream of the combustion chamber, such as by adding it to the coal before the coal enters the combustion chamber.[975] Though there are multiple places upstream of a combustion chamber, it would have at least been

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

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

obvious to add the halides, halogens, salts thereof, and combinations thereof to the coal itself, because Sjostrom discloses not only the figure, but also mentions of "coal additives."[976] Location 2 of Sjostrom discloses injecting halogens ("Cl, Br, F, I") directly into the combustion chamber.[977] Even at Location 2 of Sjostrom, it would have been obvious that there would be some mixing between the coal and halogen-containing additives. Both HBr and Br_2 are likely candidate promoters to inject directly into furnaces or further downstream into gas cleaning systems. Since HBr is a gas at ambient conditions, a POSITA would consider injecting it into the manifold that delivers secondary and tertiary air into the burners, because distributing the promoter into many burners is the best way to ensure good mixing throughout a furnace; in fact, burners are designed to completely mix the air streams with the coal that is suspended in the primary air stream. Since Br_2 is a liquid at ambient conditions, a POSITA would consider its injection as a liquid spray into the upper furnace elevations, to achieve penetration of the promoter over the entire furnace cross section. A POSITA would know that the momentum of liquid sprays is approximately three orders of magnitude greater than that of gaseous jets, all else

[976] 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).

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

the same. So a liquid spray of Br_2 could be made to penetrate much further into a furnace than a gas jet of HBr, so as to effectively mix with the burning coal in the furnace gases. With injection of halogens at either Location 1 or 2, a mixture of coal and halogen-containing 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.[978] At least Location 1 and Location 2 satisfy the claim limitation.

577. While Sjostrom does not identify which specific chemical to use for "Cl, Br, F," I," it would have been obvious to use widely available materials, including aqueous solutions of a halide compounds like $CaCl_2$ and $CaBr_2$ (for "Cl" and "Br" taught by Sjostrom). Further, Sjostrom teaches the addition of "KNX (Alstom Power)."[979] KNX was a known aqueous solution of a calcium bromide salt additive developed for enhanced mercury control.[980] As discussed above, Locations 1 and 2 of Sjostrom render obvious adding halogen-containing species upstream of the combustion chamber, such as by adding it to the coal entering the boiler, and

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

[979] EX1010 (Sjostrom) at 23.

[980] EX1106 (Variety of Hg Capture Solutions); EX1107 (KNXTM is effective).

directly to the combustion chamber.[981] Thus, Sjostrom renders obvious combusting a mixture of coal and an additive in a combustion chamber, to form the mercury-containing gas, wherein the additive is chosen from halides, halogens, salts thereof, and combinations thereof.

578. Olson-646 supplements the teachings of Sjostrom, describing "Br" containing compounds that promoted activated-carbon sorbents. Olson-646 states that the "combustion and gasification of fossil fuel such as coal generates flue gas that contains mercury . . . ."[982] 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."[983] Olson-646 teaches embodiments "wherein the halogen/halide promoter is in gaseous or vapor form" that comprises "gaseous HBr or Br_2."[984] 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

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

[982] EX1012 (Olson-646) ¶[0006].

[983] EX1012 (Olson-646) ¶[0043].

[984] EX1012 (Olson-646) ¶[0066].

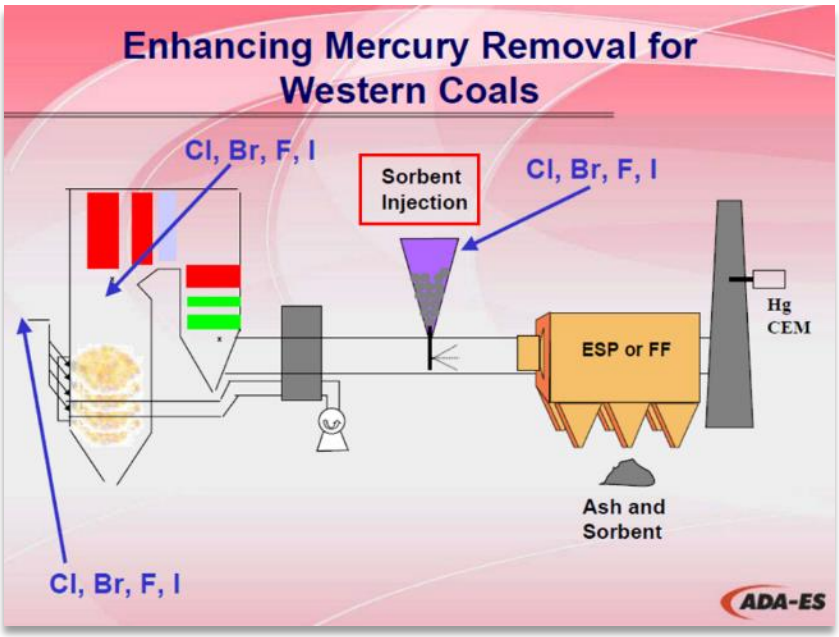
it would have been a simple substitution of one known element (e.g., the "Br" in Sjostrom at the location specified by Sjostrom) for another known element (e.g., HBr of Olson-646) to improve a known device (activated-carbon sorbent in Sjostrom and Olson-646) and obtain predictable results (e.g., more 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, such as an aqueous bromide salt solution (such as the KNX in Sjostrom), that upon combustion would yield HBr or Br_2 (which Olson-646 identifies as effective gas-phase promoters).[985]

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

579. This limitation is disclosed by Sjostrom. As shown in the annotated figure below, Sjostrom described certain tests involving sorbent injection downstream of the boiler.[986]

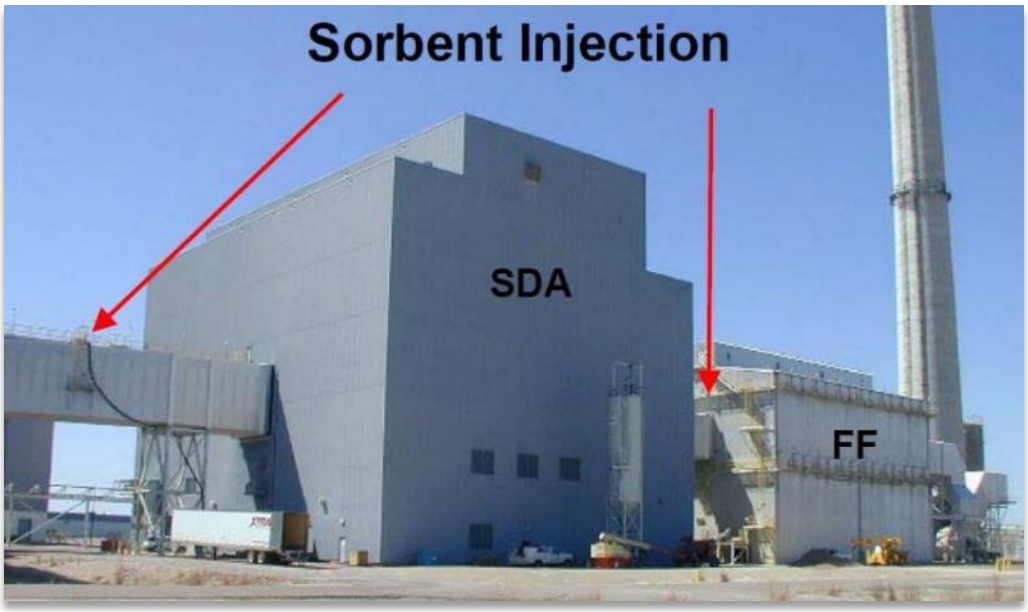
[985] EX1095 (Olson), 98:23-100:3, 231:3-9 (discussing in-flight promotion).

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

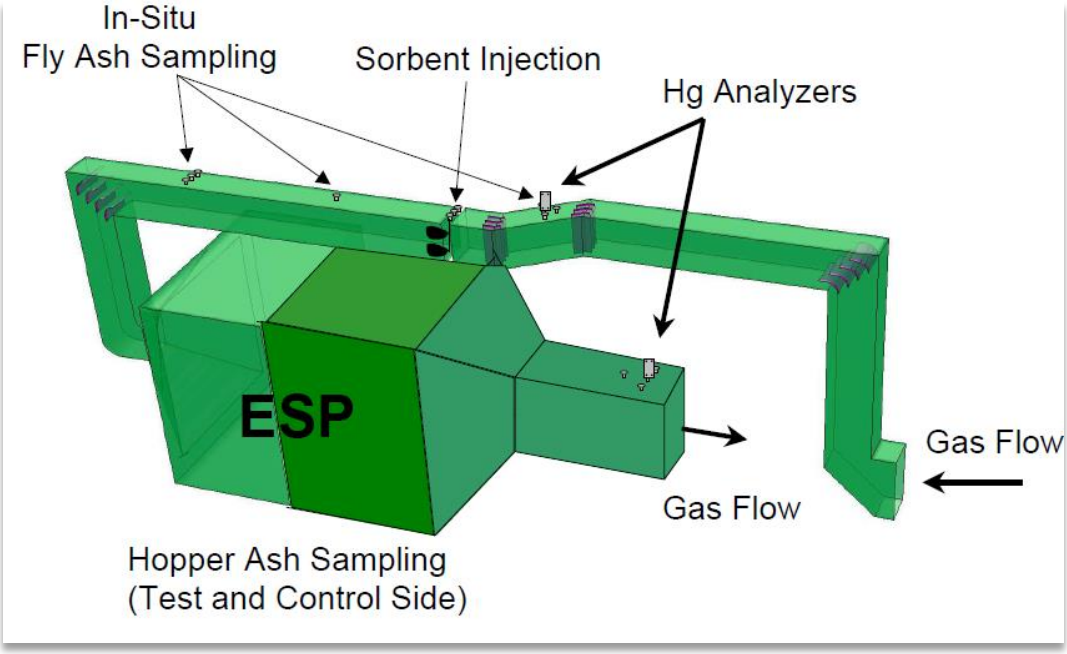


As shown in the above figure, the "Sorbent Injection" occurs downstream from a combustion chamber, and thus into the mercury-containing gas. Sjostrom refers to "Sorbent Injection Rate."[987] A photo of the sorbent injection is below (annotations in original):

[987] 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"),[988] which Sjostrom abbreviates as "ACI."[989] The specific brand of ACI is "DARCO FGD."[990] A POSITA would have understood that Norit DARCO FGD was a well-known type of activated carbon used for mercury capture.[991]

580. This limitation is further obvious over Sjostrom in view of Olson-646. Olson-646 explains that a "promoted carbon sorbent and/or an optional alkali component is injected into contaminated flue gas stream 15,"[992] where it adsorbs mercury: sorbent "that capture[s] mercury via mercury-sorbent surface reactions."[993] The "contaminated flue gas stream" refers to a stream of mercury-containing gas.

[988] EX1010 (Sjostrom) at 10.

[989] EX1010 (Sjostrom) at 11.

[990] EX1010 (Sjostrom) at 10, 11, 15-16.

[991] Technology Background and State of the Art, §IX.G.2.

[992] EX1012 (Olson-646) ¶[0061].

[993] EX1012 (Olson-646) ¶[0043].

