

the spirit of the invention and within the scope and range of equivalents of the claims.

The construction and method of operation of the invention, however, together with additional objects and advantages thereof will be best understood from the following description of specific exemplary embodiments.

FIG. 11 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. 11 shows a boiler for burning pulverized coal. The facility utilizes various devices to clean the exhaust of the boiler. In this example, a baghouse or ESP is used to collect particulates in the exhaust. A scrubber and sorbent bed are also used to remove undesired constituents from the flue gas stream, before being fed to the stack. In the example shown, the sorbent is injected into the flue gas after the boiler. The additive can be injected where desired (e.g., before, after, or within the boiler).

Another advantage of the present invention relates to the use of a feedback system to more efficiently utilize the invention. Where possible, the mercury control technology of the present invention will utilize measurement of mercury emissions as feedback to assist in control of the sorbent injection rate. Tighter control on the sorbent levels in this way will ensure mercury removal requirements are met with the minimal sorbent requirements and therefore the associated costs will be minimized. In one example, the emissions are measured at the stack.

Carbon Sorbent

Reactions of halogens and acidic species with the basic binding sites on the activated carbon sorbent create sites for oxidizing mercury. Other metal ions, such as boron, tin, arsenic, gallium, Sb, Pb, Bi, Cd, Ag, Cu, Zn, or other contaminants, will also react with the oxidation sites generated on the carbon.

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 accept 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
5 bromine is expected to be more reactive than the corresponding sorbent containing chlorine and much less expensive than the sorbent containing iodine.

A bench-scale procedure based on the above description was used to test the initial activities and capacities of several powdered carbon sorbents, including the bromine-containing activated carbons prepared from a commercially available
10 sorbent and an aerogel carbon film sorbent, as well as the original precursor carbons for comparison. Bromine-treated carbons were prepared by impregnation of the powdered activated carbon precursors in a stirred solution of bromine in carbon tetrachloride or methylene chloride, or alternatively, in an aqueous solution of HBr, followed by drying in air at ambient temperature and drying in an oven at 100°C in
15 air or nitrogen. Bromine-treated carbons were also prepared by impregnating bromine from the gas phase by passing the gas through a rotating dry bed of the activated carbon precursor. Adding a second component to the solution was demonstrated to improve the capacity of the sorbent.

The carbons were initially tested in a heated bed, where a synthetic flue gas
20 stream containing elemental mercury ($11 \mu\text{g}/\text{m}^3$) was passed through the bed. Concentrations of total and elemental Hg in the effluent gas were determined using a Sir Galahad mercury CEM. The powdered sorbent was supported on a quartz filter during the test, and the other sorbents were tested as a triple layer.

A comparison of the original commercial-grade powdered carbon sorbent
25 with the sorbent after it has been treated with 0.1 N HBr, collecting the powder by centrifugation and drying, revealed that the mercury capture activity is increased from an initial capture efficiency of about 50% of the Hg in the inlet to 100% capture. A comparison of the sorbent after subsequent regeneration with HBr indicates that it not only captures mercury at the same level as before (100%
30 capture) but is enhanced such that its capacity is prolonged by several minutes.

Similar results were obtained with the carbon film and carbon fiber sorbents by treatment with molecular bromine in solution or in dry beds as described above.

5 An activated carbon sorbent was prepared by treating the carbon by impregnating molecular bromine from a gas composition containing molecular bromine by flowing the gas through a liquid bromine reservoir in series with a fluidized bed of ebullated bed of the carbon. The amount of bromine taken up by the carbon ranges (in one example) from <1 to about 30 g per 100 g of activated carbon, depending on the proportions used.

10 In one exemplary test conducted at a facility fired with lignite coal, the flue gas phase mercury (elemental) concentration was between 10 and 11 $\mu\text{g}/\text{m}^3$. The ash and injected carbons were collected in the baghouse at 350E to 375EF. Injection of commercial-grade activated carbon powder (untreated) at a rate of 1.0 lb/Macf resulted in mercury effluent concentrations of 3.8-4.2 $\mu\text{g}/\text{m}^3$ (representing 62%-58% removal of the mercury from the gas), and at 2.0 lb/Macf, gave 74%-71% removal.
15 Injection of the bromine-treated carbon at 1.0 lb/Macf resulted in 73%-69% removal and at 2.0 lb/Macf gave 86%-84% removal. Thus, a significant increase in the mercury capture was exhibited during use of the bromine-treated carbon.

Addendum: Other References to Hg Sorption

20 *Sorbent Beds with Particulate Removal*

Carbon beds have also been utilized for mercury capture in flue gas. The German Patent 34 26 059 describes the use of a very thick carbon bed for treatment of flue gases containing polyhalogenated compounds. Although the system employed at Dusseldorf would also have the potential for Hg removal (for example,
25 see the Streng reference), it is not very practical to use such a thick bed. Spent sorbent is burned and not regenerated. The carbons are not pretreated.

The GE-Mitsui-BF system (Tsuji, K.; Shiraishi, I.; Dague, R.F. Proceedings, Sixth International Symposium, Air & Water Management Assoc., New Orleans, LA, March 10-12, 1993) employs a recirculating carbon bed, where mercury is
30 removed along with acid gases (as ammonium salts) and the carbon is regenerated at high temperatures where ammonium sulfate is decomposed to SO_2 and N_2 and

mercury is converted to the elemental form, which desorbs from the sorbent. Attrition of the sorbent results in a significant sorbent cost. The carbons are not pretreated.

5 *Sorbent Injection After Particulate Removal*

A process of injecting manganese oxide sorbent particles is described in U.S. Patent Application 2002/0150516. Regeneration is claimed by removal of spent oxide particles from the reaction zone and rinsing with dilute aqueous acid.

10 *Sorbent Beds After Particulate Removal*

Of particular interest in designing a mercury control process is to use the sorbent downstream of a particulate control device so the sorbent is not highly diluted with the ash particles. The sorbent could then be more easily regenerated and recycled. The prior art teaches several examples of this type of configuration and sorbent processing.

15 U.S. Patent 5,607,496 teaches the oxidation of mercury on a metal oxide sorbent bed and subsequent absorption to sorbent. The sorbent bed follows the particulate-removal equipment and, thus, the gas still contains the SO_x and NO_x, which react with the metal oxide sorbent to form the metal sulfates, which poison
20 the bed. High temperatures are proposed to regenerate the bed. However, Hg is only partially removed from the sorbent at temperatures up to 500°C. The sorbents do not work effectively after regeneration using this technique; the problem may be that manganese sulfate formed during the sorption cycle does not completely decompose back to an active manganese oxide form.

25 U.S. Patent 6,383,981 describes a fixed MnO₂ or Fe₂O₃ bed for removal of Hg from a hydrocarbon stream. No regeneration method appears to be included.

A recent U.S. Patent application (2001/0003116) describes the regeneration of a plate or honeycomb material composed of transition metal oxides that was used for sorption of mercury in flue gas. The claimed process involves heating the
30 sorbent in a reducing gas stream to remove poisons, followed by impregnation with a polyfunctional complex-forming reagent containing the catalyst active component

to restore mercury capture capacity. The first of these steps can remove the mercury, but it is unclear whether it actually removes the sulfate poison. The second of these steps is rather expensive, because one is actually reconstituting the reagent on the sorbent

5 Porous beds containing a mercury oxidizing reagent on a solid support are described in several patents for removal of mercury from gas streams. These include peroxomonosulfate (for example, see U.S. Patent 4,786,483), triiodide or other mixed halogens (for example, see U.S. Patents 3,194,629; 3,662,523), or sulfur (for example, see U.S. Patents 3,194,629, 4,101,631, 4,708,853, 6,258,334). The reagent
10 material is destroyed either by reaction with the flue gas during sorption or by attempts to regenerate the sorbent; there is no way to regenerate these sorbents, except by reimpregnation of the expensive reagent.

 Amalgamating noble metals (gold, silver) on a suitable support can be regenerated by microwave heating (for example, see U.S. Patent 6,136,072), but
15 they are expensive and not especially active for sorption in flue gas.

Hg Sorbents for Air or Natural Gas Treatment

 Melkersson (U.S. Patent 3786619) described a Hg sorbent comprising SeO_2 or SeS_2 for air treatment. This method did not appear to employ a carbon support or
20 halide.

 Yan (U.S. Patent 4814152) described a Hg sorbent comprising elemental sulfur and a metal catalyst on a carbon support. This method did not appear to employ a halide.

 Attia (U.S. Patent 65080281) described a sorbent for mercury and a variety
25 of other contaminants comprising an inorganic aerogel composition. This method did not appear to employ a carbon support or halide.

Following is a List of Various Background References:

 Lancia, A.; Musmarra, D.; Pepe, F.; Volpicelli, G. *Combust. Sci. & Technol.*
30 **1993**, 93, 277.

 Streng, S.; Kassebohm, B. *Fuel Proc. Technol.* **1994**, 39,431.

