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PROVISIONAL APPLICATION FOR PATENT COVER SHEET

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 CFR 1.53(c).

INVENTOR(S)

Given Name (first and middle [if any])	Family Name or Surname	Residence (City and either State or Foreign Country)
Sidney G., Jr.	Nelson	52 Aurora St. Hudson, OH 44236

☐ *Additional inventors are being named on the ___ separately numbered sheets attached hereto*

TITLE OF THE INVENTION (280 characters max)

Methods to Remove Mercury from Combustion Gases

Direct all correspondence to: **CORRESPONDENCE ADDRESS**

☐ Customer Number ________ → *Place Customer Number Bar Code Label here*

OR *Type Customer Number here*

☒ Firm *or* Individual Name	Sidney G. Nelson Jr.				
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Address	1664 East Highland Road				
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Country	USA	Telephone	330-425-2354	Fax	330-425-3983

ENCLOSED APPLICATION PARTS *(check all that apply)*

☒ Specification *Number of Pages* 14
☐ Drawing(s) *Number of Sheets* ___
☐ Application Data Sheet. See 37 CFR 1.76
☐ CD(s), Number ___
☐ Other (specify) ___

METHOD OF PAYMENT OF FILING FEES FOR THIS PROVISIONAL APPLICATION FOR PATENT

☒ Applicant claims small entity status. See 37 CFR 1.27.
☒ A check or money order is enclosed to cover the filing fees
☐ The Commissioner is hereby authorized to charge filing fees or credit any overpayment to Deposit Account Number: ___
☐ Payment by credit card. Form PTO-2038 is attached.

FILING FEE AMOUNT ($): $ 80.00

The invention was made by an agency of the United States Government or under a contract with an agency of the United States Government.
☐ No.
☒ Yes, the name of the U S Government agency and the Government contract number are: 68-D-00-263 U.S. EPA

Respectfully submitted,

SIGNATURE Sidney G. Nelson

Date 04/24/02

TYPED or PRINTED NAME Sidney G. Nelson Jr.

REGISTRATION NO. *(if appropriate)* ___

Docket Number: ___

TELEPHONE 330-656-3805

USE ONLY FOR FILING A PROVISIONAL APPLICATION FOR PATENT

This collection of information is required by 37 CFR 1.51. The information is used by the public to file (and by the PTO to process) a provisional application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 8 hours to complete, including gathering, preparing, and submitting the complete provisional application to the PTO 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, Washington, D C 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Box Provisional Application, Assistant Commissioner for Patents, Washington, D.C. 20231.

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Sorbent Technologies Corporation

Air Pollution Control

April 24, 2002

Box Provisional Application
Assistant Commissioner for Patents
Washington, D.C. 20231

Dear Assistant Commissioner for Patents:

Enclosed please find a Provisional Application for Patent entitled: "Methods to Remove Mercury from Combustion Gases."

Also enclosed is a check for $80.00 for the associated Small Entity filing fee, for which we qualify.

Sincerely,

SORBENT TECHNOLOGIES CORP.

Sidney G. Nelson Jr.
President

SNjr/cat
Encl.

1664 E. Highland Rd. Twinsburg, OH 44087 sorb@aol.com (330) 425-2354 fax: (330) 425-3983

FIRST CLASS

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SORBTECH
AIR POLLUTION TECHNOLOGIES

Sorbent Technologies Corp.
1664 East Highland Road
Twinsburg, OH 44087

To: BOX PROVISIONAL PATENT APPLICATION
COMMISSIONER FOR PATENTS
WASHINGTON DC 20231

FIRST CLASS

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PROVISIONAL PATENT APPLICATION

METHODS TO REMOVE MERCURY FROM COMBUSTION GASES

Sidney G. Nelson Jr.
Sorbent Technologies Corporation
1664 E. Highland Road
Twinsburg, OH 44087

I. FIELD OF THE INVENTIONS

These inventions relate to materials and methods for separating gases from one another, and more specifically to sequestering trace mercury from combustion gases.

II. BACKGROUND OF THE INVENTIONS

Mercury emissions from coal-fired boilers present a significant health and environmental risk and regulations on power-plant mercury will soon be promulgated and enforced. The Clean Air Act Amendments of 1990 required that the U.S. Environmental Protection Agency study the health and environmental effects of trace mercury emissions from combustion sources and regulate them if necessary. In late 1997, the EPA submitted an eight-volume Mercury Report to Congress, which detailed the suspected health and environmental effects of industrial mercury emissions.[1] In early 1998, the EPA released a Final Report to Congress (RTC) on Hazardous Air Pollutant Emissions from Electric Utility Steam Generating Units which identified coal-fired utilities as the largest remaining source of mercury emissions into the air.