4. Claim 1: Element 1(c)—"wherein a weight ratio of the additive added to the coal, added to the combustion chamber, or a combination thereof, to an amount of the sorbent material added to the mercury-containing gas is from about 1:100 to about 30:100;"

581. This limitation is obvious over Sjostrom in view of Olson-646. Olson-646 includes repeated discussion of this ratio of halogen/halide promoter to sorbent: "the promoter is added at from about 1 to about 30 grams per 100 grams of activated carbon."[994] Regardless of whether the promoter is added to the coal (Location 1) or combustion chamber (Location 2) of Sjostrom, a POSITA would expect that the quantity of halogen-containing promoter in the flue gas (with the 1:100-30:100 ratio disclosed by Olson-646) would equal the halogen-containing promoter applied to the combustion chamber and/or coal, because nearly all the promoter would come from the additive itself (e.g., as opposed to native halogens in the coal) for the Powder River Basin (PRB) (western sub-bituminous) coal in Sjostrom.[995] A POSITA would have also expected that a significant portion of any halogens applied to coal or combustion chamber (as in Sjostrom) will work their way through to the flue gas.[996] Therefore, the weight ratio would be unchanged by adding the promoter

[994] EX1012 (Olson-646), ¶¶[0023], [0027]; *see also* EX1012 (Olson-646), cls. 3, 17, 37, 47.

[995] EX1010 (Sjostrom), 1, 3.

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

to the coal or combustion chamber as opposed to directly to the sorbent as in Olson-646,

582. Claim Element 1(c) is merely an attempt to claim a workable range for combining a conventional halogens (bromine, chlorine, iodine) being used in a conventional way (to oxidize mercury and promote activated carbon) with a conventional sorbent (activated carbon). Nothing in the '370 Patent specification attributes significance to the claimed range or establishes that the claimed range achieves unexpected results. The range presents nothing more than optimization of result-effective variables that would have been obvious to a POSITA. Patent Owner's expert in the Delaware litigation involving patents related to the '370 Patent stated that "power plants employing bromine additives and activated carbon would necessarily produce a sorbent that is 1 g to 30 g bromine per 100 g of activated carbon."[997] He further cited to this analysis for a claim that requires "the mercury-containing gas comprises about 1 g to about 30 g of the element bromine per 100 g of the sorbent."[998]

[997] EX1092 (O'Keefe Report) at 153 (cl. 4).

[998] EX1092 (O'Keefe Report) at 154 (cl. 29).

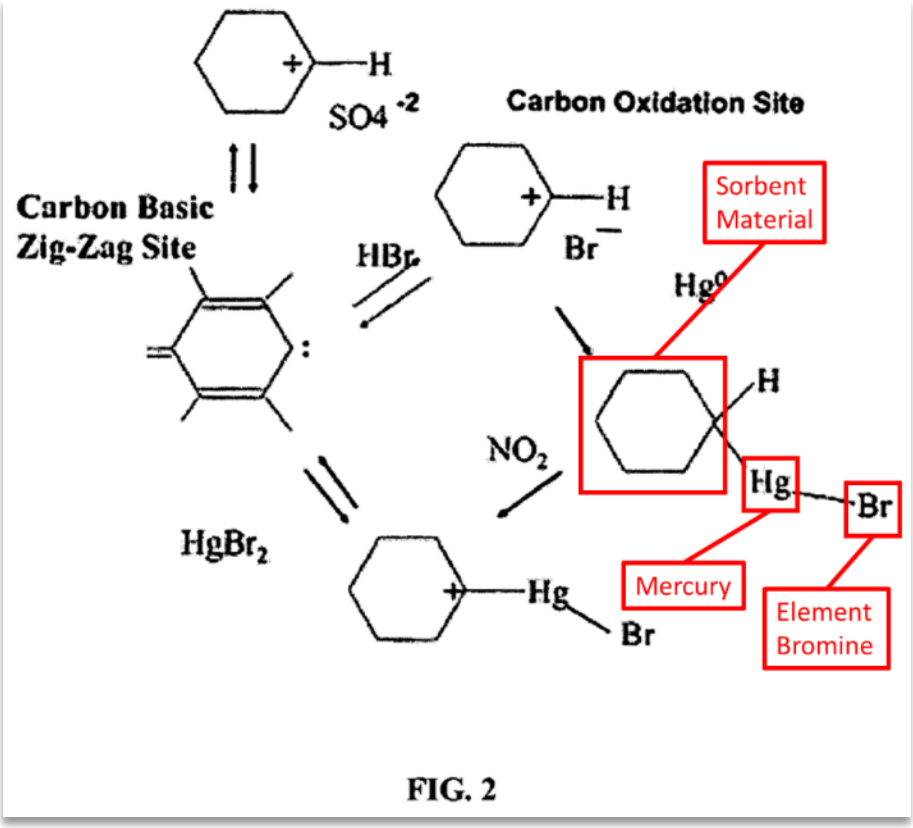
5. Claim 1: Element 1(d)—"contacting mercury in the mercury-containing gas with the sorbent material, to form a mercury-sorbent; and"

583. This limitation is disclosed by Sjostrom. The mercury in the flue gas is adsorbed, and thus contacted, with the sorbent. A POSITA would have understood that Norit DARCO FGD and related materials were referred to as a "sorbent" by Sjostrom, specifically because they adsorbed (and thus contacted) materials in the gas phase. It was a well-known use of activated carbon for adsorbing and thus removing mercury from the flue-gas stream. Upon adsorption, the mercury and activated carbon in the flue gas would form a mercury-sorbent composition.[999] Specifically, a POSITA would have understood that "sorbents" are used in a process called adsorption by which adsorbate (e.g., atoms, ions, or molecules) in a fluid (typically a gas) are bound to the surface of a sorbent, and thus by definition the sorbent is "contacting mercury in the mercury-containing gas" to form a mercury-sorbent composition, as per Claim Element 1(d).

584. This limitation is further obvious over Sjostrom in view of Olson-646. Olson-646 describes that mercury contacts the activated carbon in the flue gas. Indeed, Olson-646 discloses activated-carbon sorbent "that capture[s] mercury via

[999] Technology Background and State of the Art, §IX.C.3, §IX.G.2.

mercury-sorbent surface reactions,"[1000] Olson-646 further describes "AC mercury binding sites" (i.e., sites where mercury contacts the sorbent)[1001] and shows this mercury-sorbent composition in Figure 2 (annotated below).[1002]



Thus, Olson-646 discloses "contacting mercury in the mercury-containing gas with the sorbent material, to form a mercury-sorbent."

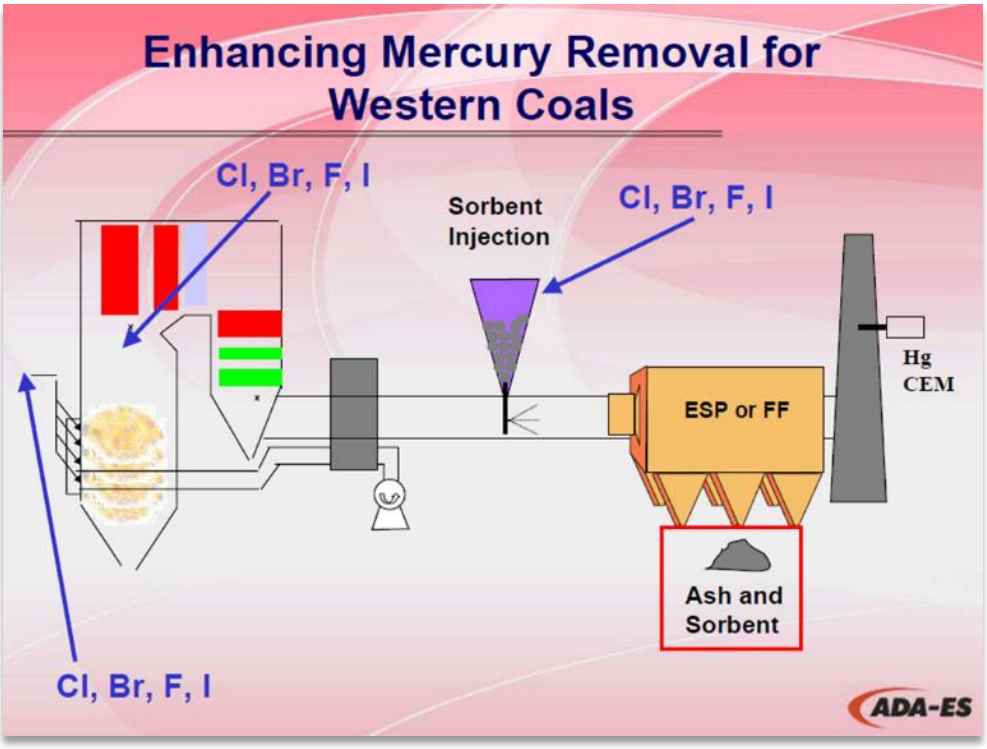
[1000] EX1012 (Olson-646) ¶[0043]; see also EX1012 (Olson-646) at Abstract.

[1001] EX1012 (Olson-646) ¶[0128].

[1002] EX1012 (Olson-646) at Figure 2.

6. Claim 1: Element 1(e)—"separating the mercury-sorbent from the mercury-containing gas."

585. This limitation is disclosed by Sjostrom. As shown in the annotated figure below, Sjostrom describes passing the flue gas through an electrostatic precipitator (ESP) or fabric filter (FF) after the bromine and sorbent injection.[1003]



This annotated figure in Sjostrom specifically shows that the mercury-sorbent composition would have been removed by the ESP or FF (pile of "Ash and Sorbent"). As described for Element 1(d), the sorbent is contacted with the mercury after it is introduced into the mercury-containing gas. Further, a POSITA would

[1003] EX1010 (Sjostrom) at 4 (annotations in red).

have understood that it was well-known that the ESP or FF would have separated solid material, including the mercury-sorbent composition.[1004] Thus, Sjostrom teaches "separating the mercury-sorbent from the mercury-containing gas."

586. It is also obvious in view of Olson-646, which discloses a particulate separator, such as an ESP or fabric filter.[1005] As described for Element 1(d), the sorbent is contacted with mercury after it is introduced into the mercury-containing gas. That mercury-sorbent composition is separated by a particulate separator (ESP or fabric filter).[1006]

D. CLAIMS DEPENDING FROM CLAIM 1

1. Claim 2: "The method of claim 1, further comprising adding the additive to the coal before combusting the coal."

587. This claim is obvious over Sjostrom in view of Olson-646. As I described above for Claim Element 1(a), the halogen-containing additive is added to the coal upstream of the combustion chamber.

[1004] *See* Technology Background and State of the Art, §IX.B.5.a.

[1005] EX1012 (Olson-646) ¶[0059]; *see also* EX1012 (Olson-646) ¶[0043] (disclosing that sorbent "capture[s] mercury via mercury-sorbent reactions").

[1006] EX1012 (Olson-646) ¶[0059].

2. Claim 3: "The method of claim 2, wherein the additive mixed with the coal is in a liquid."

588. This claim is obvious over Sjostrom in view of Olson-646. As discussed for Claim Element 1(a), Sjostrom discloses adding "KNX" at Location 1 (mixed with coal upstream of combustion chamber).[1007] KNX was an aqueous salt solution of calcium bromide.[1008] As confirmed by Claim 4, which depends from Claim 3, a "liquid" can include "water" and a "salt solution."