U.S. Patent 6,214,304 Rosenthal
U.S. Patent 4,889,698 Moller
U.S. Patent 4,956,162 Smith
U.S. Patent 5,672,323 Bhat.
5 U.S. Patent 5,827,352 Altman
U.S. Patent 6,027,551 Hwang
U.S. Patent 5,505,766 Chang
U.S. Patent 5,607,496 Brooks
U.S. Patent 6,383,981 Blankenship
10 U.S. Patent 4,786,483 Audeh
U.S. Patent 3,194,629 Dreibelbis, et al
U.S. Patent 4,101,631 Ambrsini, et al
U.S. Patent 3,662,523 Revoir
U.S. Patent 4,708,853 Matviya
15 U.S. Patent 6,258,334 Gadkaree
U.S. Patent 6,136,072 Sjostrom
U.S. Patent Application 2002/0150516
U.S. Patent Application 2001/0003116 Neufert

CLAIMS

1. A method for separating mercury from a mercury-containing gas, the method comprising:
 - 5 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;
 - 10 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
 - 15 separating the mercury-sorbent from the mercury-containing gas.
2. The method of claim 1, further comprising mixing the additive and the coal before combusting the coal.
- 20 3. The method of claim 2, wherein the additive mixed with the coal is in a liquid.
4. The method of claim 3, wherein the liquid is a hydrocarbon, a chlorinated hydrocarbon, supercritical carbon dioxide, water, salt solution, or a combination
25 thereof.
5. The method of claim 1, wherein the promoted sorbent material comprises active sites, wherein the active sites comprise halide anions bound to the activated carbon.
30
6. The method of claim 1, wherein the promoted sorbent material comprises active sites, wherein the active sites comprise carbocations bound to halide anions.

7. The method of claim 1, wherein chemically reacting the sorbent material with the additive in the mercury-containing gas comprises chemically reacting carbene species edge sites in the activated carbon with the additive.

5

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

9. The method of claim 1, wherein the additive is substantially in vapor form in
10 the mercury-containing gas.

10. The method of claim 1, wherein the additive is chosen from Cl_2 , HCl , sodium chloride, calcium chloride, and a combination thereof.

11. The method of claim 1, wherein the additive is chosen from Br_2 , HBr , sodium bromide, calcium bromide, and a combination thereof.

12. The method of claim 1, wherein the additive is chosen from PBr_3 , SCl_2 , and a combination thereof.

20

13. The method of claim 1, wherein the additive is chosen from I_2 , HI , sodium iodide, calcium iodide, potassium iodide, and combinations thereof.

14. The method of claim 1, wherein the activated carbon is chosen from
25 powdered activated carbon, granular activated carbon, carbon black, carbon fiber, aerogel carbon, pyrolysis char, and combinations thereof.

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

16. The method of claim 1, further comprising contacting at least one of the sorbent material and the promoted sorbent material with a mercury-stabilizing reagent chosen from S, Se, H₂S, SO₂, H₂Se, SeO₂, CS₂, P₂S₅, and combinations thereof.

5

17. The method of claim 1, further comprising contacting at least one of the sorbent material and the promoted sorbent material with a secondary component chosen from halogens, hydrogen halides, Group V halides, Group VI halides, and combinations thereof.

10

18. The method of claim 17, wherein the secondary component is chosen from halogens, halide salts, HI, HBr, HCl, and combinations thereof.

15 19. The method of claim 17, wherein the secondary component is chosen from I₂, HI, and combinations thereof.

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

20 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;

25 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

30 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.

Abstract

A promoted activated carbon sorbent is described that is highly effective for the removal of mercury from flue gas streams. The sorbent comprises a new
5 modified carbon form containing reactive forms of halogen and halides. Optional components may be added to increase reactivity and mercury capacity. These may be added directly with the sorbent, or to the flue gas to enhance sorbent performance and/or mercury capture. Mercury removal efficiencies obtained exceed conventional methods. The sorbent can be regenerated and reused. Sorbent treatment and
10 preparation methods are also described. New methods for in-flight preparation, introduction, and control of the active sorbent into the mercury contaminated gas stream are described.