After considerable study, the U.S. EPA announced on December 14, 2000, in an official Regulatory Finding that it had determined that: "The conclusions, as a whole, support a finding that regulation of coal-fired electric utility steam generating units for hazardous air pollutants, particularly mercury, is appropriate and necessary."[2] Thus, a regulatory rulemaking process has begun that will see final mercury regulations for all U.S. coal-fired power plants promulgated by the EPA before December 16, 2004 for national enforcement beginning in 2007.

---

1. Mercury Study - Report to Congress, U.S. E.P.A., EPA 452/R-97-0003, eight volumes, December 1997.
2. Regulatory Finding on the Emissions of Hazardous Air Pollutants from Electric Utility Steam Generating Units, U.S. Environmental Protection Agency, December 14, 2000.

3

According to the Finding:

"Mercury is highly toxic, persistent, and bioaccumulates in the food chain." In the utility RTC the EPA estimated that the industry emitted approximately 92,000 pounds of mercury in 1990, 102,000 pounds in 1994, and was projected to emit approximately 120,000 pounds in 2010 from 1,026 boiler units at 426 coal-fired plants.

The Finding further explained that:

"Mercury in the flue gas from coal combustion may be present in three different forms. The forms, called species, include elemental mercury, divalent oxidized forms, and mercury adsorbed onto the surface of fly ash or other particles. The capture of mercury is highly dependent on the relative amount of mercury species that are present in the flue gas. Particulate bound mercury can easily be removed in conventional PM emission control devices such as electrostatic precipitators and fabric filters. Divalent forms of mercury are generally soluble in water and can be captured in wet scrubbers. ... [Unfortunately, however, e]lemental mercury is insoluble in water, does not react with alkaline reagents used in FGD systems, and cannot be captured in wet scrubbers. Elemental mercury is [also] more difficult to adsorb on solid surfaces."

Unfortunately, no economical, easily-retrofitted control technologies exist for elemental mercury from coal-fired power plants. Thorough, state-of-the-art reviews of existing mercury control technologies and their associated costs were done in the two Reports to Congress. Unfortunately, as the EPA concluded in the Executive Summary of its Utility HAPs RTC:

> "Regarding potential methods for reducing mercury emissions, the EPA has not identified any demonstrated add-on control technologies currently in use in the U.S. that effectively remove mercury from utility emissions."

A leading control technology candidate is powdered activated carbon injection (PAC), but high injection rates and/or expensive gas-cooling may be required. A very easy method to retrofit is to simply inject a mercury sorbent, such as activated carbon, into the flue gas ahead of the existing electrostatic precipitator. Unfortunately, however, the results of plain activated carbon injection tests to date at power plants have been highly variable and not particularly promising. According to the EPA Mercury Report:

> "Mass carbon-to-mercury ratios of greater than 100,000:1 may be required at one second or less residence time upstream of the ESP at 300°F in order to achieve 90% mercury removal."

Activated carbons generally perform poorly at temperatures above about 250°F. Gas cooling by water injection is possible, but this would be expensive to operate, may require extending ductwork to allow the water to fully evaporate, and could cause significant downstream corrosion and opacity problems. Unfortunately, the bulk of coal-fired power plants in the U.S. only have their flue gases readily available for retrofitted treatment between their air preheaters and electrostatic precipitators, where the temperature is from about 300°F to 400°F.

Specially-impregnated carbons can work better than plain carbons, but they are very expensive to produce and need added fabric filters to take advantage of their higher mercury capacities. The cost of specially-impregnated carbons is prohibitive, as the Mercury Report noted:

> "[S]ulfur-, iodine-, chloride salt-, and $Ca(OH)_2$-impregnated activated carbons show promise for increasing the mercury removal efficiency, but further testing is needed. The cost of these modified carbons, however, can be as much as 20 times higher than that of unmodified activated carbon."