3. Claim 4: "The method of claim 3, wherein the liquid is a hydrocarbon, supercritical carbon dioxide, water, salt solution, or a combination thereof."

589. This claim is obvious over Sjostrom in view of Olson-646 for the reasons discussed for Claim 3. As discussed above for Claim 3, KNX is an aqueous salt solution of calcium bromide that liquid contains water and is a salt solution.

4. Claim 5: The method of claim 1, wherein carbocations in the activated carbon of the mercury-sorbent accept electrons from mercury atoms of the mercury-sorbent.

590. This claim limitation presents a proposed model of the chemistry already taking place when halogen-containing promoters contact activated-carbon sorbent. It is disclosed near-verbatim in Olson-646:

> [0093] According to our model, adding the bromine from the bromine reagent or a proton from a hydrogen halide acid to a

[1007] EX1010 (Sjostrom) at 23.

[1008] EX1106 (Variety of Hg Capture Solutions); EX1107 (KNXTM is effective).

> basic carbene site on the carbon edge structure forms a carbocation that accepts electrons from the neutral mercury atom forming the oxidized mercury species that is bound to the sorbent surface. The reactive site may also generate reactive bromine radicals or carbon radicals at the active sites on the carbon. Thus, the activated carbon serves to stabilize the bromine, yet provides a highly reactive bromine-containing reagent that can oxidize the mercury and promote its capture on the activated carbon. The sorbent that contains bromine is expected to be more reactive than the corresponding sorbent containing chlorine and much less expensive than the sorbent containing iodine. [1009]

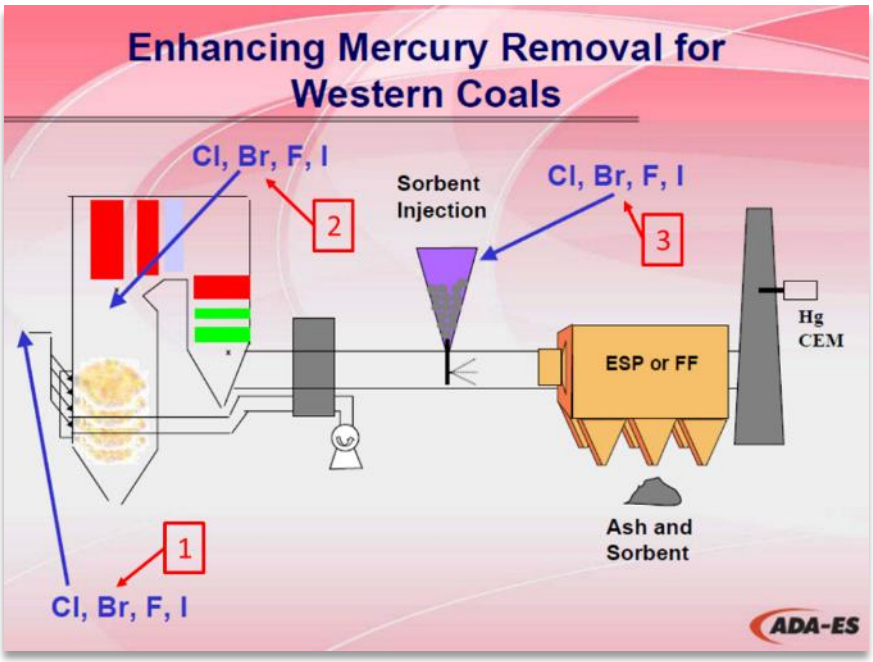
5. Claim 6: "The method of claim 1, wherein the additive is substantially in vapor form in the mercury-containing gas."

591. This limitation is obvious over Sjostrom in view of Olson-646. Sjostrom described testing mercury removal from flue gas of coal-fired power plants involving sorbent injection, halogen injection, and both sorbent and halogen injection.[1010] Specifically, the annotated figure below shows that Sjostrom teaches injection of halogens, and renders obvious injections of halides (e.g., $CaBr_2$), in at least three locations throughout the process.[1011]

[1009] EX1012 (Olson-646) ¶[0093]

[1010] EX1010 (Sjostrom) at 4.

[1011] EX1010 (Sjostrom) at 4 (annotations in red).



At combustion temperatures found within the furnace, halogens/halides added at Location 2 (directly to the combustion chamber) or Location 1 (to the coal before it enters the combustion chamber) would have been vaporized at combustion temperatures and would remain in vapor form when contacting the injected sorbent material in the mercury-containing flue gas.[1012] Sjostrom discloses that activated-carbon sorbent is injected into the mercury-containing gas at 290°F (143°C).[1013] The

[1012] EX1095 (Olson Dep.), 98:23-100:3, 231:3-9; EX1092 (O'Keefe Report) at 154 (discussion '114 Patent, claim 7).

[1013] EX1010 (Sjostrom) at 15.

boiling point of Br_2 is 58.8ºC and HBr is -66.38ºC, each well below the temperature of the mercury-containing flue gas.[1014]

592. This claim is further obvious in view of Olson-646, which teaches embodiments "wherein the halogen/halide promoter is in gaseous or vapor form" that comprises "gaseous HBr or Br_2."[1015]

6. Claim 7: "The method of claim 1, wherein the additive is chosen from Cl_2, HCl, sodium chloride, calcium chloride, and a combination thereof."

593. Sjostrom renders obvious Claim 7. As I discussed above for Claim Element 1(a), it would have been obvious to use widely available and inexpensive materials, such as calcium chloride (de-icing agent) and sodium chloride (NaCl, table salt) for the "Cl" taught by Sjostrom. A POSITA would have known that chlorides and bromides both are helpful to remediating mercury in that they oxidize mercury.[1016] For example, Crocker discusses "screening tests of several oxidation additives including chloride compounds (e.g., sodium chloride, hydrogen chloride, calcium chloride)."[1017]

[1014] EX1036 (CRC Handbook) at 4-53, 4-65.

[1015] EX1012 (Olson-646) ¶[0066].

[1016] *See, e.g.*, Technology Background and State of the Art, §§ IX.A.1, IX.A.7, IX.C.3, IX.C.4, IX.G.2; EX1048 (Carey) at 1169.

[1017] EX1062 (Crocker) at 2-3, 10.

594. It would have been obvious that the weight ratio of Claim Element 1(c) (of additive to sorbent) would be within "about 1:100 to about 30:100," at least because this range presents nothing more than optimization of result-effective variables that would have been obvious to a POSITA.

7. Claim 8: "The method of claim 1, wherein the additive is chosen from Br_2, HBr, sodium bromide, calcium bromide, and a combination thereof."

595. Sjostrom alone, and in combination with Olson-646, renders obvious Claim 8. As I discussed for Claim Element 1(a) and Claims 3-4, Sjostrom teaches using "KNX" for the "Br" additive, which was an aqueous calcium bromide solution.[1018] As I also discussed for Claim Element 1(a), Olson-646 discloses that the additive can be HBr or Br_2.

8. Claim 9: "The method of claim 1, wherein the additive is chosen from PBr_3, SCl_2, and a combination thereof."

596. Claim 9 is rendered obvious over Sjostrom in view of Olson-646. Olson-646 describes that "the halogen or halide promoter . . . may preferably

[1018] EX1106 (Variety of Hg Capture Solutions); EX 1107 (KNXTM is effective).

comprise. . . PBr_3 or SCl_2."[1019] Olson-646 also states that "the promoter is added at from about 1 to about 30 grams per 100 grams of activated carbon."[1020]

9. Claim 10: "The method of claim 1, wherein the additive is chosen from I_2, HI, sodium iodide, calcium iodide, potassium iodide, and combinations thereof."

597. Sjostrom alone, and in combination with Olson-646, renders obvious Claim 10. As I described above for Claim Element 1(a), Sjostrom describes that "I" (iodine-containing chemicals) can be added at Locations 1 and 2 to mitigate mercury. Olson-646 further motivates a POSITA to apply halogen-containing chemicals containing "I," because "the halide anions (especially bromide and iodide) were effective in promoting the oxidation by stabilizing the developing positive charge on the mercury in the transition state for oxidation. Based on this model, several innovative, inexpensive, activity-enhancing features have been developed."[1021] Olson-646 further identifies I_2 ("iodine") and HI (hydrogen iodide) as effective promoters.[1022] Olson-646 then states, "the promoter is added at from

[1019] EX1012 (Olson-646), ¶[0052]; *see also* EX1012 (Olson-646), ¶¶[0067], [0132]-[0133]; *see also* EX1012 (Olson-646), ¶¶[0023], [0037] (describing that "the promoter is added at from about 1 to about 30 grams per 100 grams of activated carbon").

[1020] EX1012 (Olson-646), ¶¶[0023], [0027]; *see* claims 3, 17, 37, 47.

[1021] EX1012 (Olson-646), ¶[0073]; *see also* EX1012 (Olson-646), cl. 40.

[1022] EX1012 (Olson-646), ¶[0067].

about 1 to about 30 grams per 100 grams of activated carbon."[1023] It would have been obvious to a POSITA to use other claimed iodine-containing chemicals, as they are widely available and effective in promoting activated carbon.[1024]

10. Claim 11: "The method of claim 1, wherein the activated carbon is chosen from powdered activated carbon, granular activated carbon, carbon black, carbon fiber, aerogel carbon, pyrolysis char, and combinations thereof."

598. This limitation is disclosed by Sjostrom. Sjostrom repeatedly discusses the use of activated carbon.[1025] Further, Sjostrom includes test results of "Untreated PAC Injection into ESP" for "PRB and Lignite Coals."[1026] The acronym "PAC" stands for "powdered activated carbon." Sjostrom also discusses testing done with the injection of "DARCO FGD" sorbent.[1027] A POSITA would have known that DARCO FGD was a well-known type of powdered activated-carbon sorbent.[1028]

[1023] EX1012 (Olson-646), ¶¶[0023], [0027]; *see* claims 3, 17, 37, 47.

[1024] *See, e.g.*, Technology Background and State of the Art, §§ IX.A.1, IX.A.7, IX.C.3, IX.C.4, IX.G.2; *see also* EX1062 (Crocker) at 2-3, 10 ("screening tests of several oxidation additives including … potassium iodide").

[1025] EX1010 (Sjostrom) at 10, 20, 34.

[1026] EX1010 (Sjostrom) at 20.

[1027] EX1010 (Sjostrom) at 15, 16,

[1028] Technology Background and State of the Art, §IX.C.3, § IX.G.2.

11. Claim 12: "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."

599. This limitation is obvious over Sjostrom in view of Olson-646. Olson-646 teaches "adding an optional alkali component."[1029] Olson-646 further discloses "co-injecting an optional alkaline material" into the mercury-containing gas, "including without limitation alkaline and alkaline earth components."[1030] Claims 31 and 40 of Olson-646 further disclose "co-injecting an optional alkaline component into the mercury containing flue gas stream."[1031] 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."[1032] 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

[1029] EX1012 (Olson-646) ¶[0017].

[1030] EX1012 (Olson-646) ¶[0026].

[1031] EX1012 (Olson-646) at claims 31, 40.