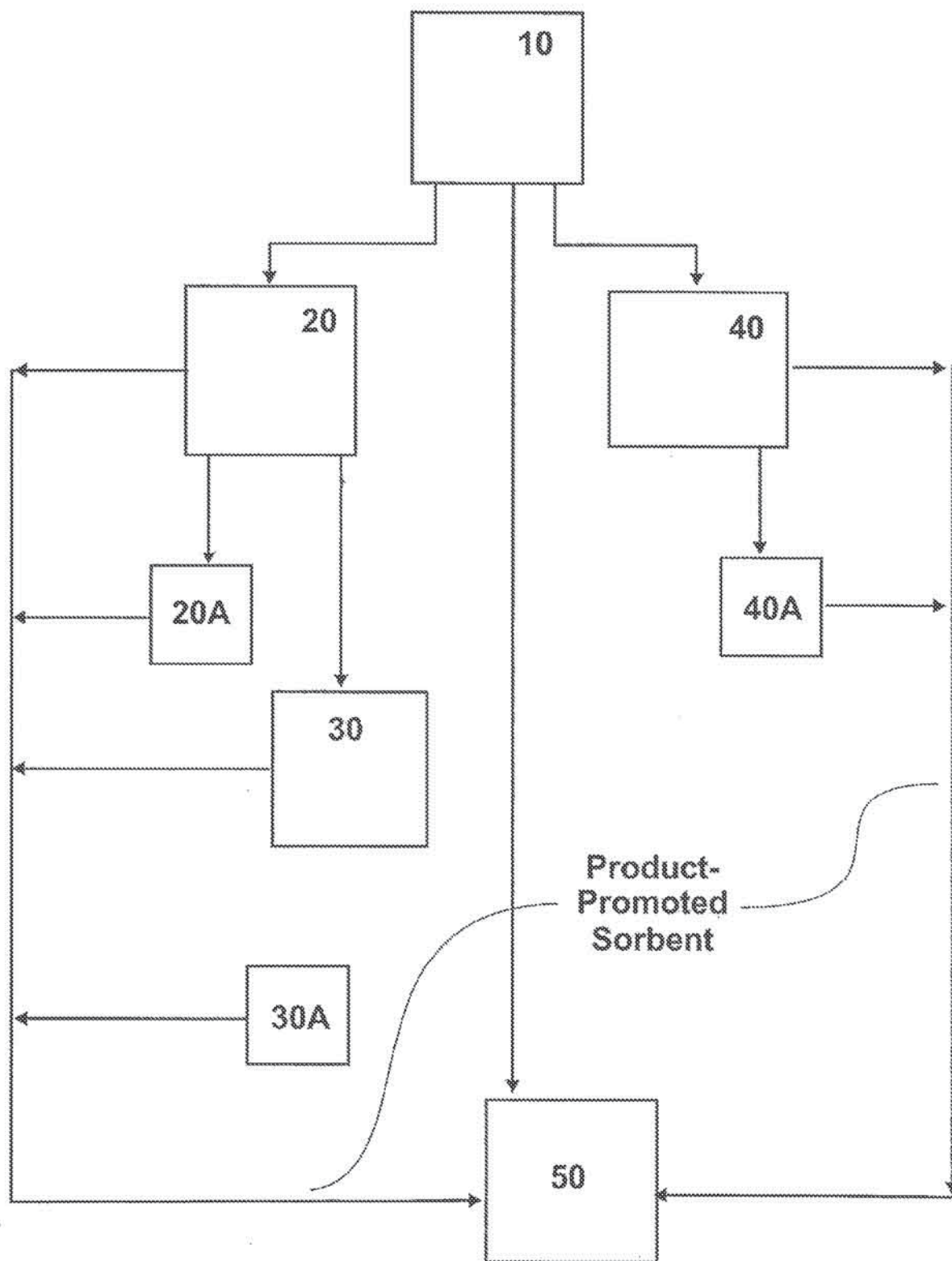


FIG. 1

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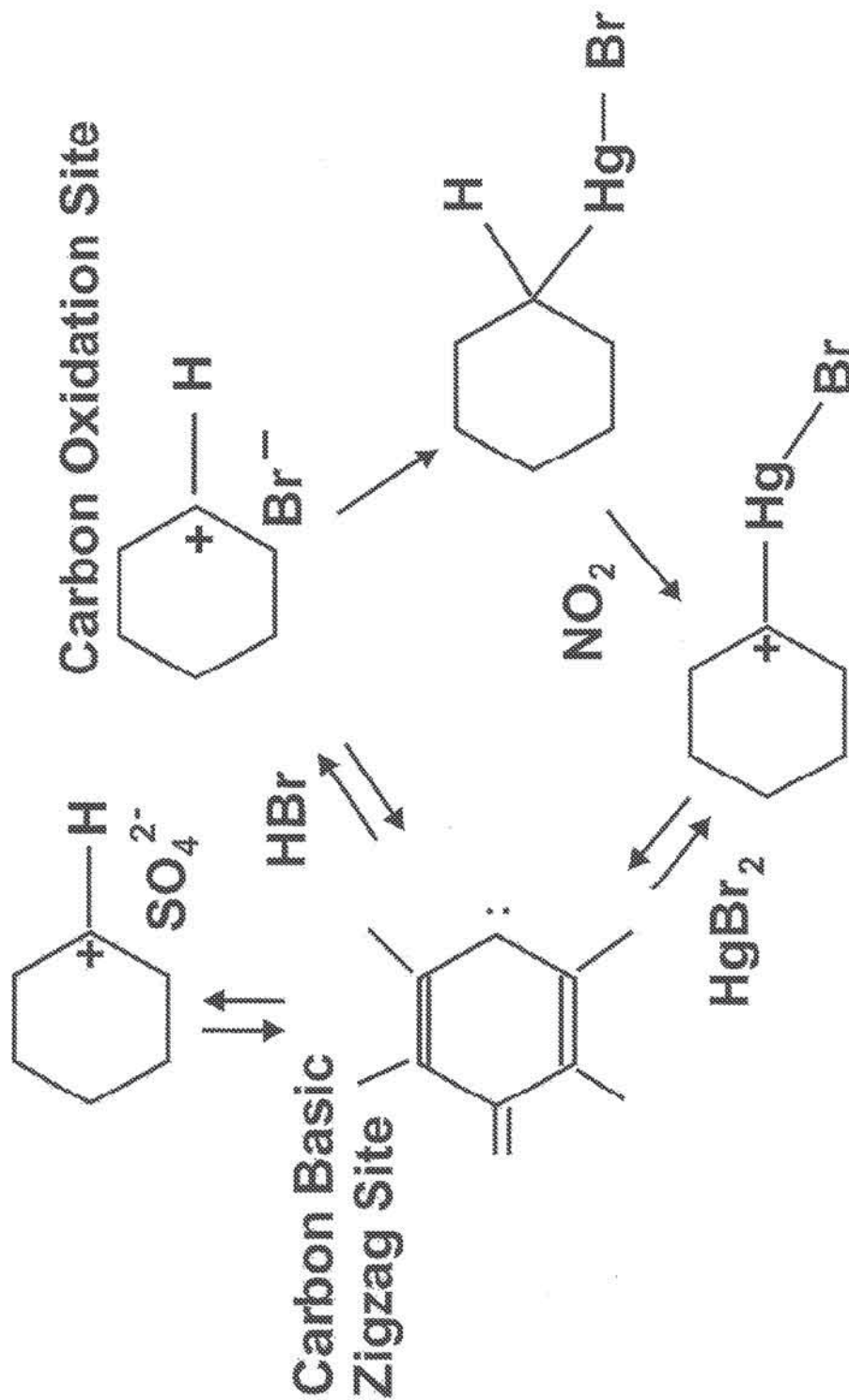


FIG. 2

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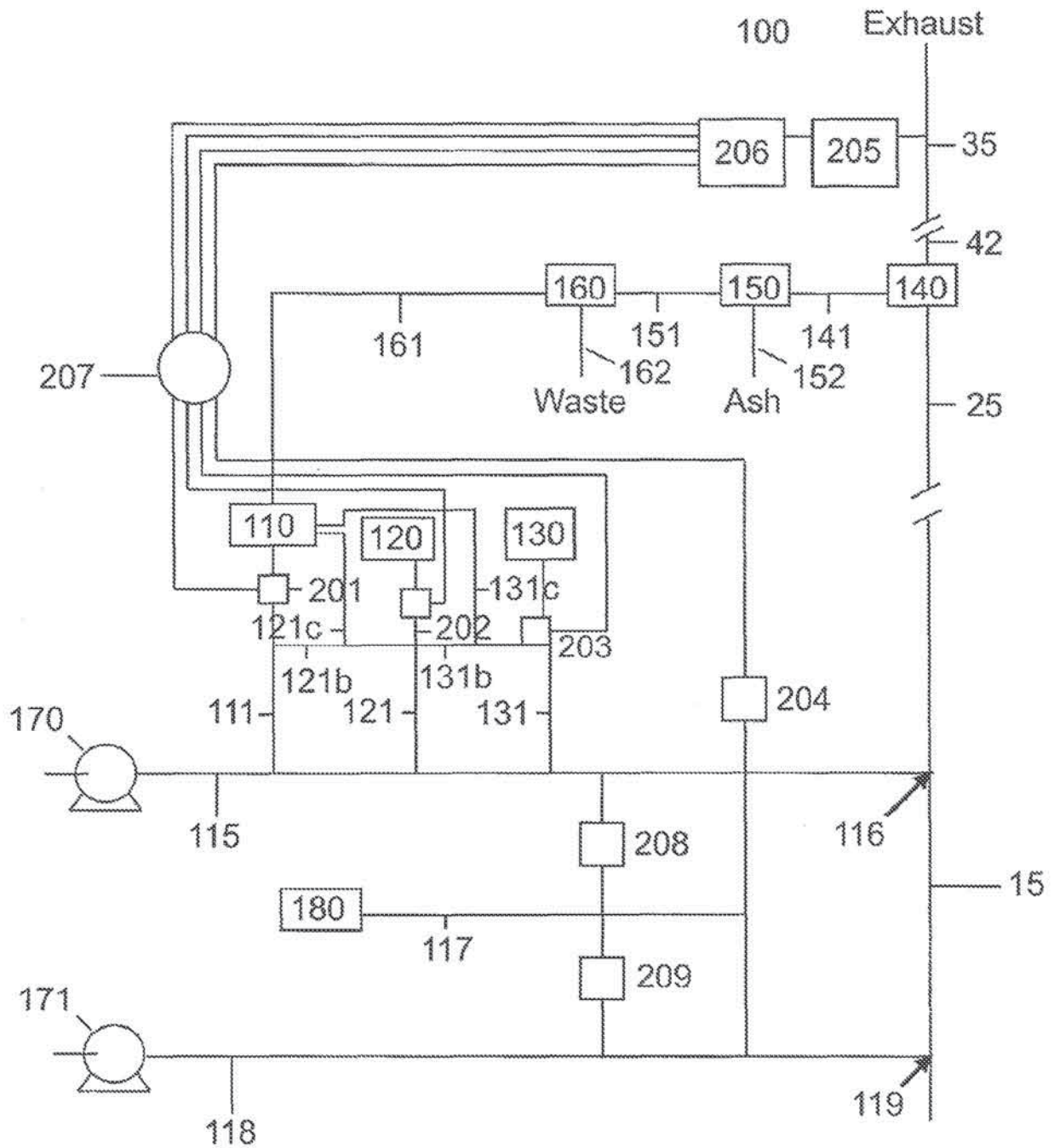


FIG. 3

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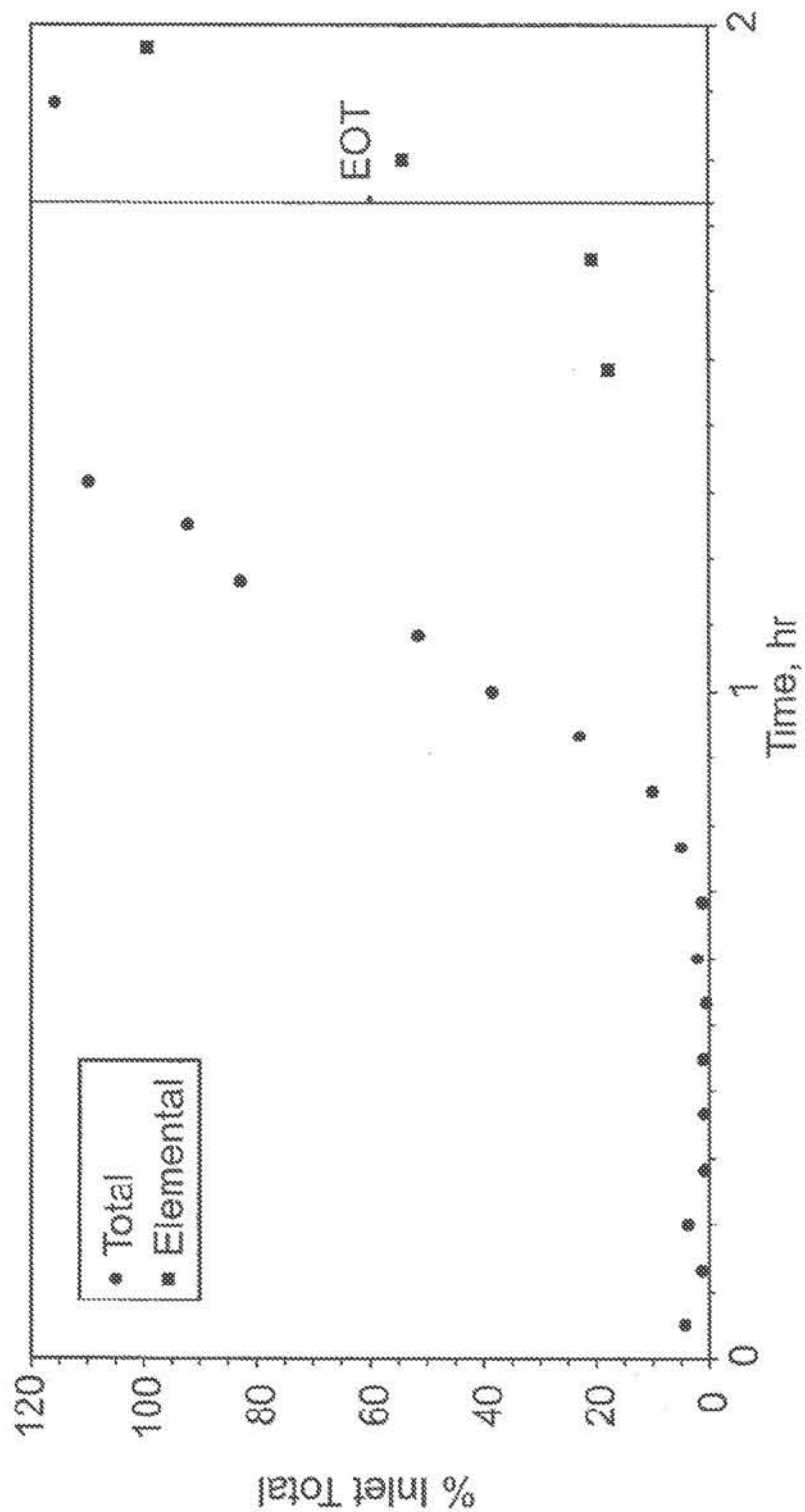