The high cost of impregnated carbons is a result of their expensive manufacture. Solvents are generally applied with the impregnate in solution and the carbons require drying and usually, post-processing. Commercially-available iodine-impregnated powdered carbons, for example, use dissolved potassium iodide salts. Such sorbents can have a high mercury capacity when given a long gas contact time, but, as the Mercury Report noted:

> "However, many of the [impregnated] sorbents exhibited deteriorated performance at the temperatures typical of coal-fired power plant operations."

A new low-cost, high-temperature, elemental-mercury sorbent is badly needed, along with process improvements to extend performance and lower costs. If coal-fired power plants are required to control their mercury emissions, it could be very expensive using existing technology. Preliminary Electric Power Research Institute (EPRI) estimates to control 50 percent of the mercury emissions from U.S. utility power plants using currently-available technology range from about $20,000 to $40,000 per-lb-of-mercury-removed and would total $1 billion to $10 billion per year.[3] Detailed modeling in the EPA Mercury Report estimates that, in most cases, the costs of substantially reducing utility mercury emissions using current technologies will be between $14,000 and $70,000 per-lb-of-mercury-removed, depending on the plant and operating assumptions. More recent cost modeling by the EPA looking at 18 different plant situations and 10 different technology combinations predicted costs ranging from 0.31 to 3.78 mills/kWh.[4]

III. DESCRIPTIONS OF THE INVENTIONS

I have discovered various improvements to the current practices which can be practiced either independently or in combination. They follow seriatim.

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3. Chang, R., and G. Offen, "Mercury Emission Control Technologies: An EPRI Synopsis," Power Engineering, 53, November 1995.

4 Srivastava, R., C. Sedman, & J. Kilgroe, "Performance and Cost of Mercury Emission Control Technology Applications on Electric Utility Boilers," U.S. EPA ORD, September 2000.

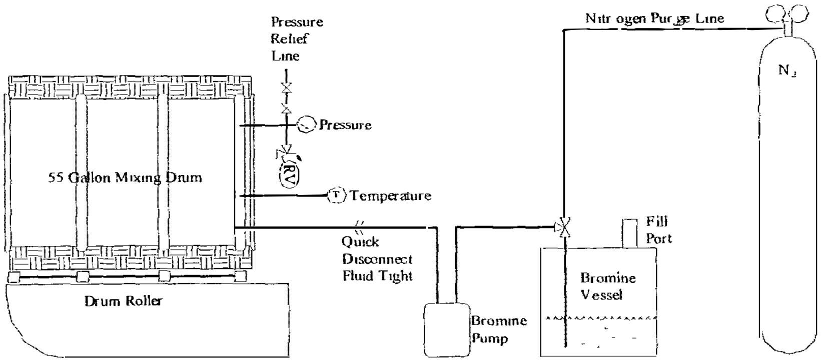
A. Bromination of the Carbon

I have discovered that the simple act of exposing powdered activated carbon (PAC) to gaseous bromine, Br_2 (g), or gaseous hydrogen bromide, HBr (g), significantly increases its ability to remove elemental mercury when injected into coal-fired flue-gas compositions at high temperatures. This could be a very important advance: an inexpensive material that can be simply injected into the duct ahead of the existing electrostatic precipitator, without the need for large sorbent volumes, flue gas cooling, or extended sorption time on an added fabric filter.

By simply exposing PAC to concentrated bromine gas, a relatively large quantity of this gas appears to react with the carbon, forming surface compounds on the large surface-area of the carbon. When the PAC is then injected into the flue gas, the elemental mercury there reacts with at least one form of the bromine-carbon surface compounds that were created and is held fast. When the carbon particles are then removed from the flue gas by the electrostatic precipitator (ESP) or fabric filter, the mercury can thus be removed with them. Because the mercury has now been chemisorbed, rather than simply physisorbed, the captured mercury appears to be very stable.

