IN THE UNITED STATES DISTRICT COURT
FOR THE DISTRICT OF DELAWARE

MIDWEST ENERGY EMISSIONS CORP. and
MES INC.,

Plaintiffs,

v.

ARTHUR J. GALLAGHER & CO., ET AL.,

Defendants.

CIV. NO. 1:19-01334- CJB

EXPERT REPORT OF PHILIP J. O'KEEFE, PE REGARDING INFRINGEMENT

[redacted]

[redacted]

1. BACKGROUND

1.1 Summary of Opinions

1. Based on my investigation in this matter, I have concluded that DTE Energy Resources, LLC; CERT Operations II LLC, CERT Operations IV LLC, CERT Operations V LLC, CERT Operations RCB LLC; AJG Iowa Refined Coal LLC, Joppa Refined Coal LLC, Walter Scott Refined Coal LLC, Louisa Refined Coal, LLC, Belle River Fuels Company, LLC, Arbor Fuels Company, LLC, Portage Fuels Company, LLC, Senescence Energy Products, LLC, Rutledge Products, LLC, Alistar Enterprises, LLC, Springhill Resources LLC, Buffington Partners LLC, Bascobert (A) Holdings LLC, Larkwood Energy LLC, Cottbus Associates LLC, George Neal Refined Coal, LLC, George Neal North Refined Coal, LLC, Superior Fuels Company 1, LLC, Erie Fuels Company, LLC, Huron Fuels Company, LLC, Coronado Refined Coal, LLC, Chouteau Fuels Company, LLC, Jasper Fuels Company, LLC, Newton RC, LLC, Canadys Refined Coal, LLC, Hastings Refined Coal LLC, Jefferies Refined Coal, LLC, and Williams Refined Coal, LLC, and Marquis Industrial Company, LLC have infringed certain claims of Plaintiffs' Midwest Energy Emissions Corp. and MES Inc. (collectively, "ME2C"), patents, U.S. Patent No. 10,343,114 (the "'114 patent"), U.S. Patent No. 8,168,147 (the "'147 patent"), U.S. Patent No. 10,589,225 (the "'225 patent"), U.S. Patent No. 10,596,517 (the "'517 patent"), and U.S. Patent No. 10,668,430 (the "'430 patent"). In this report I explain how I arrived at this opinion as well as other opinions and findings.

1.2 Personal Background

2. I have been retained by ME2C, and its counsel, Caldwell Cassady & Curry, as an expert in the lawsuit captioned above. I am being compensated at a rate of $300 per hour for my time spent working in connection with this case.

3. A detailed record of my professional qualifications is set forth in the attached Appendix C, which is a curriculum vitae, including a list of publications, awards, research grants, and professional activities.

4. I have summarized in this section relevant educational background, career history, and other relevant qualifications.

5. I am presently employed by EngineeringExpert.net, LLC, (an engineering consulting firm located at Winona, Minnesota). During this employment, I provide various product development design consulting, intellectual property consulting, and technical training services in the private industry. Additionally, I provide engineering expert witness and forensic engineering services to attorneys in cases involving patent litigation, trade secret misappropriation, product liability, personal injury, and professional malpractice. I have particular knowledge and experience in the areas of coal burning electric utility power plants.

6. I received a BS in Mechanical Engineering from the Illinois Institute of Technology, Chicago, Illinois in 1981.

7. I am a licensed Professional Engineer and a Certified Model Law Engineer. I have over 40 years of experience in coal-fired power plant operations, designing combustion control systems, industrial controls, production tooling/equipment, medical devices, industrial products, and consumer products.

8. Throughout my professional career, I have worked with various mechanical/electronic technologies. For example, from 2006 to 2009, I was employed as a Consulting Engineering Manager at Omni Engineering Services (a contract engineering services firm located in Winona, Minnesota). During this employment, I designed and evaluated various electronic hardware, electronic software, and mechanical components for various industrial and