[1032] EX1012 (Olson-646) ¶[0026].

by Olson-646 in combination with Sjostrom as Olson-646 teaches that its use "improve[s] the efficiency of mercury capture."[1033]

600. Olson-646 further teaches that the alkaline component can "includ[e] without limitation alkaline and alkaline earth components," including "lime."[1034] Olson-646 further discloses that "the optional alkaline material may preferably comprise calcium oxide, sodium carbonate, and the like, as are known in the art."[1035] 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."

12. Claim 13: "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."

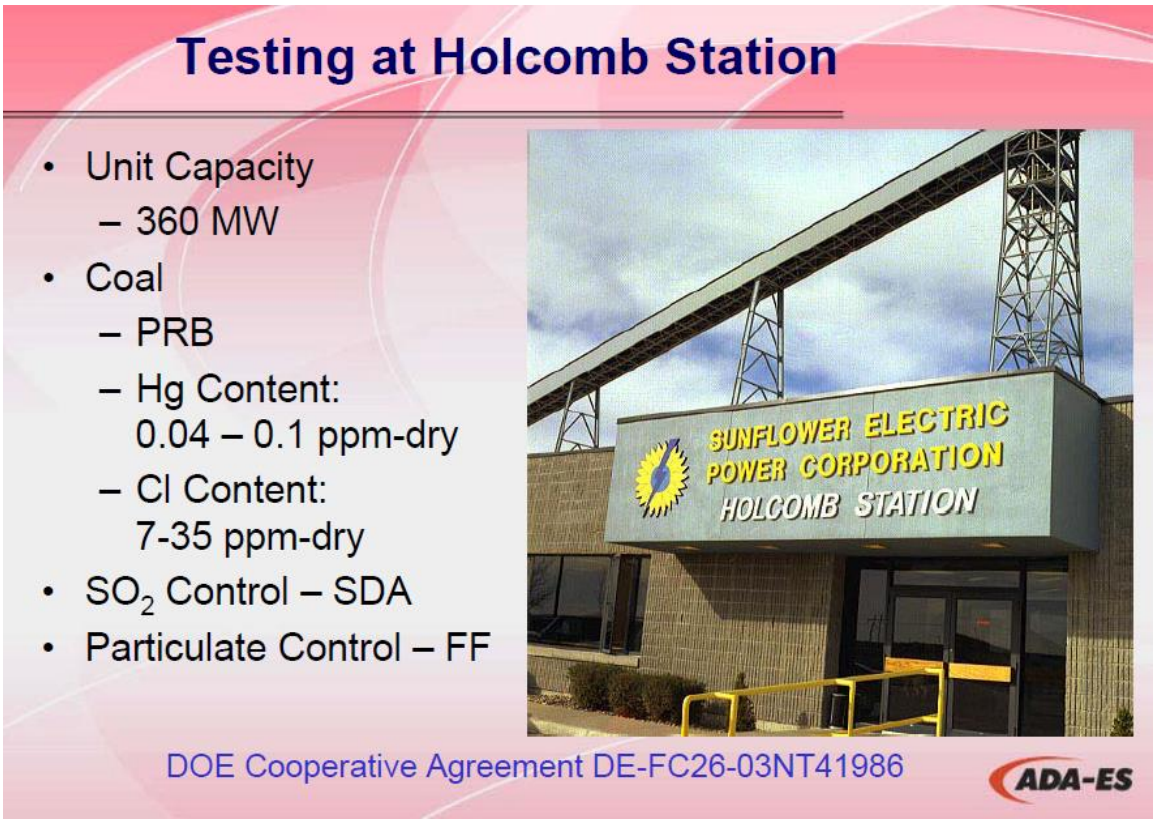
601. This limitation is disclosed by Sjostrom. Sjostrom discloses that SO_2 is present in the mercury-containing gas with the sorbent:[1036]

[1033] EX1012 (Olson-646) ¶¶[0026], [0127].

[1034] EX1012 (Olson-646) ¶ [0026].

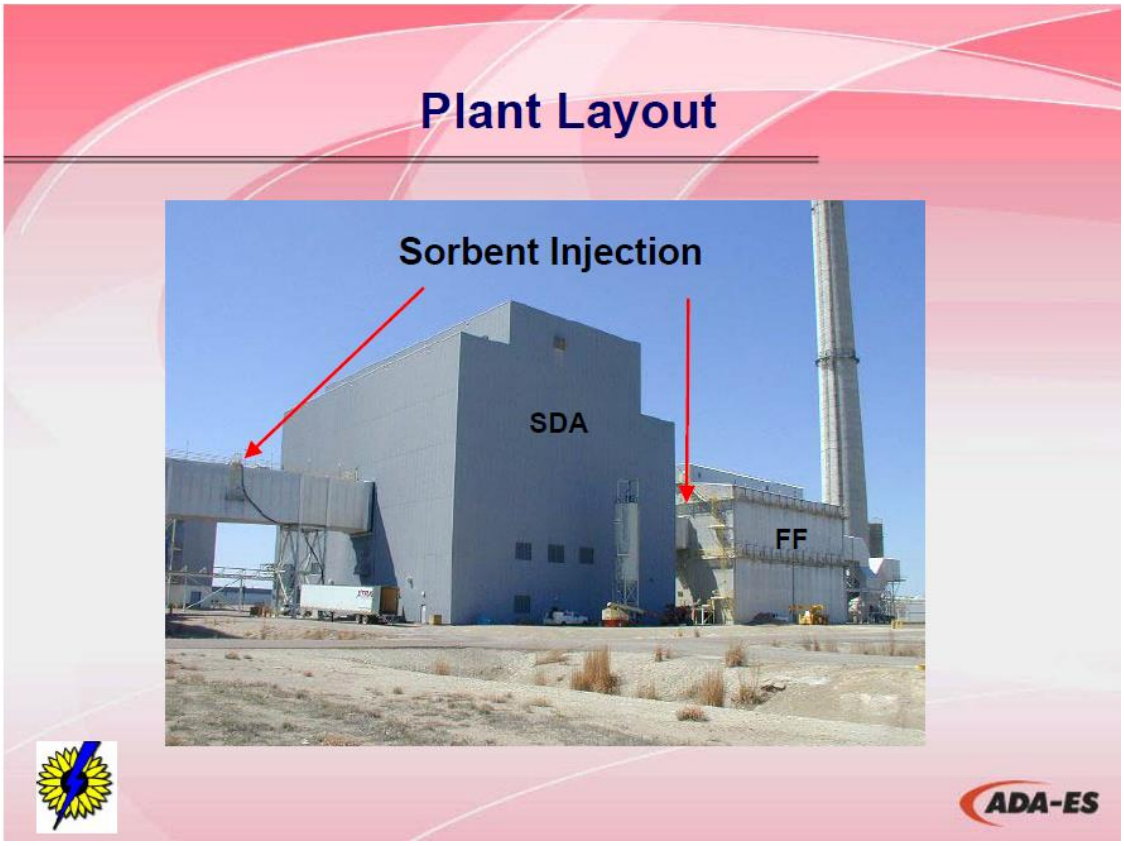
[1035] EX1012 (Olson-646) ¶ [0026].

[1036] EX1010 (Sjostrom) at 12 (describing "SO_2 Control – SDA").



The SO_2 is formed within the combustion chamber during coal combustion. Sjostrom confirms in the above graphic that the SO_2 is present 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.[1037]

[1037] EX1010 (Sjostrom) at 13.



Thus, a POSITA would have understood that the SO_2 would contact the sorbent material in the mercury-containing gas.

602. 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."[1038] A POSITA would have been

[1038] 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.[1039]

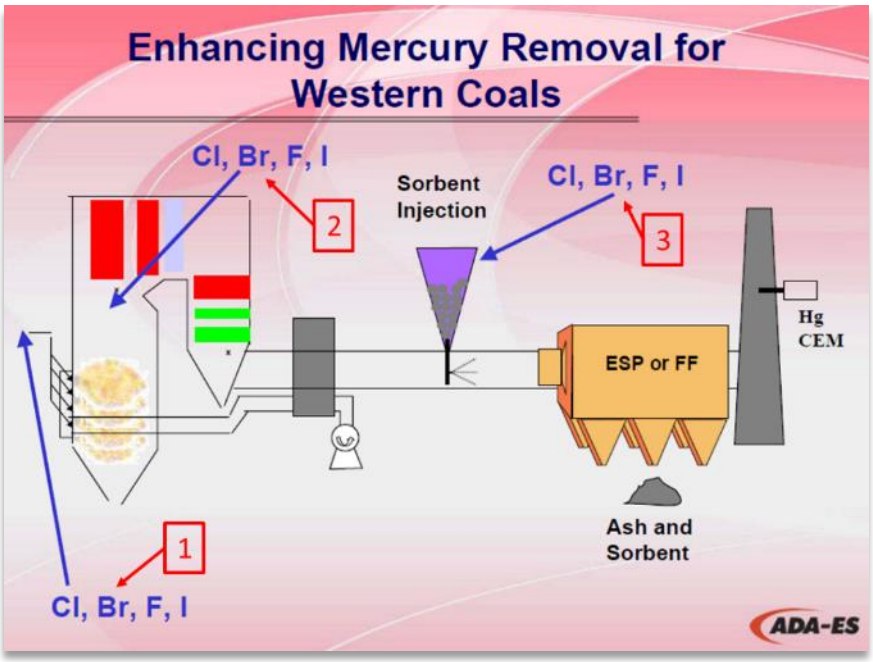
13. Claim 14: "The method of claim 1, further comprising contacting the sorbent material with a secondary component chosen from halogens, hydrogen halides, Group V halides, Group VI halides, and combinations thereof."

603. 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.[1040] Specifically, 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:[1041]

[1039] EX1012 (Olson-646) ¶[0074].

[1040] EX1010 (Sjostrom) at 4.

[1041] EX1010 (Sjostrom) at 4 (annotations in red).



Location 3 of Sjostrom teaches adding bromine or other halogens to the activated-carbon sorbent that is injected into the flue gas.[1042] 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.

604. This limitation is also obvious over Sjostrom in view of Olson-646. Olson-646 repeatedly refers to a "secondary component."[1043] Olson-646 provides

[1042] EX1010 (Sjostrom) at 4 (annotations in red).