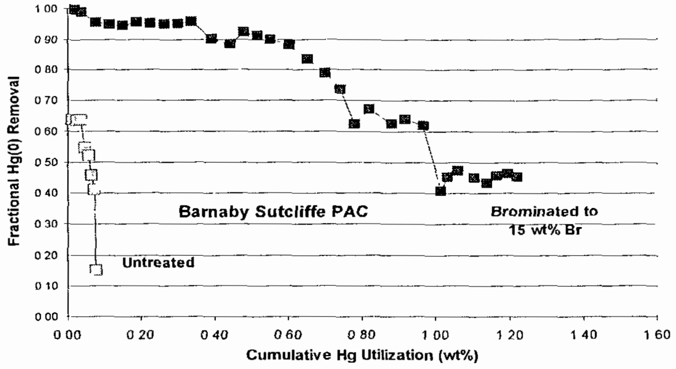
Production is simple. The carbon material and the bromine gas need simply be exposed to each other for the advantageous mercury-reactive surface compounds to form. Elemental bromine is a liquid at room temperature, but turns to a gas at only a modestly elevated temperature. Hydrogen bromide is a gas at even room temperature. Using a gas the carbon reactant considerably simplifies production of the sorbent. Any common mixing method and equipment can be used, though it is preferably of a corrosion-resistant material, because bromine can be quite corrosive. It is also preferable that the mixing of bromine gas and carbon be done at an elevated temperature. This keeps the bromine gas in the gaseous form, but also decreases the amount of any bromine physisorption into the pores of the carbon. Such physisorbed bromine is not chemically adsorbed and can be emitted from the carbon when injected into a hot flue gas.

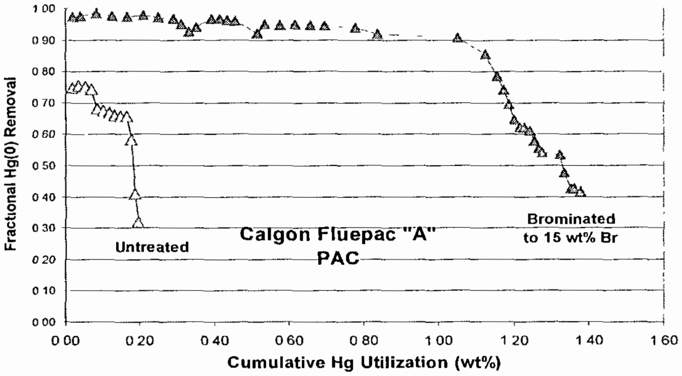
To produce larger volumes of the improved sorbent, commercial powdered activated carbon can be placed in a Teflon-lined barrel covered with a heat blanket, insulation, and metal covering. See the drawing below. The barrel and material are heated to from 65°C to 175°C while on a drum roller. The proper amount of liquid bromine, under a nitrogen purge, is then metered by a calibrated pump into the heated drum where it vaporizes. The connection line is then disconnected and the drum roller turned on. Pressure originally builds up in the drum, but subsides to atmospheric when all of the bromine has been incorporated into the carbons. This process can easily be scaled up to tonnage quantities and either be used independently or added onto the PAC production process.

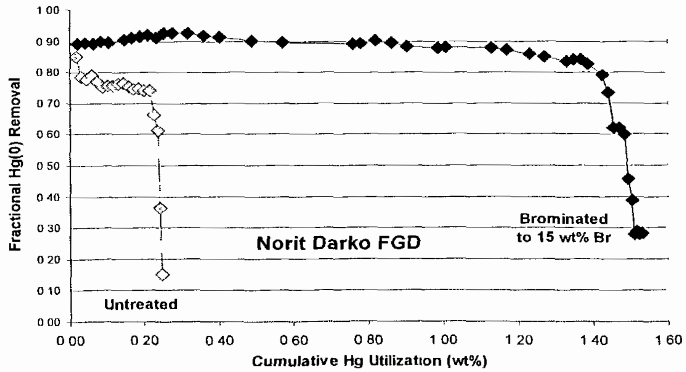


By reacting the carbon material with bromine, the capacity of the carbon for mercury is significantly increased. This gas-phase bromine treatment was tested on many different commercially-available powdered activated carbons (PACs). Each was found to be easily "brominated" to at least 15 wt% Br, including PACs from Barnaby Sutcliffe, Calgon (both Centaur® and Fluepac A), General Carbon, Nichem, Action Carbon, Advance Recovery Technologies, and Norit's Darko FGD®, the standard PAC typically used by other researchers.

The bromine-gas treatment markedly increased the elemental-mercury removal-capacity of every PAC tested. To the right are fixed-bed mercury breakthrough-curves for three of the PACs, comparing the mercury capacities of both the untreated and treated materials.