consumer products, such as medical devices and air conditioning equipment. From 2004 to present, I am employed by EngineeringExpert.net, (an engineering consulting firm located at Winona, Minnesota). During this employment, I provide various product development design consulting, intellectual property consulting, and technical training services in the private industry. From 2000 to 2004, I was employed as a Director of Engineering at Fischer Industries (a medical device manufacturer located in Geneva, Illinois). During this employment, I designed and evaluated various electronic hardware, electronic software, and mechanical components for various X-ray film processors and percussion therapy devices. From 1997 to 2000, I was employed as a Manager of Development and Testing for Echo (a manufacturer of outdoor power equipment in Lake Zurich, Illinois). During this employment, I designed and evaluated various mechanical and electrical systems and their components in various hand-held products, such as string trimmers, leaf blowers, and chainsaws, powered by gasoline engines, mains electrical connection, or rechargeable battery packs. From 1996 to 1997, I was employed as a part-time engineering consultant for Richard M. Hanson and Associates (a forensic engineering firm located in Lombard, Illinois). During such employment, I examined and evaluated various technical evidence collected in electrical fires to determine causes thereof. From 1995 to 1997, I was a Plant Engineer at Karp's (a food manufacturing company in Elk Grove, Illinois). During such employment, I designed a frozen laminated dough production line, which included various improvements to various conveyors, dough forming machinery, fruit depositors, and industrial control systems. From 1981 to 1995, I was employed in various engineering and engineering management capacities in coal-fired power plants at Commonwealth Edison (a large electric utility in Chicago, Illinois). During such employment, I inspected, tested, and trouble-shot coal-fired furnace equipment, pollution control equipment, steam turbine/generator equipment, water purification equipment, and fuel handling/processing equipment. In addition, I designed industrial control systems, including combustion control systems and burner management systems.

9. During the past four years, I testified in the following cases:

Laitram, LLC, et al v. Ashworth Bros., United States District Court for the District of Delaware, Case 1:19-cv-01130-UNA.

Certain Percussive Massage Devices, United States International Trade Commission, Washington, D.C., Investigation No. 337-TA-1206.

10. My opinions, as explained below, are based on my years of education, research, experience, and background in the fields discussed herein, as well as my investigation and study of relevant materials. My opinions are made to a reasonable degree of engineering certainty.

1.3 My Investigation of Defendants 'Infringement

11. The fundamental question I was tasked with answering in my investigation was: "Have the Defendants infringed any claims of the patent-in-suit?" To answer this question, I studied and considered a variety of facts and evidence. I studied the patent-in-suit and its prosecution history. I studied publicly available information about Defendants, their operations, and the power plants to whom Defendants supplied refined coal. I reviewed papers in this litigation—including briefs written by the parties, correspondence from Defendants' attorneys, the Court's Orders and written discovery and responses. I also reviewed the infringement contentions served by ME2C in this case as well as the invalidity contentions served by Defendants. I also reviewed hearing and deposition transcripts and exhibits. In my investigation, I also had access to a database of documents that ME2C, Defendants, and third parties produced in this litigation. I could (and did) perform searches of documents in these databases. Naturally, my review of these materials was done in view of my education, my experience in and knowledge of the coal-fired electric utility industry.

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1.4 Understanding of the Law

12. I have been informed of some legal principles relating to patent infringement that I relied upon in reaching the opinions set forth in this report.

13. The claims describe the invention made by the inventor and describe what the patent owner owns and what the owner may prevent others from doing. Claims may describe products, such as machines or chemical compounds or processes for making or using a product. Claims are usually divided into parts or steps called limitations or elements. For example, a claim that covers the invention of a table may recite the tabletop, four legs, and the glue that secures the legs on the tabletop. The tabletop, the legs, and the glue in that claim would each be a separate limitation or element of the claim. There are two types of claims—independent claims and dependent claims. An independent claim sets forth all the requirements that must be met in order to be covered by that claim. Thus, it is not necessary to look at any other claim to determine what an independent claim covers. A dependent claim does not itself recite all of the requirements of the claim but refers to another claim for some of its requirements. In this way, the claim depends on another claim. The law considers a dependent claim to incorporate all of the requirements of the claims to which it refers. The dependent claim then adds its own additional requirements. To determine what a dependent claim covers, it is necessary to look at both the dependent claim and any other claims to which it refers. A product or method that meets all of the requirements of both the dependent claim and the claims to which it refers is covered by that dependent claim.

14. In deciding whether a claim has been infringed, the first step is to understand the meaning of the words used in the patent claims. The parties have agreed on the meaning of some terms, and the Court has construed some terms. I have applied the Court's and the parties agreed constructions in my analysis. For claim language that the Court has not interpreted or construed,

I understand that such claim language is to be given its ordinary and accustomed meaning as understood by one of skill in the art.