[1043] EX1012 (Olson-646) ¶¶[0011], [0014], [0015], [0017], cls. 4-8, 11, 24-27, 38-43.

more detail of injecting a secondary component into flue gas in Figure 3, reproduced below.[1044]

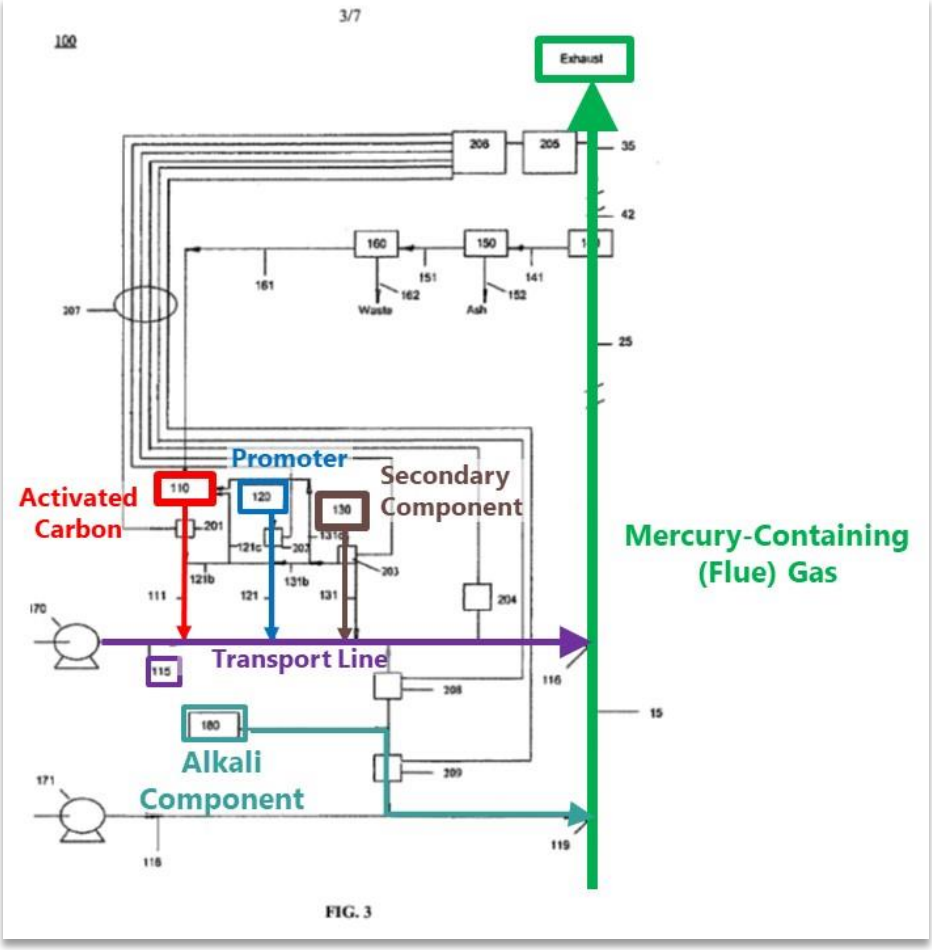


FIG. 3

Figure 3 of Olson-646 shows a schematic of "mercury control system 100 comprising preparation of promoted carbon sorbents," which includes "an optional secondary component reservoir 130, and an optional akali [*sic*] component reservoir

[1044] EX1012 (Olson-646) ¶[0056], Figure 3.

180."[1045] Specifically, Olson-646 teaches that "the optional secondary component may be contacted and react directly in transport line 115 via line 131, or optionally as described above with respect to the halogen/halide, via lines 131b and 131c."[1046] 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.[1047]

605. Olson-646 teaches that in certain embodiments, the "optional secondary component compris[es] a halogen or a hydrohalide."[1048] Olson-646

[1045] EX1012 (Olson-646) ¶[0056].

[1046] EX1012 (Olson-646) ¶[0063].

[1047] EX1012 (Olson-646) ¶[0128].

[1048] EX1012 (Olson-646) ¶[0014]; *see also* EX1012 (Olson-646) at Claim 4.

explains that these secondary components are added "such that the reactivity and mercury capacity of the sorbent are enhanced," by reacting with SOx to minimize competition with mercury for active binding sites on activated-carbon sorbent.[1049] A POSITA would have desired 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."[1050]

606. 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.[1051] 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.[1052] Thus, a POSITA would have had a reasonable expectation of success in adding the optional secondary component of Olson-646 to Location 3

[1049] EX1012 (Olson-646) ¶¶[0014], [0128]; *see also* EX1012 (Olson-646) at Claim 4.

[1050] EX1012 (Olson-646) ¶[0011].

[1051] EX1010 (Sjostrom) at 4.

[1052] EX1010 (Sjostrom) at 4.

of Sjostrom as they are described in both references as the location for simultaneous injection of sorbent and halogen.

607. In addition, Olson discloses embodiments wherein "the optional secondary component is selected from the group consisting of Group V halides, Group VI halides, HI, HBr, HCl, and combinations thereof."[1053] 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."[1054]

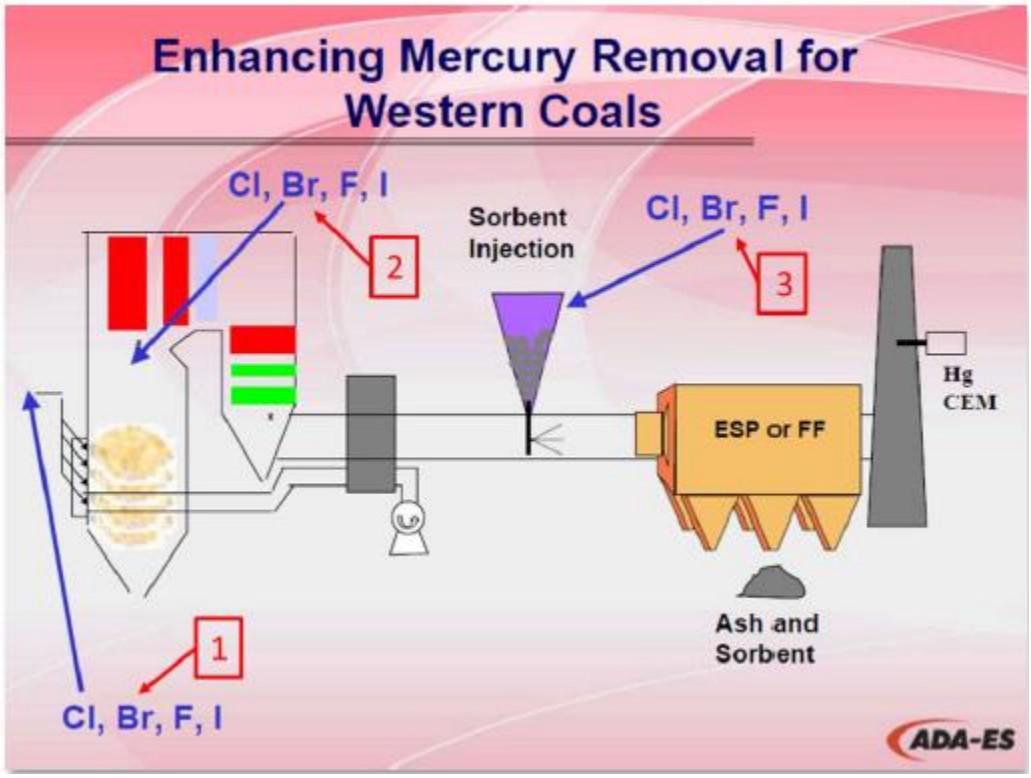
14. Claim 15: "The method of claim 14, wherein the secondary component is chosen from halogens, halide salts, HI, HBr, HCl, and combinations thereof."

608. As discussed for Claim 14, Sjostrom discloses injecting halogens ("Cl, Br, F, I") as a secondary component at Location 3 downstream of the combustion chamber. [1055]

[1053] EX1012 (Olson-646) ¶[0017]; *see also* EX1012 (Olson-646) at Claim 7.

[1054] EX1012 (Olson-646) ¶[0025]; *see also* EX1012 (Olson-646) at Claim 39.

[1055] EX1010 (Sjostrom) at 4 (annotations in red).



609. Claim 15 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."[1056]

15. Claim 16: "The method of claim 14, wherein the secondary component is chosen from I_2, HI, and combinations thereof."

610. As discussed for Claim 14, Sjostrom discloses injecting a secondary component comprising halogens ("Cl, Br, F, I") downstream of the combustion chamber at Location 3.[1057] It would have been obvious to a POSITA to inject "HI"

[1056] EX1012 (Olson-646) ¶[0017]; *see also* EX1012 (Olson-646) at Claim 7.

[1057] EX1010 (Sjostrom) at 4.

as the iodine agent ("I") taught by Sjostrom. Olson-646 discloses the "secondary component is selected from the group consisting of … HI."[1058]

16. Claim 18: "The method of claim 1, wherein the additive comprises a and b, b and c, a and c, or a, b, and c: a) I^- and/or I_2, b) Br^- and/or Br_2, c) Cl^- and/or Cl_2."

611. Claim 18 is rendered obvious by Sjostrom in view of Olson-646, further in view of Eckberg. As discussed above for Element 1(a) Sjostrom teaches adding various halogens, including "Cl, Br, …, I" to the combustion chamber and/or coal. As additionally discussed above for Claim Element 1(a), it would have been obvious to use widely available materials, including aqueous solutions of a halide compounds like $CaCl_2$ and $CaBr_2$ (for the "Cl" and "Br" taught by Sjostrom). A POSITA would have understood that bromine and chlorine compounds in an aqueous solution would dissociate such that the solution contains Br- and Cl- ions, respectively. A POSITA would also have been motivated to add both aqueous solutions of halide compounds as Sjostrom teaches the addition of multiple types of halogens. Nothing in the '370 Patent specification attributes significance to the addition of multiple types of halogens versus only one type of halogen or establishes that the combination of halogens interacts in an unpredictable or unexpected way or achieves unexpected results.

[1058] EX1012 (Olson-646) ¶[0017]; *see also* ¶¶[0067], [0074] (similar).

E. INDEPENDENT CLAIM 17

612. Claim 17 is nearly identical to Claims 1 and 18, with minor changes, as shown in the redline below:

~~1~~17. A method for separating mercury from a mercury-containing gas, the method comprising:

combusting ~~a mixture of~~ coal ~~and~~comprising an additive in a combustion chamber, ~~to form the mercury-containing gas,~~ wherein the additive is chosen from halides, halogens, salts thereof, and combinations thereof~~; [18.~~, to form the mercury-containing gas, wherein the additive comprises a and b, b and c, a and c, or a, b, and c:

a) I^- and/or I_2,

b) Br^- and/or Br_2,

c) Cl^- and/or Cl_2~~.]~~;

~~adding a particulate~~injecting a sorbent material comprising activated carbon into the mercury-containing gas, wherein a weight ratio of the additive added to the coal, added to the combustion chamber, or a combination thereof, to an amount of the sorbent material added to the mercury-containing gas is from about 1:100 to about 30:100;

contacting mercury in the mercury-containing gas with the sorbent material, to form a mercury-sorbent; and

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

Claim 17 is disclosed for the reasons described for Claims 1 and 18. The differences are discussed below.

1. Claim 17: Preamble—"A method for separating mercury from a mercury-containing gas, the method comprising:"

613. The language of Claim Element 17(Preamble) is identical to the language of Claim Element 1(Preamble). Accordingly, the explanation I provide

above for Claim Element 1(Preamble) applies equally to Claim Element 17(Preamble).

2. Claim 17: Element 17(a)—"combusting coal comprising an additive in a combustion chamber, wherein the additive is chosen from halides, halogens, salts thereof, and combinations thereof, to form the mercury-containing gas, wherein the additive comprises a and b, b and c, a and c, or a, b, and c: a) I^- and/or I_2, b) Br^- and/or Br_2, c) Cl^- and/or Cl_2;"

614. The language of Claim Element 17(a) is nearly identical to the language of Claim Element 1(a) and Claim 18. Accordingly, the explanation I provide above for Claim Element 1(a) and Claim 18 applies equally to Claim Element 17(a). As discussed above for Claim Element 1(a) and Claims 7 and 10, Sjostrom in view of Olson-646 discloses that the coal combusted in the combustion chamber comprises the additive.