The standard laboratory fixed-bed testing procedure was similar to that of other researchers and generates a typical breakthrough curve. In the standard procedure used in these experiments, thin fixed-beds of PAC of about 50-mg were vacuum-applied to filters and placed in a filter-holder in a 175°C laboratory oven. The treated samples had been earlier exposed to gaseous bromine at 175°C in a closed container until no gaseous bromine was detected. A challenge gas was sent through heated lines to each of the materials at 6.7 lpm that contained an average of about 400 ug/Nm^3 of elemental Hg from VICI permeation tubes in a temperature-controlled oil bath. To simulate a coal-fired gas stream, 1400 ppm SO_2 and 400 ppm NO from bottled gases and 4 wt% water from a peristaltic pump were also spiked into the gas with the balance being 11.5% O_2 and the rest, N_2. Mercury levels both into and out of the materials were measured with an Arizona Instruments Jerome elemental mercury analyzer.

The bromine pretreatments increased the elemental mercury capacity of these PACs by **500% to 1000%**. (Plotting the curve as a function of cumulative Hg utilization in terms of wt% of the sorbent, rather than as a function of time, normalizes the curves for comparison under different conditions. Note that the inverse of the utilization at breakthrough corresponds to the minimally required sorbent injection expressed as a sorbent weight-ratio to mercury in the flue gas.

Examples of patent claims for this improvement to the practiced art could be:

I claim:

A.1. In a process for removing mercury from a combustion gas comprising:

a. discharging a carbon material from a storage container,
b. injecting the carbon material into the combustion gas,
c. allowing the carbon material to widely disperse within the gas and adsorb mercury there from, and then
d. separating the carbon material from the combustion gas,

the improvement comprising:

exposing said carbon material to a bromine-containing gas prior to said injection.

A.2. A method as in A.1., wherein

the bromine-containing gas comprises gaseous bromine or hydrogen bromide.

A.3. A method as in A.2., wherein

the carbon material comprises powdered activate carbon.

A.4. A method as in A.2., wherein

the exposure of the carbon material to the bromine-containing gas occurs above a temperature of 75°C.

A.5. A method as in A.2., wherein

the exposure of the carbon material to the bromine-containing gas occurs above a temperature of 150°C.

B. Use of Carbon Black as an Injected Sorbent

Even given adequate sorbent capacity and kinetics, bulk-gas mass transfer might pre-limit mercury removal performance. Before mercury atoms or molecules can adsorb onto or react with sorbent particles, they must first find them. If there is not enough sorbent macro-surface area available in a given exposure time, all the mercury will not have the opportunity to transverse the sorbent particle's "boundary layer" to adsorb or react with the sorbent's micro-surface area. This constraint can be relieved either by adding more sorbent (and so, more macro-surface area) to the duct, by providing additional particle residence time, or by decreasing the average particle size.

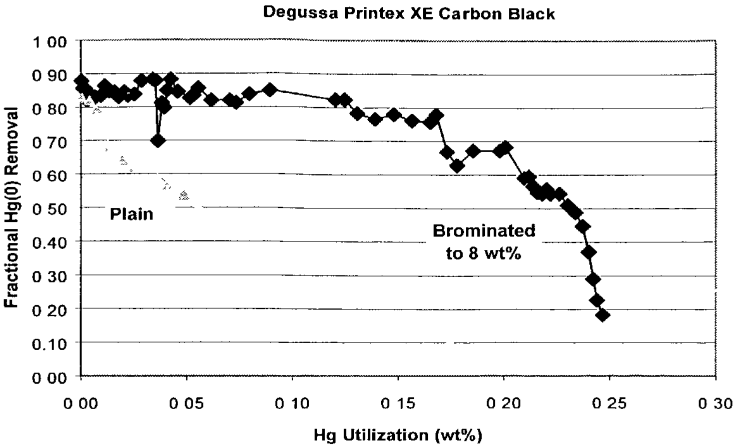
Ideally, to avoid wasting money, mercury sorbents should be saturated in use close to their innate capacities, unconstrained by other possible rate-limiting factors. Unfortunately, it does appear that otherwise high-capacity, high-reactivity PACs, plain or impregnated, may sometimes be "artificially" limited in duct-injection applications by bulk-gas mass transfer limitations. The finest grades of commercial PACs still have a mass-mean diameter of about 10 microns. At this size, calculations have shown that bulk-gas mass-transfer may prevent optimum performance. Relieving this limitation by adding more sorbent or residence time adds significantly to total costs. However, there may be an alternative.

To get around the mass-transfer problem, I teach to use carbon blacks as an alternative to powdered activated carbon as the bromine substrate in this project.