15. For infringement, I understand that any person or business entity that, without the patent owner's permission, makes, uses, imports, sells, or offers to sell a device or practices a method, that is covered by at least one claim of a patent before the patent expires infringes the patent. A patent owner has the right to stop others from infringing the patent claims during the life of the patent. Only the claims of a patent may be infringed. To determine infringement, one must compare each of the asserted claims, as the Court has construed them, to the accused instrumentalities or acts of infringement and determine whether or not there is infringement. A claim limitation may be met in one of two ways—literally or under the Doctrine of Equivalents. A claim limitation is literally met if it exists in the accused product or method just as it is described in the claim language. The second way is under the Doctrine of Equivalents. A claim limitation is present in an accused product or method under the Doctrine of Equivalents if the differences between the claim limitation and a comparable element of the accused product or method are insubstantial. One way to determine whether a difference is insubstantial is to look at whether the accused product or method performs substantially the same function in substantially the same way to achieve substantially the same result as the claimed invention. Another way to determine whether a difference is insubstantial is to consider whether, at the time of the alleged infringement, a person having ordinary skill in the field of technology of the patent would have known of the interchangeability of the alternative feature and the unmet requirement of the claim. Interchangeability at the present time is not sufficient in order for the features to be considered to be interchangeable; rather, the interchangeability of the two features must have been known to persons of ordinary skill in the field of technology at the time the infringement

began. In this way, an inventor need not have foreseen and the patent need not describe all potential equivalents to the invention covered by the claims.

16. It is improper to determine infringement by comparing the accused products or methods with any specific example set out in the patent—the only correct comparison is with the language of the claim itself with any meanings that the Court may have given to claim terms. Also, infringement must be determined by considering each claim individually. There are three ways that a claim may be infringed, namely direct infringement, inducement, and contributory infringement.

17. **Direct Infringement.** If any person makes, uses, imports, sells, or offers to sell what is covered by the claims of a patent without the patent owner's permission, that person is said to infringe the patent. This type of infringement is also called direct infringement. To determine direct infringement, one must compare the accused product or method with each of the asserted claims of the patent-in-suit. A patent claim is directly infringed only if the accused product or method includes (either literally or under the Doctrine of Equivalents) each and every element in that patent claim. An accused product infringes a claim if it is reasonably capable of satisfying the claim elements, even though it may also be capable of non-infringing modes of operation. If an accused product or method includes each element or step of the claim, then the product or method infringes the claim even if such product or method contains additional elements or steps that are not recited in the claim. A person or company can directly infringe a patent without knowing that what it is doing is an infringement of the patent, and direct infringement does not even require knowledge of the patent. A person or company may also directly infringe, even though, in good faith, it believes that what it is doing is not an infringement of any patent, and even if it did not know of the patent infringement. Infringement

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does not require proof that the person copied a product or the patent. The asserted claims of the patent-in-suit must be considered individually in deciding whether making, selling, importing, offering to sell, or using the accused apparatuses or performing the accused methods infringes that claim.

18. **Induced Infringement.** With regard to inducement, infringement must be determined on a claim-by-claim basis. A company is liable for active inducement of a claim only if the patent holder proves by a preponderance of the evidence that: (1) the company took action during the time the patent was in force that was intended to cause and led to infringing acts by someone else; (2) the company was aware of the patent and knew that the acts, if taken, would constitute infringement of the patent, or that or that the company believed there was a high probability that the acts would infringe the patent and the company took deliberate steps to avoid learning of that infringement; and (3) the acts were actually carried out by someone else that directly infringed the claim.

19. In order to establish inducement of infringement, it is not sufficient that alleged infringer was merely aware of the act(s) that allegedly constitute the direct infringement. Rather, in order to find inducement of infringement, the accused inducer must have specifically intended for the direct infringer to infringe the patent or that the accused inducer must have believed that there was a high probability that the direct infringer would infringe, but deliberately avoided learning of the infringement.

20. **Contributory Infringement.** With regard to contributory infringement, infringement must be determined on a claim-by-claim basis. A company is liable for contributory infringement of a claim if the patent holder proves by a preponderance of the evidence: (1) the company sells, offers to sell, or imports within the United States a component of a product,

material, or apparatus for use in a process, during the time the patent is in force; (2) the component, material, or apparatus is not a staple article or commodity of commerce suitable for substantial noninfringing use; (3) the component, material, or apparatus constitutes a material part of the invention; (4) the company is aware of the patent and knows that the component, material, or apparatus is especially made or adapted for use as an infringement of the claim; and (5) someone uses the component, material, or apparatus to directly infringe a claim.