3. Claim 17: Element 17(b)—"injecting a sorbent material comprising activated carbon into the mercury-containing gas,"

615. The language of Claim Element 17(b) is nearly identical to the language of Claim Element 1(b) except "adding" is replaced with "injecting" and "particulate" has been removed. As described above for Claim Element 1(b), Sjostrom in view of Olson-646 discloses injecting a sorbent material comprising activated carbon into the mercury-containing gas.

4. Claim 17: Element 17(c)—"wherein a weight ratio of the additive added to the coal, added to the combustion chamber, or a combination thereof, to an amount of the sorbent material added to the mercury-containing gas is from about 1:100 to about 30:100;"

616. The language of Claim Element 17(c) is identical to the language of Claim Element 1(c). Accordingly, the explanation I provide above for Claim Element 1(c) applies equally to Claim Element 17(c). When using multiple types of halogens (e.g., mixing iodine-containing chemicals, chlorine-containing chemicals, and bromine-containing chemicals), it would have been obvious for the weight ratios to remain within the 1:100 to 30:100 range, as I describe above for Claims 7, 10, and 18.

5. Claim 17: Element 17(d)—"contacting mercury in the mercury-containing gas with the sorbent material, to form a mercury-sorbent; and"

617. The language of Claim Element 17(d) is identical to the language of Claim Element 1(d). Accordingly, the explanation I provide above for Claim Element 1(d) applies equally to Claim Element 17(d).

6. Claim 17: Element 17(e)—"separating the mercury-sorbent from the mercury-containing gas."

618. The language of Claim Element 17(e) is identical to the language of Claim Element 1(e). Accordingly, the explanation I provide above for Claim Element 1(e) applies equally to Claim Element 17(e).

XIX. GROUND B4: OBVIOUSNESS OVER SJOSTROM IN VIEW OF OLSON-646, FURTHER IN VIEW OF ECKBERG

619. It is my opinion that Claims 1-18 would have been obvious over the combination of Sjostrom and Olson-646, further in view of Eckberg (Ground B4). Ground B4 relies on the combination of Sjostrom and Olson-646 (Ground B3), with certain claim limitations also disclosed by Eckberg. In the subsections below, I discuss the reasons a POSITA would have combined Sjostrom and Olson-646 with Eckberg, followed by disclosure of the specific combination.

A. REASONS TO COMBINE

620. A person of skill in the art would have been motivated to combine the combination of Sjostrom and Olson-646 (Ground B3) with 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). The references teach the use of 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."[1059] Sjostrom provides an overall process schematic showing activated-

[1059] EX1010 (Sjostrom) at 1.

carbon sorbents for mercury removal in coal-fired flue gas.[1060] Sjostrom discusses that activated carbon was a well-known sorbent for mercury control and discloses suitable ranges for sorbent injection rate.[1061] Sjostrom teaches adding halogen-containing reagents (including bromine-containing, chlorine-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 halogen-containing chemical to use or the quantity to add.[1062]

621. 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."[1063] Eckberg includes a similar process schematic as Sjostrom that shows injection of halogens into a coal-fired boiler for mercury removal.[1064] Eckberg tells a POSITA

[1060] EX1010 (Sjostrom) at 4.

[1061] EX1010 (Sjostrom) at 10, 11, 16.

[1062] EX1010 (Sjostrom) at 4.

[1063] EX1011 (Eckberg) at 1.

[1064] EX1011 (Eckberg) at 5.

the type of bromine and chlorine to be used (aqueous solutions of 52 wt% calcium bromide, $CaBr_2$, and 25 wt% calcium chloride).[1065]

622. 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.[1066] 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.[1067] Namely, Sjostrom was presented in the A3b slot and Eckberg was presented in the A3c slot.[1068] Further, both presentations included a common author—Dr. Ramsay Chang, Ph.D.—and shared a common partner, namely EPRI.[1069] 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

[1065] EX1011 (Eckberg) at 3, 9, 14, 15.

[1066] EX1030 (EUEC Handout) at 23.

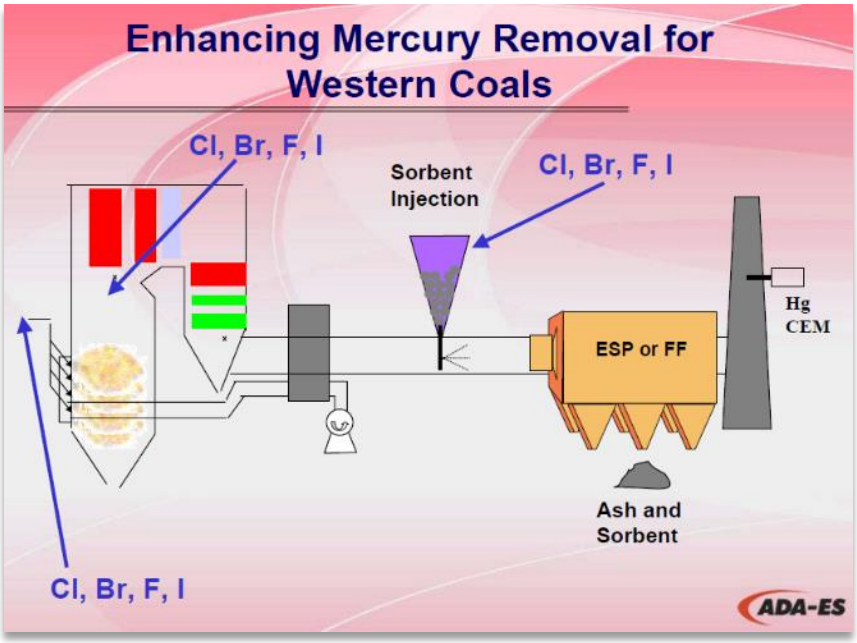
[1067] EX1030 (EUEC Handout) at 23.

[1068] EX1030 (EUEC Handout) at 23.

[1069] EX1030 (EUEC Handout) at 23.

Eckberg sequentially, thereby increasing the likelihood that a POSITA would have viewed the two references as interoperable with each other.

623. 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.[1070]



Sjostrom demonstrates that activated-carbon sorbent injection was a well-known way of treating mercury emissions in flue gas.[1071] Sjostrom also teaches that halogens (e.g., "Cl, Br, F, I") may be injected within the process in multiple

[1070] EX1010 (Sjostrom) at 4.

[1071] EX1010 (Sjostrom) at 10-11.

locations.[1072] A POSITA would have understood that the "Cl, Br, F, I" of Sjostrom referred generally to the addition of chlorine, bromine, fluorine, and iodine in any form, rather than the pure elemental form alone. In fact, a POSITA would have understood that the pure elemental forms of these elements are not readily obtainable and would not have been strong candidates for injection in the system of Sjostrom. Sjostrom includes numerous charts detailing the "Hg Removal (%)" and "Hg Removal Efficiency (%)" achieved throughout the testing performed on coal flue gas.[1073] 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.[1074]

624. 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. To the extent that Sjostrom and Olson-646 do not identify the specific halogen-containing chemical to add to the combustion chamber or coal, Eckberg provides those implementation

[1072] EX1010 (Sjostrom) at 4.

[1073] EX1010 (Sjostrom) at 8, 15-17, 20, and 21.

[1074] EX1010 (Sjostrom) at 16.

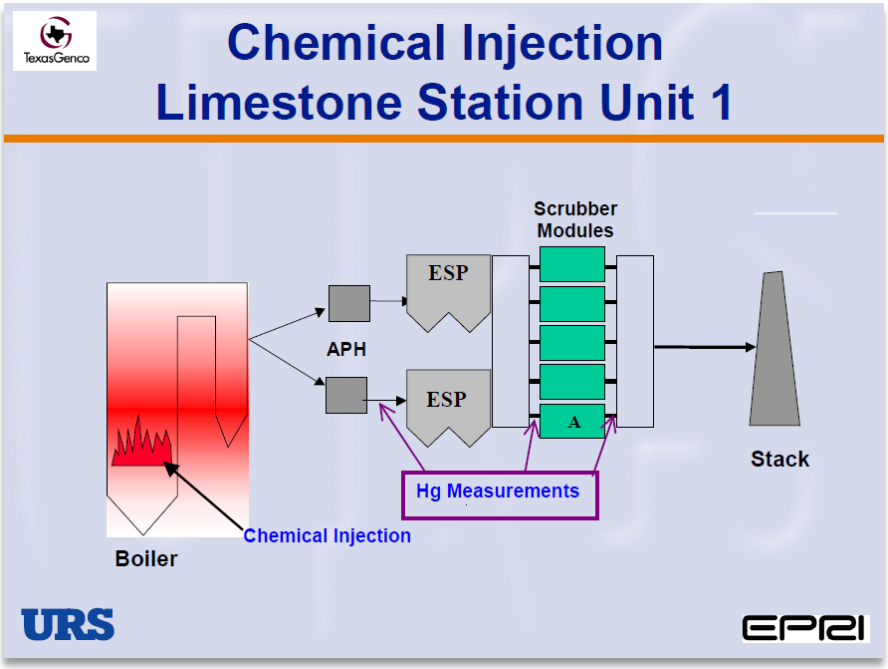
details and supplements the teachings of Sjostrom. A person of skill in the art would have looked to the Eckberg reference to further tune implementation of a system like that of Sjostrom, because it expressly describes the chemical formula of the halogen (adding calcium bromide, $CaBr_2$, and calcium chloride, $CaCl_2$), onto the coal or into the combustion chamber and having it react to provide HBr or HCl in the flue gas. Specifically, Eckberg teaches injection of "$CaCl_2$ (25 wt%)" or "$CaBr_2$ (52 wt%)" into the combustion chamber.[1075]

625. 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."[1076] 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.[1077]

[1075] EX1011 (Eckberg) at 9.

[1076] EX1011 (Eckberg) at 3.

[1077] EX1011 (Eckberg) at 5.

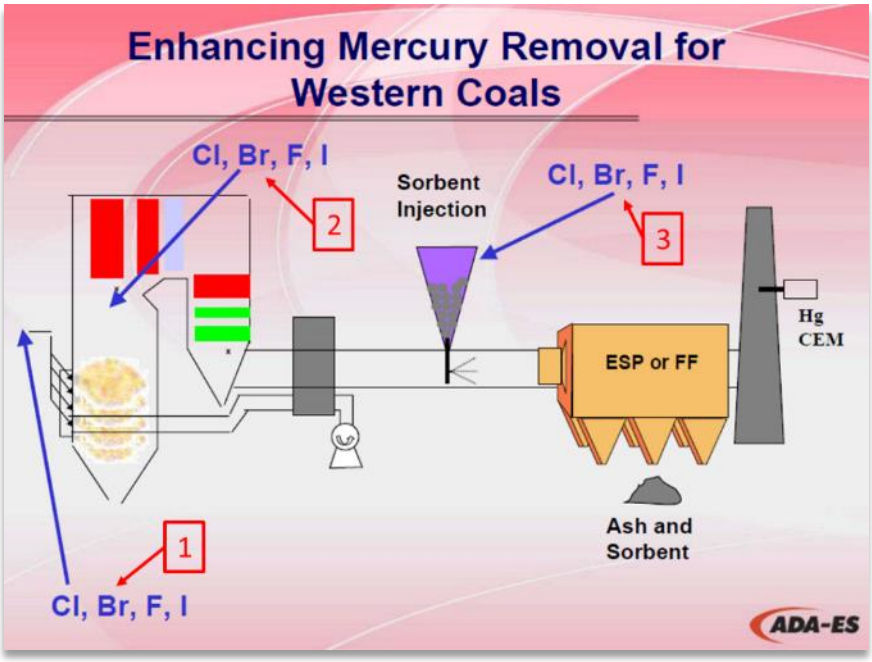


As discussed below, a POSITA would have been motivated to apply the teachings of Eckberg to Sjostrom because it would have provided well-known chemical substances that could be used as the "Br" and "Cl" identified in the figures of Sjostrom.