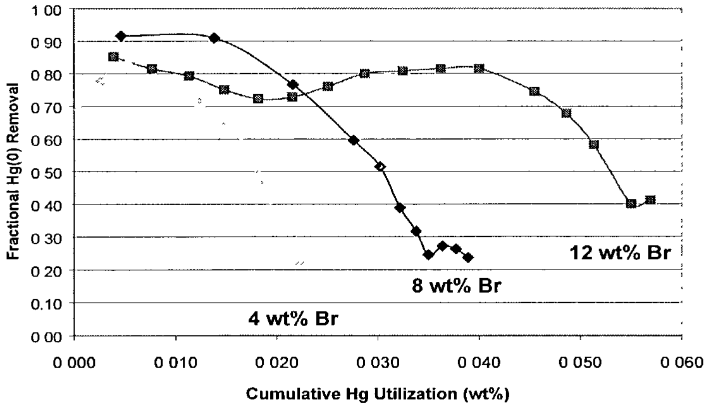
Carbon black is a common, high-volume, commercially-available product. It is mixed into rubber to provide durability and opaqueness in automobile tires, compounded with plastics to provide static dissipation, and used in the toner producing the print on this page. There are many different varieties available. Blacks are produced from the intentionally-quenched, partial combustion of hydrocarbons. Carbon black prices range from about $1,000 per ton up to $3,000 or more for specialty blacks.

If the in-duct mercury performance of PAC is rate-limited by bulk-gas mass transfer, smaller carbon particles should perform significantly better. Carbon black particles, and even carbon black aggregates, are significantly smaller than PAC particles. Individual furnace black particles usually have diameters ranging from about 10 to 50 nanometers. Powdered activated carbons, on the other hand, average over 10,000 nanometers in diameter. Brominated carbon blacks would be so small as to constitute "nanosorbents" for mercury.

A number of commercial carbon blacks were acquired and tested for their bromination capabilities. The procedures for their production and use are the same as those described earlier for PACs. Like PACs, the blacks could be easily brominated, but to somewhat lower levels. As with the PACs, the bromine of the treated materials appeared very stable. And most importantly, like with the PACs, the bromine-gas pretreatment increased the elemental mercury removal-capacity of these materials by 500 to 1000%. See the following example.



The mercury removal performance of these new sorbent materials appears to be a direct function of their bromination level. See the breakthrough curve results below for a Monarch carbon black, tested under the standard conditions previously outlined, which had been brominated to different levels.



Clearly, the higher the added bromine, the higher the mercury capacity of the sorbents. These results also reinforce the conclusion that the mercury removals are chemisorptions.

In fixed-bed tests, the bromine-treated blacks do not have the mercury capacities of the treated PACs, but their capacities were still relatively large. Moreover, in the actual duct-injection mode, all of their capacity may be utilized. They could be used on their own, or possibly mixed in with the much larger, treated PACs to remove the last 10 to 20% of the elemental mercury.

Moreover, I have found, surprisingly, that carbon black has utility as a duct-injectant, by itself, unbrominated, for capturing oxidized forms of mercury, such as $HgCl_2$, from hot gas streams. At my direction, laboratory mercury-chloride fixed-bed testing was performed by URS Corp. on a variety of carbon black samples in tests similar to those described previously. The challenge gas contained 400 ppm SO_2, 400 ppm NOx, 50 ppm HCl, 7% H_2O, approximately 50 ug/Nm^3 $HgCl_2$, with the balance N_2. The results follow.

Capacity of Carbon Blacks for Mercury Chloride under Flue Gas Conditions

URS Testing		Elemental Hg			Oxidized Hg ($HgCl_2$)		
Sorbent		Initial Capacity (µg/g@ 50 µg/Nm^3)	Equil. Capacity (µg/g@50 µg/Nm^3)	Breakthru Slope^{-1} (µg/g@50 µg/Nm^3)	Initial Capacity (µg/g @50 µg/Nm^3)	Equil. Capacity (µg/g@ 50 µg/Nm^3)	Breakthru Slope- (µg/g@50 µg/Nm^3)
C.C. 1200 Black					190	260	70
C.C. 1255 Black		80	175	95	230	310	80
1255 - 5%Br_2		190	230	40	280	370	90
1255 - 5%HBr		140	210	70	240	290	50
Cabot Elftex 8					320	400	80
Elftex 8-4% Br_2					105	280	175
C.C. Conductex					445	615	170

C.C. = Columbian Carbons

These oxidized mercury capacities are relatively large and the breakthrough slopes are steep, indicating good reactivity for duct-injection application. Therefore, carbon blacks can be injected by themselves to remove oxidized mercury.