1.5 The Organization of Patents

21. Patents are organized into different sections. Notable sections of patents are the drawings, which are sometimes referred to as figures; the background of the invention, which discusses the state of the art before the invention; the summary of the invention; the detailed description of the invention, which discusses various preferred embodiments; and the claims, which define and set out the patent property right given to the patentee by the United States. The term "preferred embodiment" refers to a specific, particular way to practice or implement the ideas of the patent, but patents typically are not limited to their preferred embodiments. Patents also have a title; a list of prior art, which is all deemed to have been considered by the USPTO; the filing date of the patent; related applications and their filing dates; a list of the inventors; the date the patent was issued; and the assignee, which is the person or company who owns the patent.

1.6 The Level of Ordinary Skill in the Art

22. A person of ordinary skill in the art of the patent-in-suit at the time of the invention would have a bachelor's degree in mechanical engineering, chemical engineering, chemistry, or a related field of technology and at least two years of experience dealing with power plant operation, and/or pollution control equipment. Additional work experience in

relevant industries could compensate for less education, or education in a different field. Similarly, advanced education and degrees could compensate for less work experience.

23. I base this opinion on the background of the inventors—including their experience level—and the subject matter of the patent-in-suit. I have also considered the engineers and power plant employees with whom I had experience in the timeframe of the filing dates of the patent-in-suit, specifically: (i) the education level and background needed for them to begin to grasp this material; and (ii) the practical experience needed to allow them to understand the patent in making effective use of the material laid out in this patent.

2. Technology Background

24. A person of ordinary skill in the art would be aware of some facts and principles related to power plant operation and mercury control.

2.1. Overview of Power Plant Operation

25. Generally speaking, coal-fired power plants convert the chemical energy in coal into electrical energy used in our homes and businesses. This is done by burning (combusting) the coal to release heat that turns water into steam. The steam drives rotating steam turbines. The rotating steam turbines drive rotating electrical generators that produce electricity.

26. In more detail, the coal is delivered to the plant in trains or barges. The coal is unloaded and sent by conveyors to a coal pile for long term storage. Coal is removed from the pile as needed, via a reclaim system, and moved by conveyor belts to the bunkers (coal silos). Coal is removed from the bunkers via gravity and sent to feeders. The feeders meter specific amounts of coal to the pulverizers depending on rate of combustion and steam demand. The pulverizers grind the coal into fine powder, which is combined with primary air and conveyed up by exhausters, or primary air fans. The primary air fans or exhausters blow the coal-primary air mixture to the burners in the furnace which is part of the steam generation system (often referred

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to as the steam generator, or boiler) of the plant. The area near the burners form a combustion chamber, the furnace section of the boiler. Downstream of the combustion chamber there are series of heat exchangers and tubes in the convective heat transfer sections of the boiler that further extract heat from flue gas that exits the furnace. Combustion gases are formed and undergo chemical changes as coal is burned in the furnace. As the coal is completely combusted the products of combustion leave the furnace as flue gas.

27. At the burners, the coal-primary air is further mixed with secondary air, ignited, and a fireball is formed in the furnace. The radiant heat released by the fireball, heats water in surrounding waterwall tubes until it becomes saturated steam. This saturated steam is sent to a steam drum, where it is collected and sent over to superheater tubes.

28. Babcock and Wilcox developed an alternate to the pulverized coal furnace. This is known as the cyclone furnace. Coal is conditioned, that is, broken into small chunks prior to arriving at the furnace. The chunks are fed into a number of horizontally oriented cyclone burners along with primary and secondary air. The coal/air mixture is admitted to the cyclone burners tangentially and the coal is ignited. This forms a whirling fireball within the cyclone burner (combustion chamber). Burning coal chunks are flung by centrifugal force into the molten slag coating the cyclone burner walls. The fireballs leave the cyclone burners and combustion of coal is completed in the furnace. The heat generated and absorbed in the cyclones and immediate furnace are used to heat up the water to saturated conditions.

29. The superheater tubes are located in the convection passes of the boiler just downstream of the furnace. Flue gas exiting the furnace enters the convective superheater tubes and converts the saturated steam into superheated steam. The superheated steam is then sent to the steam turbine. Superheated steam drives the turbine-generator to produce electricity. The

turbine exhausts the steam into a condenser. The condenser uses a separate source of cooling water to condense the used steam back into water. The water is then pumped back to and within the boiler to repeat the cycle.