626. 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.[1078] Specifically, the

[1078] EX1010 (Sjostrom) at 4.

annotated figure below shows that Sjostrom teaches adding halogens in at least three locations.[1079]



Location 2 of Sjostrom teaches Br into the boiler,[1080] the same location as in Eckberg.

627. A POSITA would have a reasonable expectation of success applying Eckberg's teachings regarding the specific type and concentration of addition of halogen-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

[1079] EX1010 (Sjostrom) at 4 (annotations in red).

[1080] EX1010 (Sjostrom) at 4 (annotations in red).

operating at similar conditions. Indeed, both references teach mercury removal for the same types of coal, Powder River Basin (abbreviated PRB and also referred to as western subbituminous) and Texas Lignite.[1081] Thus, a POSITA would have had a reasonable expectation of success in using the salt solutions of Eckberg in the system of Sjostrom.

628. 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.[1082] Both references include similar surrounding equipment, such as boilers, air pre-heaters, and an ESP.[1083]

629. Thus, applying implementation details from Eckberg into the teachings of Sjostrom would be a simple substitution of one known element (the halogen-containing additives in Sjostrom) for another known element (the $CaBr_2$ and/or $CaCl_2$ in Eckberg) to obtain predictable results of at least 70% mercury removal. Both references use known techniques (halogen/halide promotion) to improve

[1081] EX1010 (Sjostrom) at 3-8; EX1011 (Eckberg) at 2, 6.

[1082] EX1010 (Sjostrom) at 4; EX1011 (Eckberg) at 2, 9.

[1083] EX1010 (Sjostrom) at 4; EX1011 (Eckberg) at 5.

known materials (activated carbon) in the same way. Both Sjostrom and Eckberg are in the same field of endeavor, as they were presented one right after the other at the 2005 EUEC. In combining Sjostrom with Eckberg, no modifications would need to be made to the overall process equipment, operating conditions, or activated carbon sorbent used in Sjostrom.

B. DISCLOSURE AND TEACHINGS OF THE COMBINATIONS

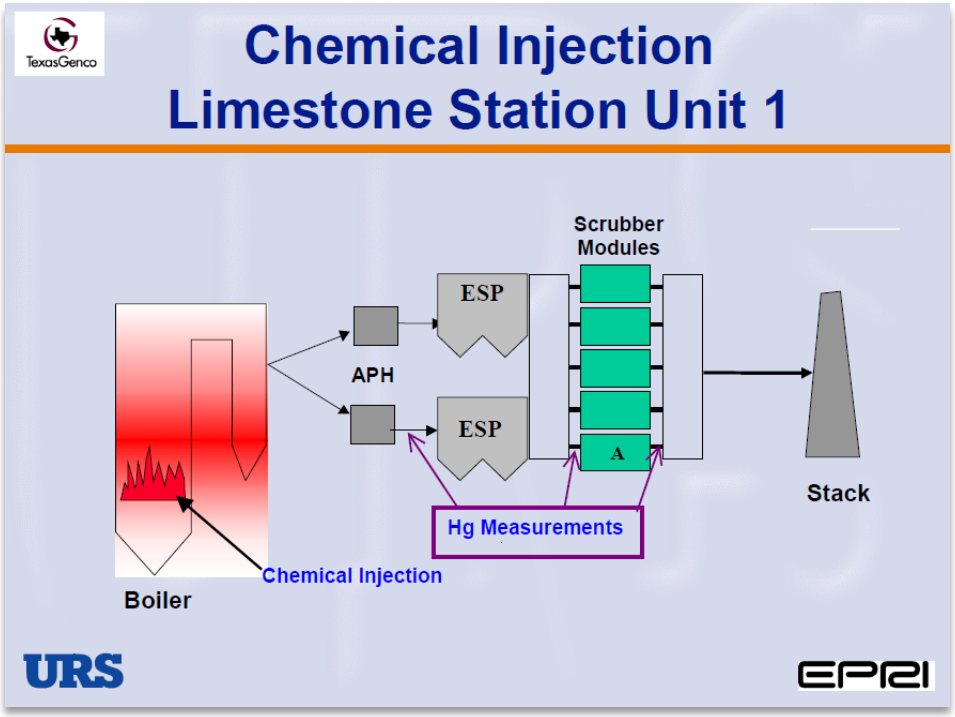
630. It is my opinion that the combination of Sjostrom in view of Olson-646, and further in view of Eckberg (Ground B4) renders obvious the claims below, as well as the claims discussed in Ground B3, of the Challenged Patent.

C. INDEPENDENT CLAIM 1

1. Claim 1: Element 1(a)—"combusting a mixture of coal and an additive in a combustion chamber, to form the mercury-containing gas, wherein the additive is chosen from halides, halogens, salts thereof, and combinations thereof;"

631. In addition to the reasons I discussed for Ground B3, this limitation is further obvious over Eckberg. As shown in the figure below, Eckberg explicitly describes combusting coal in a boiler.[1084]

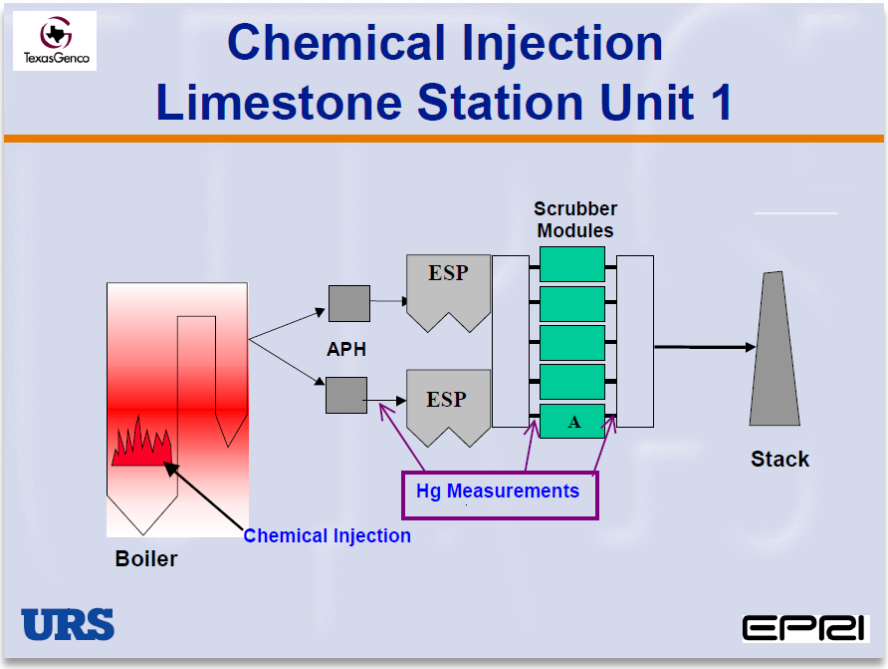
[1084] EX1011 (Eckberg) at 5.



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.

632. The identification of the specific halogen-containing ingredient is also obvious over Eckberg. As shown in the figure below, Eckberg teaches "chemical injection" to the boiler.[1085]

[1085] EX1011 (Eckberg) at 5.



Specifically, Eckberg teaches injection of aqueous solutions of "$CaBr_2$ (52 wt%)" and "$CaCl_2$ (25 wt%)" into the boiler.[1086] A POSITA would have understood that calcium bromide and calcium chloride were examples of a halides and halide salts.

633. 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 $CaBr_2$ and/or $CaCl_2$) to the system of Sjostrom. A POSITA would have been motivated to supplement the system of Sjostrom ("Br" and "Cl" at Locations 1 and/or 2) with the teachings of Eckberg (aqueous solution of $CaBr_2$ and/or $CaCl_2$ as the "Br" and "Cl"), at least because calcium bromide and calcium chloride were widely obtainable and relatively cheap

[1086] EX1011 (Eckberg) at 9; see also EX1011 (Eckberg) at 8.

form of bromine and chlorine. A POSITA would have been further motivated to add the $CaBr_2$ and/or $CaCl_2$ of Eckberg to the coal and combustion chamber, because when it is heated in the furnace, it would react to form the hydrohalide and molecular-halogen (e.g. HBr and Br_2) gas-phase promoters called for by Olson-646.[1087]

D. CLAIMS DEPENDING FROM CLAIM 1

1. Claim 3: "The method of claim 2, wherein the additive mixed with the coal is in a liquid."

634. This claim is obvious over Sjostrom in view of Olson-646, further in view of Eckberg. As described for Claim Element 1(a) in Ground B3, Sjostrom discloses adding "Br" or "Cl" at Location 1 (mixed with coal upstream of combustion chamber).

635. Eckberg discloses that the form of the halogen-containing chemicals are aqueous solutions of calcium bromide and/or calcium chloride (i.e., salt solutions), which are liquids.[1088] As confirmed by Claim 4, which depends from Claim 3, a "liquid" can include "water" and a "salt solution."

[1087] EX1095 (Olson Dep.) at 98:23-100:3, 231:3-9.

[1088] EX1011 (Eckberg) at 5, 8-9.

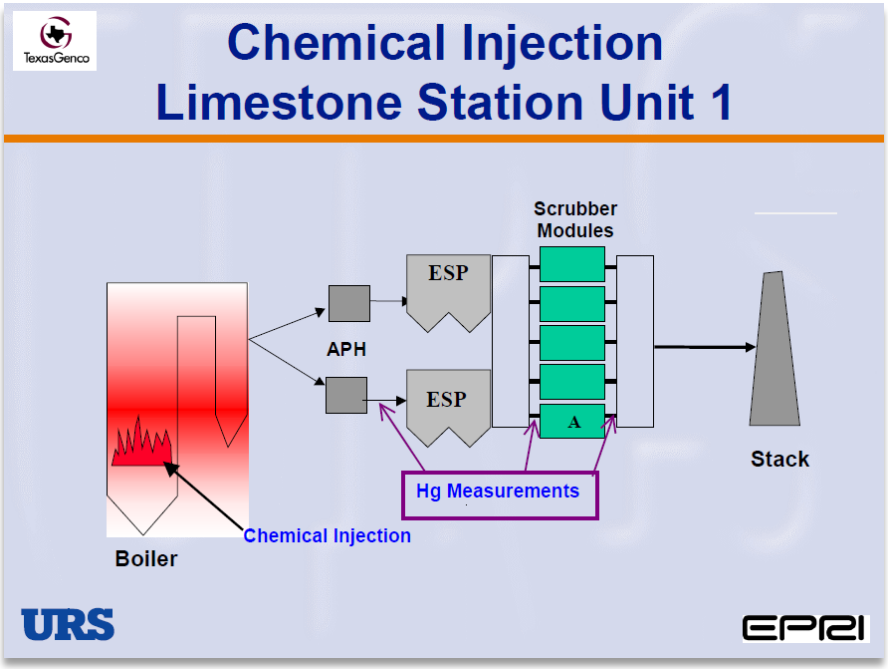
2. Claim 4: "The method of claim 3, wherein the liquid is a hydrocarbon, supercritical carbon dioxide, water, salt solution, or a combination thereof."