Examples of patent claims for this improvement to the practiced art could be:

I claim:

B.1. In a process for removing mercury from a combustion gas comprising:

a. discharging a carbon material from a storage container,
b. injecting the carbon material into the combustion gas,
c. allowing the carbon material to widely disperse within the gas and adsorb mercury there from, and then
d. separating the carbon material from the combustion gas,

the improvement comprising:

using carbon black as the carbon material.

B.2. A method as in A.2., wherein

the carbon material comprises carbon black beads or pellets.

C. Injection-Line Jet-Milling

If carbon black sorbents are to be utilized, jet milling may also be required. Carbon blacks are commercially available in two forms: agglomerated beads and "fluffies." The majority of carbon black is sold, shipped, stored, and discharged into their use in bead form. The finer fluffy material is not dense enough to be shipped by pneumatic bulk trucks or to be fed from large hoppers. This form is used only in small batches in specialty applications, such as inks and coatings.

In this new mercury-sorbent application for carbon black, it is the finer, deagglomerated form that will perform best. However, because of the quantities needed, it will have to be, optionally, pretreated; shipped; stored; and discharged from storage as a bead. Consequently, I teach that to effectively use carbon black as a mercury sorbent material, on its way to be injected it would advantageously first encounter a jet mill. With the help of pressurized air, the carbon black would be torn apart and autogenously abraded the jet mill, producing smaller, more-active particles. The outlet of the jet mill would then lead to the injection ports.

Injection-line jet-milling would improve the performance of powdered activated carbons as well. Decreasing the PAC particle size will increase the mercury mass transfer by increasing the external surface are available to connect with the mercury vapor. Thus more of the innate mercury capacity of the PAC can be utilized, increasing the removal rate while decreasing sorbent consumption requirements.

Examples of patent claims for this improvement to the practiced art could be:

I claim:

C.1. In a process for removing mercury from a combustion gas comprising:

a. discharging a carbon material from a storage container,
b. injecting the carbon material into the combustion gas,
c. allowing the carbon material to widely disperse within the gas and adsorb mercury there from, and then
d. separating the carbon material from the combustion gas,

the improvement comprising:

discharging the carbon material to a jet-milling device which mills the carbon material to finer particles prior to its injection into the combustion gas.

C.2. A method as in C.1., wherein

the carbon material comprises powdered activate carbon.

C.3. A method as in C.2., wherein

the carbon material comprises carbon black beads or pellets.

D. Electrostatically Charging the Sorbent

Once injected into the fast-flowing combustion gas in the ductwork, the fine sorbent particles will usually only spend about one or two seconds adsorbing mercury until they are separated from the gas stream by an electrostatic precipitator. Consequently, it is crucial that the fine particles adequately deagglomerate and disperse as quickly and as uniformly as possible.

Such deagglomeration and dispersion can be improved by providing all of the sorbent particles with a common electrostatic charge. Such a common charge can be transferred to the particles by passing the entrained particles through an electrostatic powder gun element, such as those used in powder painting.

Examples of patent claims for this improvement to the practiced art could be:

I claim:

D.1. In a process for removing mercury from a combustion gas comprising:

a. discharging a carbon material from a storage container,
b. injecting the carbon material into the combustion gas,
c. allowing the carbon material to widely disperse within the gas and adsorb mercury there from, and then
d. separating the carbon material from the combustion gas,

the improvement comprising:

electrostatically charging the carbon material prior to allowing it to widely disperse within the gas stream.

D.2. A method as in D.1., wherein

the carbon material is negatively charged by passing close to a corona discharge electrode.

D.3. A method as in D.1., wherein

the carbon material is positively charged byrubbing the particles across a tribo-charging surface.

E. Pre-Treating the Sorbent to Decrease AEA Interference

When flyash is substituted for cement in concretes, special air entraining agents (AEAs) are added for a better final product. Unfortunately, carbon particles, especially highly adsorbent high-surface-area carbon materials such as those used as mercury sorbents, can scavenge the AEAs, making the flyash in which they end up mixed unsuitable for cement use.