FIG. 4

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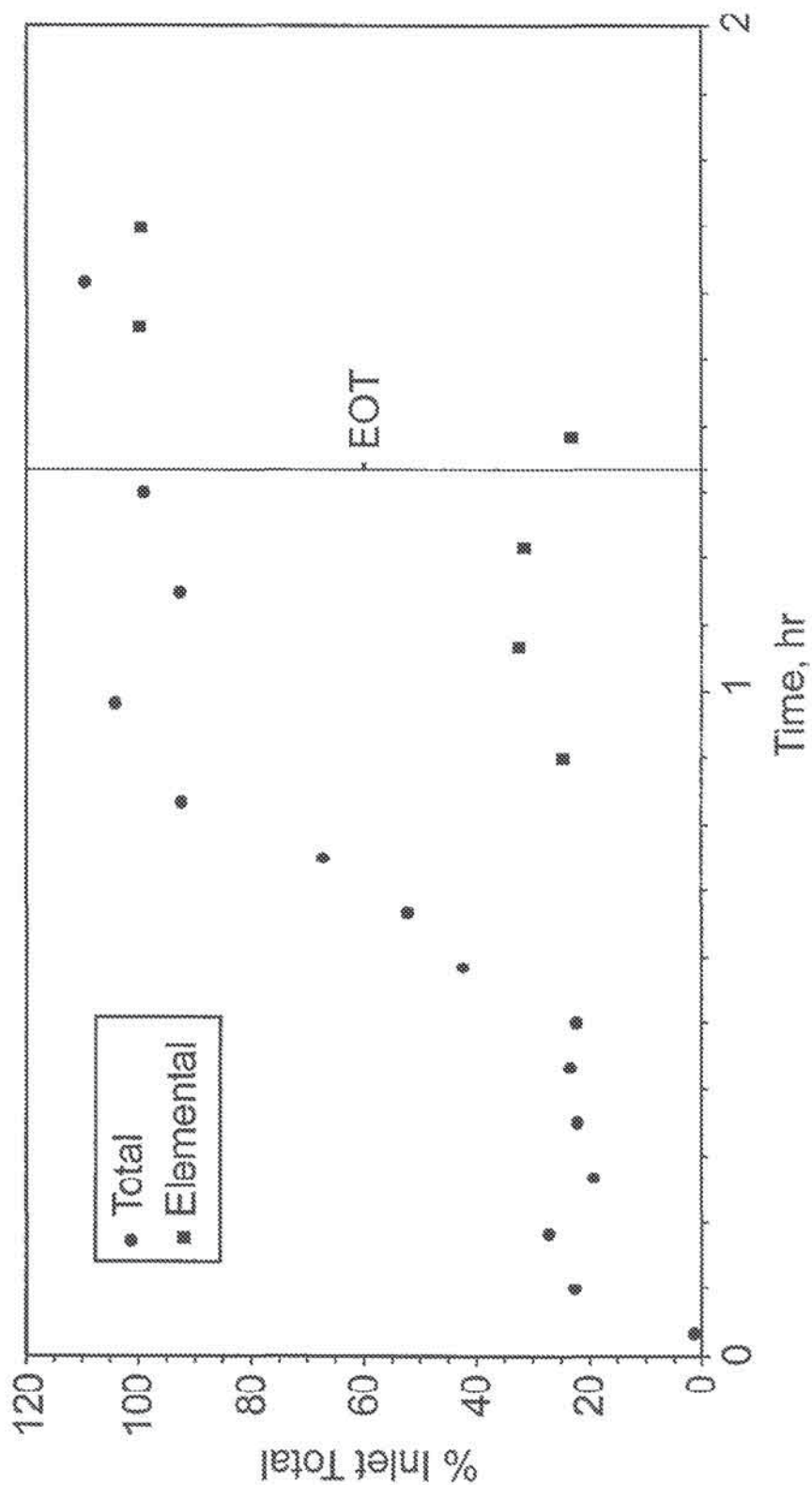


FIG. 5

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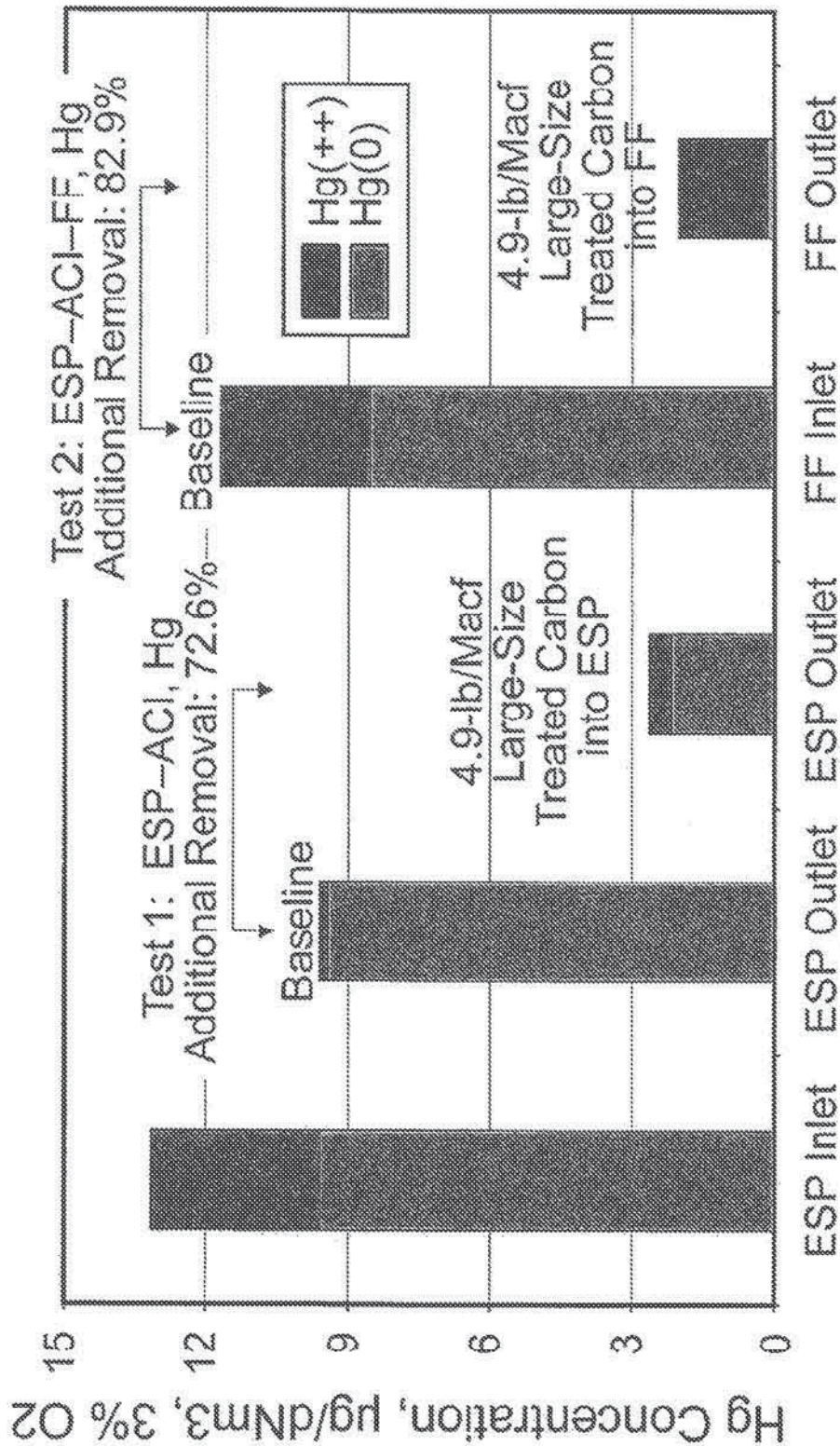