636. This claim is obvious over Sjostrom in view of Olson-646, further in view of Eckberg, for the reasons discussed for Claim 3. As discussed above for Claim 3, the liquid contains water and is a salt solution.

3. Claim 6: "The method of claim 1, wherein the additive is substantially in vapor form in the mercury-containing gas."

637. This claim is obvious over Sjostrom in view of Olson-646, further in view of Eckberg. In addition to the reasons I discussed for Ground B3, this claim is further obvious over Eckberg. As discussed for Claim Element 1(a), Eckberg teaches "chemical injection" to the boiler.[1089]

[1089] EX1011 (Eckberg) at 5.



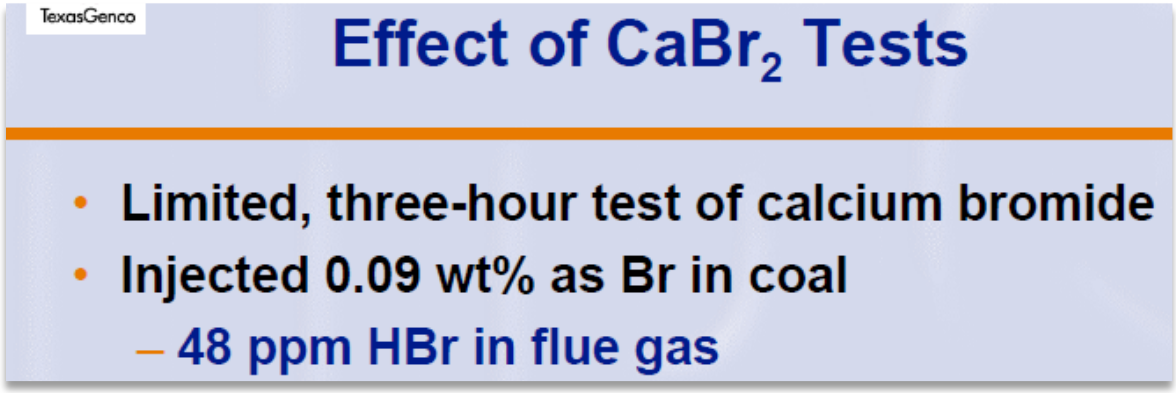
Specifically, Eckberg teaches injection of aqueous solutions of "$CaBr_2$ (52 wt%)" and "$CaCl_2$ (25 wt%)" into the boiler.[1090] Further, Eckberg explains that the $CaBr_2$ and $CaCl_2$ salt is injected at a "Liquid Salt Feed Rate (gpm)."[1091]

638. A POSITA would have known that the Br and Cl injected in Sjostrom would have been in the form of an aqueous solution containing a bromide salt and/or chloride salt, which are in liquid form as taught by Eckberg. A POSITA would have understood that at combustion temperatures found within the boiler, at least a portion of the aqueous calcium bromide and/or calcium chloride injected at either Location 1 or Location 2 would have vaporized and reacted in the combustion chamber,

[1090] EX1011 (Eckberg) at 8-9.

[1091] EX1011 (Eckberg) at 9.

leaving the boiler as HBr and HCl, respectively, in the vapor phase.[1092, 1093] Eckberg repeatedly refers to concentrations of HBr and HCl vapor in the mercury-containing gas:[1094]



TexasGenco **Chemical Addition to Unit 1 Boiler Limestone Station**

Salt	Weight % Chloride/ Bromide (% relative to coal)	Liquid Salt Feed Rate (gpm)	Theoretical Gas Conc. (ppm HCl or ppm HBr)
$CaCl_2$ (25 wt%)	0.03	1.9	40
	0.06	4.0	80
	0.10	6.4	120
	0.13	8.2	155
$CaBr_2$ (52 wt%)	0.09	1.6	50

[1092] Patent Owner's expert agrees. EX1092 (O'Keefe Report) at 154, 170, 176.

[1093] EX1036 (CRC Press: March 2005) at 4-53 and 4-65.

[1094] EX1011 (Eckberg) at 2, 7, 9, 11, 13-14.

4. Claim 7: "The method of claim 1, wherein the additive is chosen from Cl_2, HCl, sodium chloride, calcium chloride, and a combination thereof."

639. This claim is obvious over Sjostrom in view of Olson-646, further in view of Eckberg. In addition to the reasons I discussed for Ground B3, this claim is further obvious over Eckberg. As described for Element 1(a), it would have been obvious to a POSITA to use widely available materials, including aqueous solutions of a halide compounds like calcium chloride ($CaCl_2$) (for "Cl" taught by Sjostrom, as disclosed by Eckberg).

5. Claim 8: "The method of claim 1, wherein the additive is chosen from Br_2, HBr, sodium bromide, calcium bromide, and a combination thereof."

640. This claim is obvious over Sjostrom in view of Olson-646, further in view of Eckberg. In addition to the reasons I discussed for Ground B3, this claim is further obvious over Eckberg. As described for Element 1(a), it would have been obvious to use widely available materials, including aqueous solutions of a halide compounds like calcium bromide ($CaBr_2$) (for "Br" taught by Sjostrom, as disclosed by Eckberg).

6. Claim 18: "The method of claim 1, wherein the additive comprises a and b, b and c, a and c, or a, b, and c: a) I^- and/or I_2, b) Br^- and/or Br_2, c) Cl^- and/or Cl_2."

641. Claim 18 is rendered obvious by Sjostrom in view of Olson-646, further in view of Eckberg. In addition to the reasons described for Claim 18 in Ground B3,

this claim is further obvious over Eckberg. As discussed above for Claim Element 1(a) for Ground B3, Sjostrom teaches adding various halogens, including "Cl, Br," to the combustion chamber and/or coal. As discussed above for Claim Element 1(a) for Ground B4, Eckberg discloses injection of aqueous solutions of $CaBr_2$, $CaCl_2$,[1095] and a POSITA would have been motivated to supplement the system of Sjostrom ("Br" and "Cl" at Locations 1 and/or 2) with Eckberg's aqueous solutions of $CaBr_2$ and/or $CaCl_2$, respectively. A POSITA would have understood that calcium bromide and calcium chloride would dissociate in aqueous solutions such that the solution contains Br- and Cl- ions, respectively. A POSITA would have been motivated to add aqueous solutions of both halide compounds as Sjostrom teaches the addition of multiple types of halogens. Nothing in the '370 Patent specification attributes significance to the addition of multiple types of halogens versus only one type of halogen or establishes that the combination of halogens interacts in an unpredictable or unexpected way or achieves unexpected results.

E. INDEPENDENT CLAIM 17

642. Claim 17 is nearly identical to Claims 1 and 18, with minor changes, as shown in the redline below:

[1095] EX1011 (Eckberg) at 8-9.

~~1~~17. A method for separating mercury from a mercury-containing gas, the method comprising:

combusting ~~a mixture of~~ coal ~~and~~comprising an additive in a combustion chamber, ~~to form the mercury-containing gas,~~ wherein the additive is chosen from halides, halogens, salts thereof, and combinations thereof~~; [18.~~, to form the mercury-containing gas, wherein the additive comprises a and b, b and c, a and c, or a, b, and c:

a) I^- and/or I_2,

b) Br^- and/or Br_2,

c) Cl^- and/or Cl_2.~~]~~;

~~adding a particulate~~injecting a sorbent material comprising activated carbon into the mercury-containing gas, wherein a weight ratio of the additive added to the coal, added to the combustion chamber, or a combination thereof, to an amount of the sorbent material added to the mercury-containing gas is from about 1:100 to about 30:100;

contacting mercury in the mercury-containing gas with the sorbent material, to form a mercury-sorbent; and

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

Claim 17 is disclosed for the reasons described for Claims 1 and 18. The differences are discussed below.

1. Claim 17: Preamble—"A method for separating mercury from a mercury-containing gas, the method comprising:"

643. The language of Claim Element 17(Preamble) is identical to the language of Claim Element 1(Preamble). Accordingly, the explanation I provide above for Claim Element 1(Preamble) applies equally to Claim Element 17(Preamble).

2. Claim 17: Element 17(a)—"combusting coal comprising an additive in a combustion chamber, wherein the additive is chosen from halides, halogens, salts thereof, and combinations thereof, to form the mercury-containing gas, wherein the additive comprises a and b, b and c, a and c, or a, b, and c: a) I^- and/or I_2, b) Br^- and/or Br_2, c) Cl^- and/or Cl_2;"

644. The language of Claim Element 17(a) is nearly identical to the language of Claim Element 1(a) and Claim 18. Accordingly, the explanation I provide above for Claim Element 1(a) and Claim 18 applies equally to Claim Element 17(a). As discussed above for Claim Element 1(a), Sjostrom discloses that the coal combusted in the combustion chamber comprises the additive.

3. Claim 17: Element 17(b)—"injecting a sorbent material comprising activated carbon into the mercury-containing gas,"

645. The language of Claim Element 17(b) is nearly identical to the language of Claim Element 1(b) except "adding" is replaced with "injecting" and "particulate" has been removed. As described above for Claim Element 1(b), Sjostrom discloses injecting a sorbent material comprising activated carbon into the mercury-containing gas.

4. Claim 17: Element 17(c)—"wherein a weight ratio of the additive added to the coal, added to the combustion chamber, or a combination thereof, to an amount of the sorbent material added to the mercury-containing gas is from about 1:100 to about 30:100;"

646. The language of Claim Element 17(c) is identical to the language of Claim Element 1(c). Accordingly, the explanation I provide above for Claim Element 1(c) applies equally to Claim Element 17(c). When using multiple types of halogens (e.g., mixing iodine-containing chemicals, chlorine-containing chemicals, and bromine-containing chemicals), it would have been obvious for the weight ratios to remain within the 1:100 to 30:100 range, as I describe above for Claims 7, 10, and 18.

5. Claim 17: Element 17(d)—"contacting mercury in the mercury-containing gas with the sorbent material, to form a mercury-sorbent; and"

647. The language of Claim Element 17(d) is identical to the language of Claim Element 1(d). Accordingly, the explanation I provide above for Claim Element 1(d) applies equally to Claim Element 17(d).

6. Claim 17: Element 17(e)—"separating the mercury-sorbent from the mercury-containing gas."

648. The language of Claim Element 17(e) is identical to the language of Claim Element 1(e). Accordingly, the explanation I provide above for Claim Element 1(e) applies equally to Claim Element 17(e).

F. OTHER CLAIMS

649. Claims 2, 5 and 9-16 are obvious for the reasons described above in Ground B3.

XX. CONCLUSION

650. 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 24, 2025



Dr. Stephen Niksa