This improvement teaches the pretreatment of the carbon sorbent materials to lessen the carbon's scavenging of AEAs. I have found that by pretreating the carbons with fatty acid surfactants, such as Darex II, their AEA adsorption in concrete mixtures is considerably lessened. Alternately, oxidizers such as hydrogen peroxide or ozone can be used to similar effect. These various agents in solution can be applied to the carbons by moistening and then drying the materials before injection, or with e.g. ozone, by exposure in gaseous form.

Examples of patent claims for this improvement to the practiced art could be:

I claim:

E.1. In a process for removing mercury from a combustion gas comprising:

a. discharging a carbon material from a storage container,
b. injecting the carbon material into the combustion gas,
e. allowing the carbon material to widely disperse within the gas and adsorb mercury there from, and then
d. separating the carbon material from the combustion gas,

the improvement comprising:

pretreating the carbon material before it is injected into the combustion gas with a surfactant or an oxidizer.

E.2. A method as in E.1., wherein

the surfactant comprises fatty acids, such as Darex II.

E.3. A method as in E.1., wherein

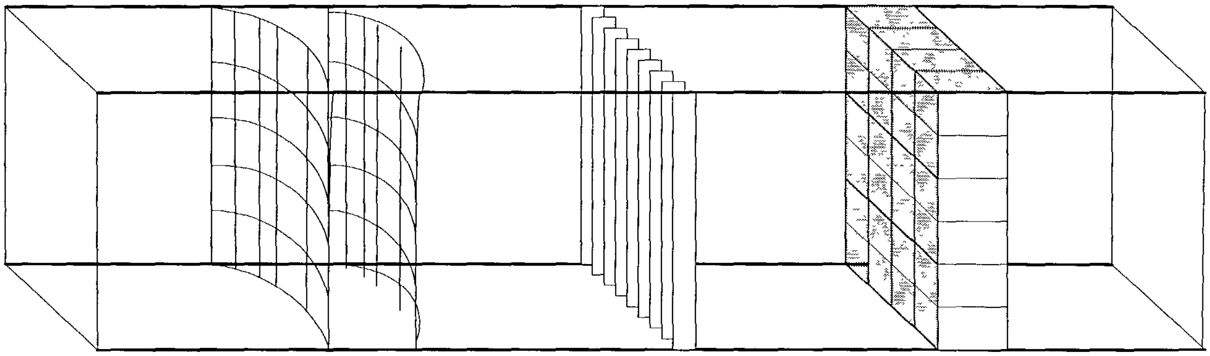
the oxidizer comprises hydrogen peroxide or ozone.

F. Increasing Mass Transfer Surface Area

Much of the mercury capacity of duct-injected sorbents is not utilized because of the short residence time of the materials within the combustion gas. Sorbent which impacts and clings to the walls of the duct, or to turning vanes, however, stays in contact with the gas, and its mercury, and can become fully utilized before being reentrained in the gas flow.

This improvement teaches the retrofitting of high-surface area structures into the ductwork to intentionally temporarily catch injected sorbent. Such structures should be inexpensive, trap a high fraction of the injected sorbent, create very little pressure drop for the large volumes of gas passing by, be corrosion and temperature resistant, be lightweight so as not to require costly duct support, and be self-cleaning or easily-cleaned of the clinging sorbent once it has become more fully utilized. Advantageously, a cleaning mechanism, such as a sonic horn, can be periodically utilized to clear part of the structures for collecting fresh sorbent.

Examples of possible structures include a line of short, parallel carbon-fiber flags extending floor-to-ceiling or a number of parallel fiber nets suspended across the ductwork. Alternately, such a structure can be made of groups of parallel wavy plates or fine open honeycomb, like traditional catalyst supports, but without the catalyst. See below.



Examples of patent claims for this improvement to the practiced art could be:

I claim:

F.1. In a process for removing mercury from a combustion gas comprising:

a. discharging a carbon material from a storage container,
b. injecting the carbon material into the combustion gas,
c. allowing the carbon material to widely disperse within the gas and adsorb mercury there from, and then
d. separating the carbon material from the combustion gas,

the improvement comprising:

obstructing the path of the carbon materials by impacting them upon a high-surface-area structure positioned so as to collect much of the sorbent and have it periodically dislodged back into the gas stream.

F.2. A method as in F.1., wherein

the structure comprises a line of flags across the ductwork.

F.3. A method as in F.2., wherein

the structure comprises a net or nets across the ductwork.

F.4. A method as in F.2., wherein

the structure comprises a group of parallel wavy plates or open ceramic honeycomb.