FIG. 6

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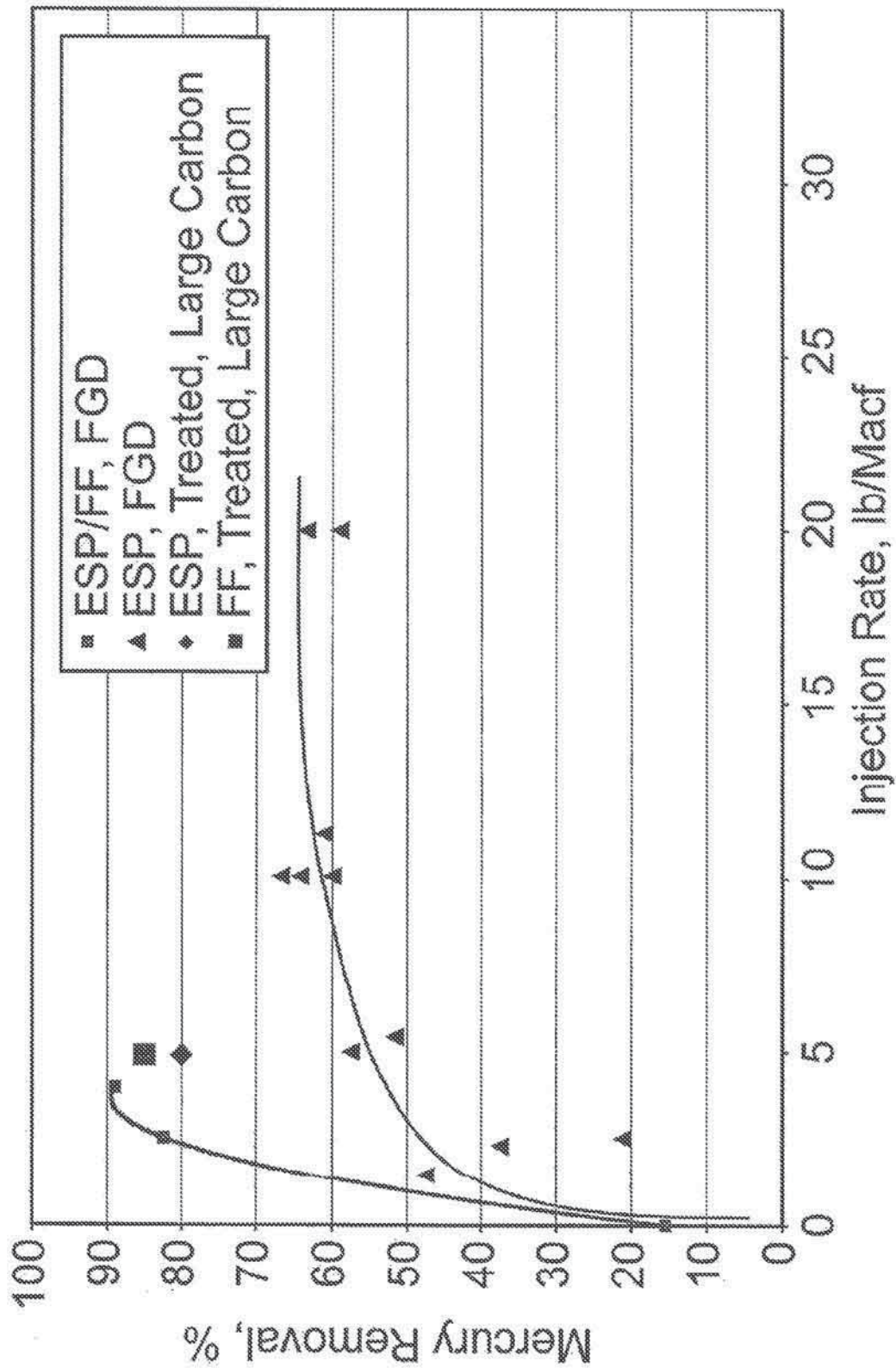
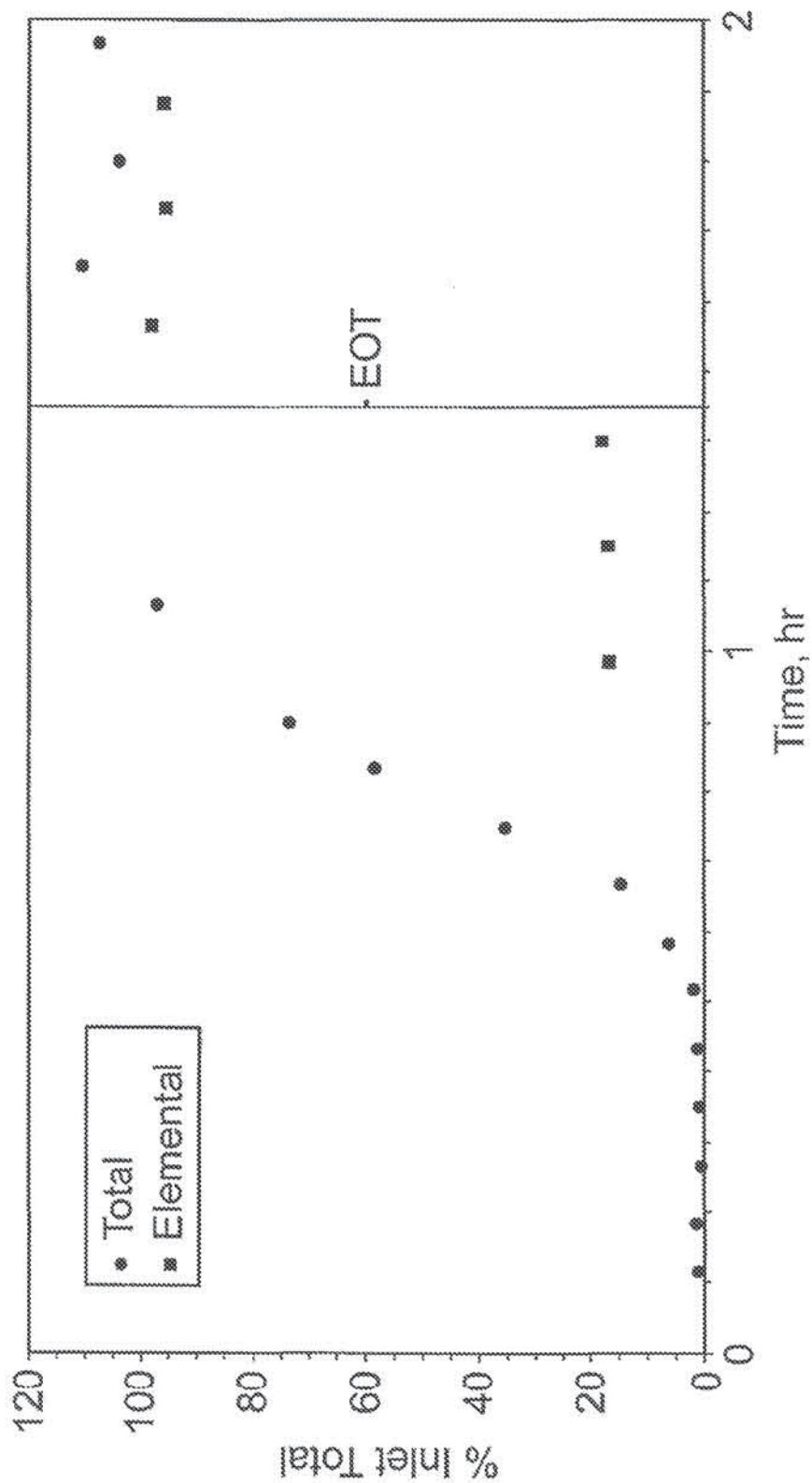
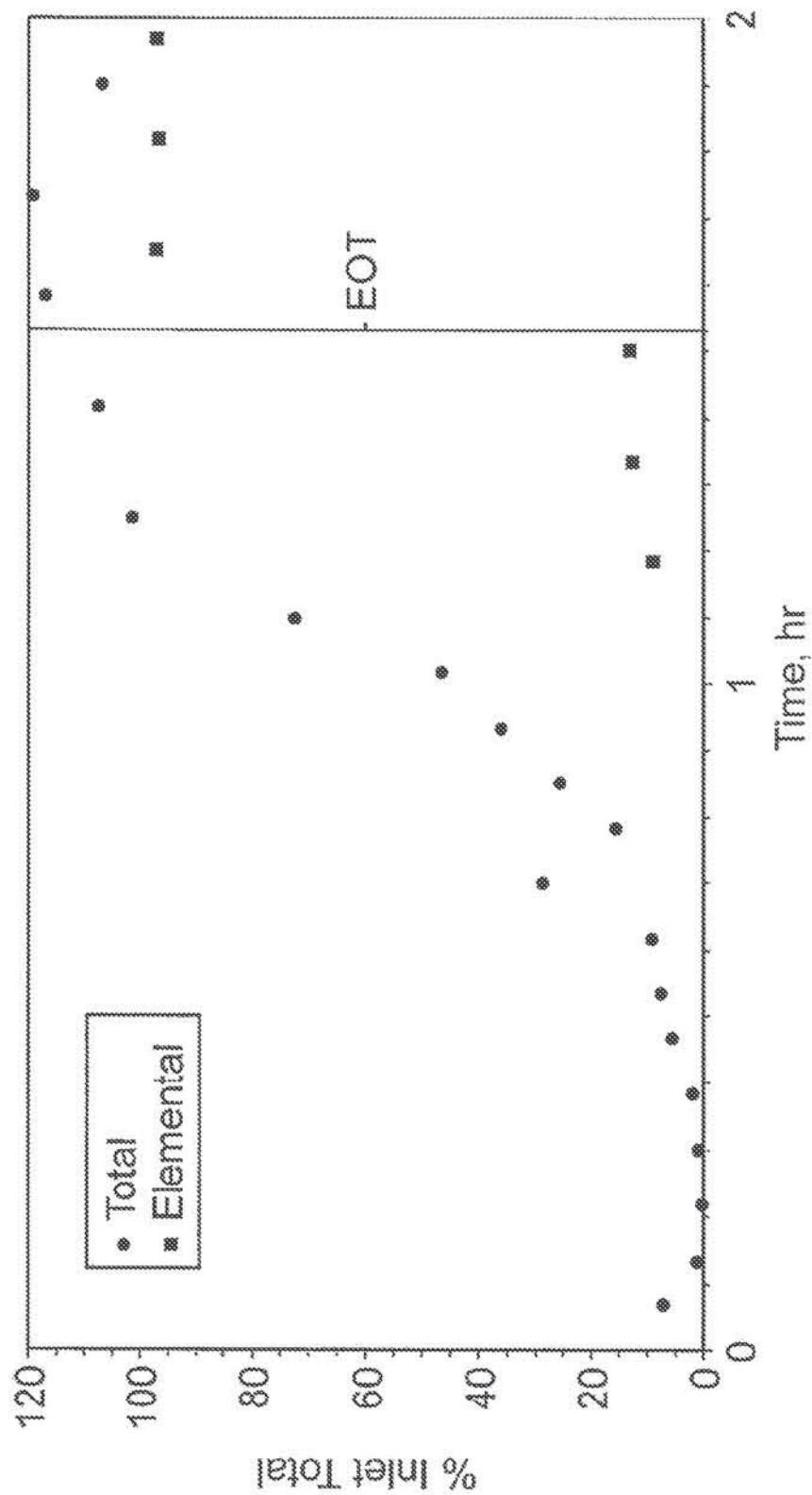


FIG. 7

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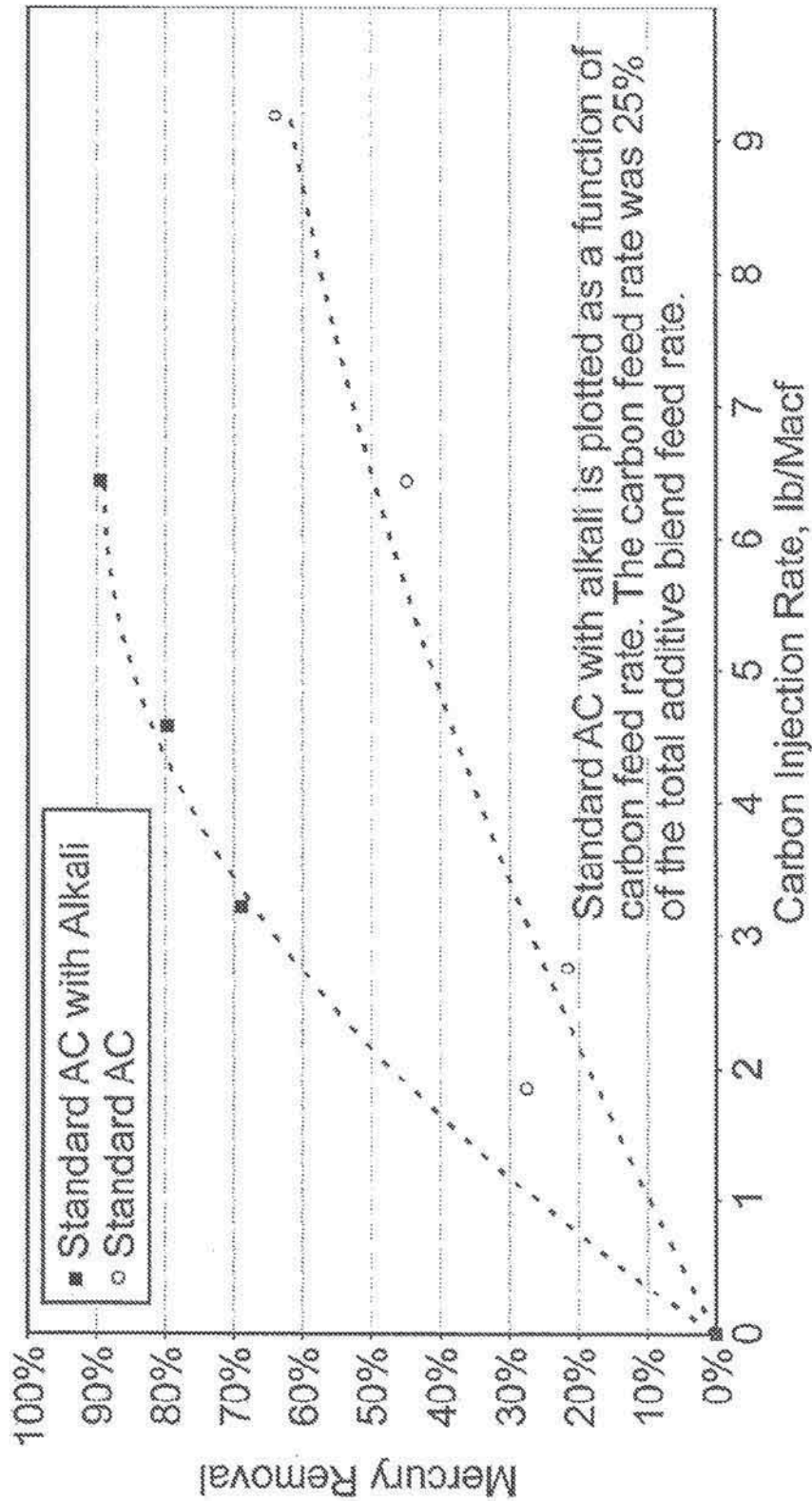


FIG. 10

11/11

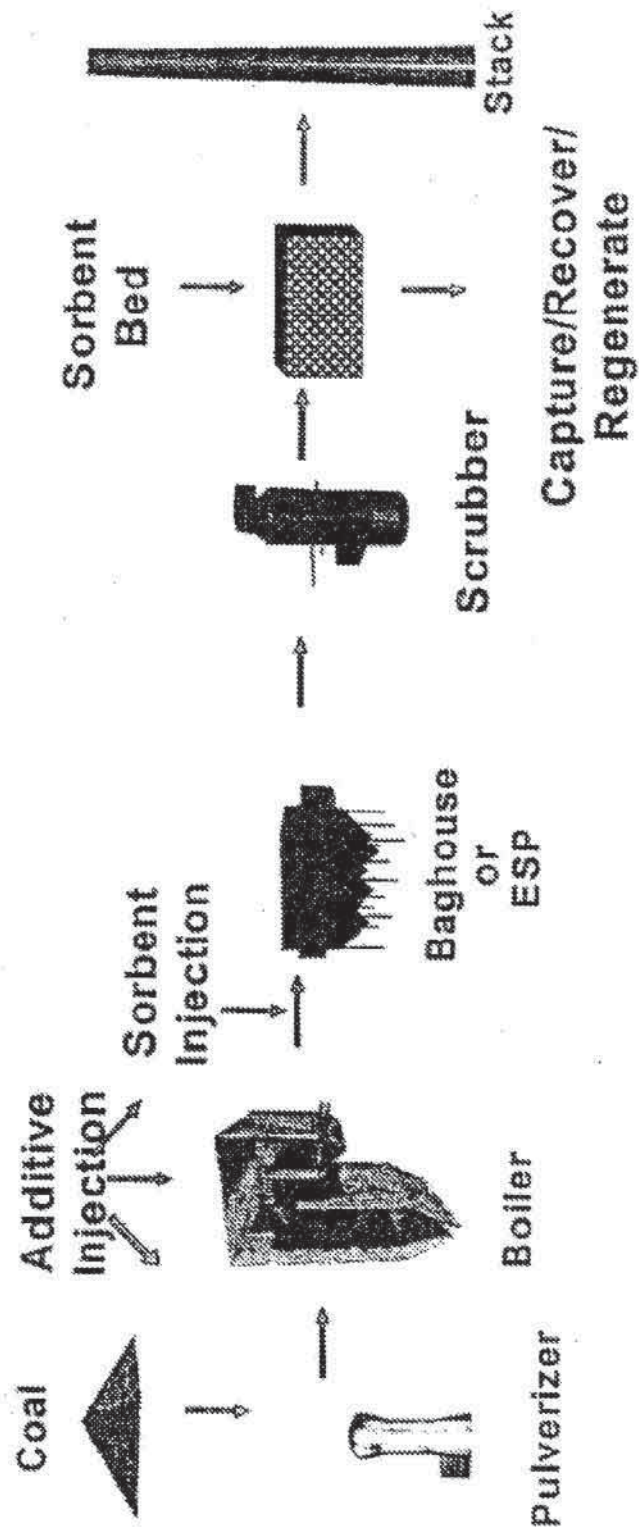


FIG. 11

**DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN
APPLICATION DATA SHEET (37 CFR 1.76)**

Title of Invention	SORBENTS FOR THE OXIDATION AND REMOVAL OF MERCURY
As the below named inventor, I hereby declare that: This declaration is directed to: ☐ The attached application, or ☒ United States application or PCT international application number <u>13/966,768</u>, filed on <u>August 14, 2013</u>. The above-identified application was made or authorized to be made by me. I believe that I am the original inventor or an original joint inventor of a claimed invention in the application. I hereby acknowledge that any willful false statement made in this declaration is punishable under 18 U.S.C. 1001 by fine or imprisonment of not more than (5) years, or both. WARNING: Petitioner/applicant is cautioned to avoid submitting personal information in documents filed in a patent application that may contribute to identity theft. Personal information such as social security numbers, bank account numbers, or credit card numbers (other than a check or credit card authorization form PTO-2038 submitted for payment purposes) is never required by the USPTO to support a petition or an application. If this type of personal information is included in documents submitted to the USPTO petitioners/applicants should consider redacting such personal information from the documents before submitting them to the USPTO. Petitioner/applicant is advised that the record of a patent application is available to the public after publication of the application (unless a non-publication request in compliance with 37 CFR 1.213(a) is made in the application) or issuance of a patent. Furthermore, the record from an abandoned application may also be available to the public if the application is referenced in a published application or an issued patent (see 37 CFR 1.14). Checks and credit card authorization forms PTO-2038 submitted for payment purposes are not retained in the application file and therefore are not publicly available. LEGAL NAME OF INVENTOR Inventor: <u>Edwin S. Olson</u> Date (Optional): _____ Signature: <u></u> Note: An application data sheet (PTO/SB/14 or equivalent), including naming the entire inventive entity, must accompany this form. Use an additional PTO/AIA/01 form for each additional inventor.	

This collection of information is required by 35 U.S.C. 112 and 37 CFR 1.63. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 1 minute to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

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0338-005US5

**DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN
APPLICATION DATA SHEET (37 CFR 1.76)**

Title of
Invention

SORBENTS FOR THE OXIDATION AND REMOVAL OF MERCURY

As the below named inventor, I hereby declare that:

This declaration

is directed to:



The attached application, or



United States application or PCT International application number 13/366,768,
filed on August 14, 2013.

The above-identified application was made or authorized to be made by me.

I believe that I am the original inventor or an original joint inventor of a claimed invention in the application.

I hereby acknowledge that any willful false statement made in this declaration is punishable under 18 U.S.C. 1001
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LEGAL NAME OF INVENTOR:

Inventor: Michael J. Holmes

Date (Optional): Oct. 24, 2013

Signature: Michael J. Holmes

Note: An application data sheet (PTO/SF/14 or equivalent), including naming the entire inventive entity, must accompany this form.
Use an additional PTO/AIA/01 form for each additional inventor.

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3338.D03U55

**DECLARATION (37 CFR 1.63) FOR UTILITY OR DESIGN APPLICATION USING AN
APPLICATION DATA SHEET (37 CFR 1.76)**

Title of Invention	SORBENTS FOR THE OXIDATION AND REMOVAL OF MERCURY
As the below named inventor, I hereby declare that:	
This declaration is directed to:	
☐ The attached application, or	
☒ United States application or PCT International application number <u>13/966,768</u> , filed on <u>August 14, 2013</u> .	
The above-identified application was made or authorized to be made by me.	
I believe that I am the original inventor or an original joint inventor of a claimed invention in the application.	
I hereby acknowledge that any willful false statement made in this declaration is punishable under 18 U.S.C. 1001 by fine or imprisonment of not more than (5) years, or both.	
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LEGAL NAME OF INVENTOR	
Inventor: <u>John Henry Pavlish</u> Date (Optional): _____	
Signature: <u>John Pavlish</u>	
Note: An application data sheet (PTO/SF/14 or equivalent), including naming the entire inventive entity, must accompany this form. Use an additional PTO/AIA/01 form for each additional inventor.	

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3338 005US5

Electronic Patent Application Fee Transmittal				
Application Number:				
Filing Date:				
Title of Invention:		SORBENTS FOR THE OXIDATION AND REMOVAL OF MERCURY		
First Named Inventor/Applicant Name:		Edwin S. Olson		
Filer:		Jose M. Nunez/Megan Reed		
Attorney Docket Number:		4820.001US9		
Filed as Large Entity				
Filing Fees for Track I Prioritized Examination - Nonprovisional Application under 35 USC 111(a)				
Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Basic Filing:				
UTILITY APPLICATION FILING	1011	1	300	300
UTILITY SEARCH FEE	1111	1	660	660
UTILITY EXAMINATION FEE	1311	1	760	760
REQUEST FOR PRIORITIZED EXAMINATION	1817	1	4000	4000
Pages:				
Claims:				
Miscellaneous-Filing:				
PROCESSING FEE, EXCEPT PROV. APPLS.	1830	1	140	140

Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Miscellaneous:				
Total in USD (\$)				5860

Electronic Acknowledgement Receipt

EFS ID:	32568544
Application Number:	15974343
International Application Number:	
Confirmation Number:	1072
Title of Invention:	SORBENTS FOR THE OXIDATION AND REMOVAL OF MERCURY
First Named Inventor/Applicant Name:	Edwin S. Olson
Customer Number:	21186
Filer:	Jose M. Nunez/Megan Reed
Filer Authorized By:	Jose M. Nunez
Attorney Docket Number:	4820.001US9
Receipt Date:	08-MAY-2018
Filing Date:	
Time Stamp:	17:13:48
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	DA
Payment was successfully received in RAM	\$5860
RAM confirmation Number	050918INTEFSW00004554190743
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			646d47241e55720d3d973a32ee07c7f3be155a07		
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	Transmittal of New Application		1	1	
	TrackOne Request		2	2	
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	Abstract		71	71	
	Drawings-only black and white line drawings		72	82	
	Oath or Declaration filed		83	85	
Warnings:					
Information:					
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Warnings:					
Information:					
Total Files Size (in bytes):			4815918		

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New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

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New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

S/N 15/974.343

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventor(s): Edwin S. Olson et al.

Examiner: UNKNOWN

Serial No.: 15/974,343

Group Art Unit: UNKNOWN

Filed: 5/8/2018

Docket: 4820.001US9

Customer No.: 21186

Confirmation No.: UNKNOWN

Title: SORBENTS FOR THE OXIDATION AND REMOVAL OF MERCURY

PRELIMINARY AMENDMENT

MS Amendment

Commissioner for Patents

P.O. Box 1450

Alexandria, VA 22313-1450

Prior to taking up this application for examination, please enter the following amendments:

IN THE CLAIMS

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

combusting a mixture of coal and an additive that has been added to the coal, the additive comprising a bromide compound, 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~~ Br₂, HBr, Br⁻, or a combination thereof, in-flight ~~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.

2. (Original) The method of claim 1, further comprising mixing the additive and the coal before combusting the coal.

3. (Original) The method of claim 2, wherein the additive mixed with the coal is in a liquid.

4. (Original) The method of claim 3, wherein the liquid is a hydrocarbon, a chlorinated hydrocarbon, supercritical carbon dioxide, water, salt solution, or a combination thereof.

5. (Original) The method of claim 1, wherein the promoted sorbent material comprises active sites, wherein the active sites comprise halide anions bound to the activated carbon.
6. (Original) The method of claim 1, wherein the promoted sorbent material comprises active sites, wherein the active sites comprise carbocations bound to halide anions.
7. (Original) The method of claim 1, wherein chemically reacting the sorbent material with the additive in the mercury-containing gas comprises chemically reacting carbene species edge sites in the activated carbon with the additive.
8. (Original) The method of claim 1, wherein carbocations in the activated carbon of the mercury-sorbent accept electrons from mercury atoms of the mercury-sorbent.
9. (Original) The method of claim 1, wherein the additive is substantially in vapor form in the mercury-containing gas.
10. (Currently Amended) The method of claim 1, wherein the additive ~~is chosen from Cl₂, HCl, sodium chloride, calcium chloride, and a combination thereof~~ comprises Ca, Na, or a combination thereof.
- 11-13. (Canceled)

14. (Original) 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.

15-20. (Canceled)

21. (New) The method of claim 1, wherein the coal and the additive are mixed at a location upstream of a combustion furnace where combustion occurs.

22. (New) The method of claim 1, comprising separating greater than 70 wt% of the mercury from the mercury-containing gas.

23. (New) The method of claim 1, comprising separating greater than 70 wt% of the mercury from the mercury-containing gas on the sorbent.

24. (New) The method of claim 1, wherein the sorbent material has a composition comprising from about 1 to about 30 grams of additive per 100 grams of activated carbon.

25. (New) The method of claim 1, wherein the method is a method for reducing mercury in the mercury-containing gas to a desired level, wherein separating the mercury-sorbent from the mercury-containing gas forms a cleaned gas, the method further comprising:

monitoring the mercury content of the cleaned gas; and

controlling, in response to the monitored mercury content of the cleaned gas, an injection rate of injecting the sorbent into the mercury-containing gas, the sorbent composition, or a combination thereof, so that the mercury content of the cleaned gas is maintained at or below the desired level.

REMARKS

Claims 1 and 10 are amended, claims 11-13 and 15-20 are canceled, and claims 21-25 are added; as a result, claims 1-10, 14, 21-25 are now pending in this application.

Claim 1 is amended to recite "...an additive that has been added to the coal..." Support can be found in the application as filed at Figure 11.

Claim 1 is amended to recite "...the additive comprising a bromide compound..." Support can be found in the application as filed at page 50 line 10.

Claim 1 is amended to recite "...chemically reacting the sorbent material with ~~the additive~~ Br₂, HBr, Br⁻, or a combination thereof..." Support can be found in the application as filed at page 18 lines 25-26 and at page 19 lines 2-7.

Claim 1 is amended to recite that the sorbent material is reacted with the Br₂, HBr, Br⁻, or combination thereof "...in-flight the mercury-containing gas, to form a promoted sorbent material..." Support can be found in the application as filed at page 20 lines 9 to 19 and FIG. 11.

Claim 10 is amended to recite "...wherein the additive ~~is chosen from Cl₂, HCl, sodium chloride, calcium chloride, and a combination thereof~~ comprises Ca, Na, or a combination thereof." Support can be found in the application as filed at page 42, lines 10-11.

No new matter is added via the amendments or new claims herein.

CONCLUSION

Applicant respectfully submits that the claims are in condition for allowance and notification to that effect is earnestly requested. The Examiner is invited to telephone Applicant's attorney at (612) 349-9580 to facilitate prosecution of this application.

PRELIMINARY AMENDMENT

Serial Number: 15/974,343

Filing Date: 5/8/2018

Title: SORBENTS FOR THE OXIDATION AND REMOVAL OF MERCURY

Page 7

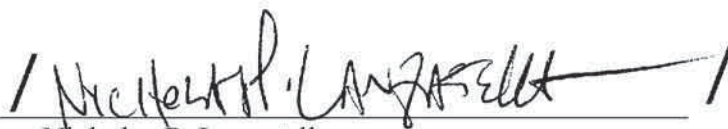
Docket No: 4820.001US9

If necessary, please charge any additional fees or credit overpayment to Deposit Account No. 19-0743.

Respectfully Submitted,

SCHWEGMAN, LUNDBERG & WOESSNER, P.A.
P.O. Box 2938
Minneapolis, MN 55402
(612) 349-9580

Date May 15, 2018

By 
Nicholas P. Lanzatella
Reg. No. 63,803

Electronic Acknowledgement Receipt

EFS ID:	32628572
Application Number:	15974343
International Application Number:	
Confirmation Number:	1072
Title of Invention:	SORBENTS FOR THE OXIDATION AND REMOVAL OF MERCURY
First Named Inventor/Applicant Name:	Edwin S. Olson
Customer Number:	21186
Filer:	Jose M. Nunez/Megan Reed
Filer Authorized By:	Jose M. Nunez
Attorney Docket Number:	4820.001US9
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Filing Date:	
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Application Type:	Utility under 35 USC 111(a)

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File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		SIGNED_4820_001US9_Prelim Amdmt.pdf	116961	yes	8
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	Multipart Description/PDF files in .zip description		
	Document Description	Start	End
	Transmittal Letter	1	1
	Preliminary Amendment	2	2
	Claims	3	6
	Applicant Arguments/Remarks Made in an Amendment	7	8

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New Applications Under 35 U.S.C. 111

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Inventor(s): Edwin S. Olson et al.

Title: SORBENTS FOR THE OXIDATION AND REMOVAL OF MERCURY

Docket No.: 4820.001US9

Filed: May 8, 2018

Examiner: Unknown

Customer No.: 21186

Serial No.: 15/974,343

Due Date: May 25, 2018

Group Art Unit: Unknown

Confirmation No.: 1072

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

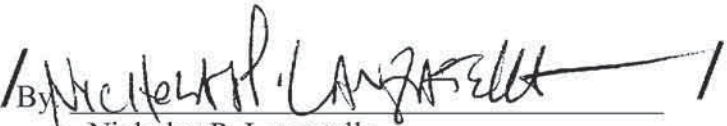
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☒ Preliminary Amendment (7 pgs.)

If not provided for in a separate paper filed herewith, please consider this a PETITION FOR EXTENSION OF TIME for sufficient number of months to enter these papers and please charge any additional fees or credit overpayment to Deposit Account No. 19-0743. If applicable, any papers or fees supplied herewith are considered to be timely filed pursuant to 37 C.F.R. § 1.7(a), the response period falling on a Federal Holiday, Saturday or Sunday being extended to the next succeeding business day.

SCHWEGMAN LUNDBERG & WOESSNER, P.A.

Customer No.: 21186

By 
Nicholas P. Lanzatella
Reg. No. 63,803

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Substitute for form 1449A/PTO INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Use as many sheets as necessary)	<i>Complete if Known</i>	
	Application Number	15/974,343
	Filing Date	May 8, 2018
	First Named Inventor	Edwin S. Olson
	Group Art Unit	Unknown
	Examiner Name	Unknown
Sheet 1 of 19		Attorney Docket No: 4820.001US9

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EXAMINER

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	Application Number	15/974,343
	Filing Date	May 8, 2018
	First Named Inventor	Edwin S. Olson
	Group Art Unit	Unknown
	Examiner Name	Unknown
Sheet 2 of 19		Attorney Docket No: 4820.001US9

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Examiner Initial *	USP Document Number	Publication Date	Name of Patentee or Applicant of cited Document
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	Filing Date	May 8, 2018
	First Named Inventor	Edwin S. Olson
	Group Art Unit	Unknown
	Examiner Name	Unknown
Sheet 3 of 19		Attorney Docket No: 4820.001US9

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Examiner Initial *	USP Document Number	Publication Date	Name of Patentee or Applicant of cited Document
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	Filing Date	May 8, 2018
	First Named Inventor	Edwin S. Olson
	Group Art Unit	Unknown
	Examiner Name	Unknown
Sheet 4 of 19		Attorney Docket No: 4820.001US9

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Examiner Initial *	USP Document Number	Publication Date	Name of Patentee or Applicant of cited Document
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	Application Number	15/974,343
	Filing Date	May 8, 2018
	First Named Inventor	Edwin S. Olson
	Group Art Unit	Unknown
	Examiner Name	Unknown
Sheet 5 of 19		Attorney Docket No: 4820.001US9

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	First Named Inventor	Edwin S. Olson
	Group Art Unit	Unknown
	Examiner Name	Unknown
Sheet 6 of 19		Attorney Docket No: 4820.001US9

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	Application Number	15/974,343
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	First Named Inventor	Edwin S. Olson
	Group Art Unit	Unknown
	Examiner Name	Unknown
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	Application Number	15/974,343
	Filing Date	May 8, 2018
	First Named Inventor	Edwin S. Olson
	Group Art Unit	Unknown
	Examiner Name	Unknown
Sheet 8 of 19	Attorney Docket No: 4820.001US9	

OTHER DOCUMENTS – NON PATENT LITERATURE DOCUMENTS		
Examiner Initial *	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T 1
	"Application Serial No. 12/201,595, Non Final Office Action mailed 04-16-09", 21 pgs.	
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	Examiner Name	Unknown
Sheet 9 of 19	Attorney Docket No: 4820.001US9	

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	Examiner Name	Unknown
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	First Named Inventor	Edwin S. Olson
	Group Art Unit	Unknown
	Examiner Name	Unknown
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Substitute for form 1449A/PTO INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Use as many sheets as necessary)	<i>Complete if Known</i>	
	Application Number	15/974,343
	Filing Date	May 8, 2018
	First Named Inventor	Edwin S. Olson
	Group Art Unit	Unknown
	Examiner Name	Unknown
Sheet 19 of 19	Attorney Docket No: 4820.001US9	

OTHER DOCUMENTS – NON PATENT LITERATURE DOCUMENTS		
Examiner Initial *	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T 1
	ZHENG, YUANJING, et al., "Review of technologies for mercury removal from flue gas from cement production processes", Progress in Energy and Combustion Science, Vol. 38, No. 5, (26 April 2012), 599-629	
	ZHU, JIANZHONG, et al., "Enhanced mercury ion adsorption by amine-modified activated carbon", Journal of hazardous materials 166, (2009), 866-872	

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EFS ID:	32666047
Application Number:	15974343
International Application Number:	
Confirmation Number:	1072
Title of Invention:	SORBENTS FOR THE OXIDATION AND REMOVAL OF MERCURY
First Named Inventor/Applicant Name:	Edwin S. Olson
Customer Number:	21186
Filer:	Jordan Rivard Golomb/Jamie Johnson
Filer Authorized By:	Jordan Rivard Golomb
Attorney Docket Number:	4820.001US9
Receipt Date:	18-MAY-2018
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Application Type:	Utility under 35 USC 111(a)

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