30. The last set of tube bundles (heat exchangers) in the boiler are referred to as the economizer. The economizer is located downstream of the superheater tubes (heat exchangers) in the convective pass of the boiler. The economizer is used to further extract energy from the flue gas to heat up water/steam before the flue gas exits the boiler.

31. When coal is burned in the fireball (furnace), it generates a waste product in the form of molten slag, often referred to as bottom ash. This slag flows by gravity into a hopper below the fireball in the furnace where it is cooled, solidified, and removed. The amount of bottom ash produced is dependent on the coal type (i.e. the amount of ash in the coal), boiler/furnace type, and combustion conditions. Generally, about 20-40% of the ash in the coal is converted to bottom ash with the remaining amount of 60-80% of the ash in the coal as fly ash. Fly ash is the ash that leaves the furnace and enters the convective pass of the boiler. The fly ash is transported by the flue gas through the convective pass of the boiler to downstream particulate removal devices, such as electrostatic precipitators (ESPs) or baghouses. A small amount of fly ash is removed in a hopper at the economizer as the flue gas makes a right angle turn upon leaving the economizer. The fly ash is collected and removed from the hopper on an ongoing basis.

32. From the economizer, the flue gas leaves the boiler and goes to a selective catalytic reduction (SCR) unit for NOx control. SCR units have been installed at many plants to reduce NOx emissions; however, not all plants are equipped with SCRs. SCRs can have a significant impact on mercury oxidation and subsequent removal in downstream equipment. For

units that have SCRs, the flue gas leaves the SCRs and enters an air heater, or multiple air heaters. For plants without SCRs, the flue gas leaving the economizer goes directly to the air heaters. Note, while not common, there are a few plants that are equipped with hot-side ESPs for particulate control which are located between the economizer and air heaters.

33. The air heaters transfer heat from the flue gas to the primary and secondary air before it is sent to the pulverizers, burners, and furnace

34. Depending on the plant, after leaving the air heater(s), the flue gas flows through a series of emissions control equipment such as bag houses, and/or electrostatic precipitators (ESPs), and scrubbers, to remove regulated pollutants (ie. NOx, SOx, PM, Hg, etc) and most of the remaining fly ash before the gas flows up the stack to the atmosphere. The emissions control equipment that is installed at a plant can have a significant impact on mercury removal from the flue gas. For example, bag houses are more effective at capturing mercury than ESPs. Further, scrubbers are only effective at removing oxidized mercury.

35. ESPs remove fly ash by attracting it to electrically charged plates and wires. Bag houses remove fly ash by passing the flue gas through fabric filters. At the base of the ESP or bag house, a series of hoppers are used to collect the fly ash from the flue gas. The fly ash is removed from the hoppers, and in some cases, is sold to be used to make cement products.

36. Depending on the design of the plant, there are two types of scrubbers: wet and dry. Wet Scrubber systems extract sulfur compounds or oxides of sulfur such as sulfur dioxide (SO_2) and fly ash. Wet Scrubbers get their name because of the scrubbing action of flue gas in contact with water that has reacted with an alkaline material such as limestone. The reagent water (slurry) scrubs off air pollutants from the flue gas via reactions with spray droplets interacting with the flue gas. In a typical wet scrubber there are a number of spray levels and

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nozzles within a vessel to optimize contact of the slurry and flue gas. Although not overly common, there is a slight variation of this referred to as a wet particulate scrubber, or a venturi wet scrubber. The venturi scrubber first removes particulate in an initial venturi stage and then subsequently removes SO2 in a following section of the scrubber. The dry scrubber systems use reagents to remove sulfur compounds from the flue gas. The reagents are derived from limestone or lime. The flue gas is sprayed with these reagents in the dry scrubber to react with the sulfur in the flue gas, with the reaction products collected downstream in ESPs or bag houses.

37. Coal is classified into four main ranks: anthracite, bituminous, subbituminous and lignite. These different types of coal have different heating values, meaning that a pound of bituminous coal, for example, can produce more heat than a pound of lignite. This heating value is often measured in pounds per British thermal unit or lbs/Btu:[1]

- ***Anthracite*** *contains 86% 97% carbon and generally has the highest heating value of all ranks of coal. Anthracite accounted for less than 1% of the coal mined in the United States in 2020. All of the anthracite mines in the United States are in northeastern Pennsylvania. In the United States, anthracite is mainly used by the metals industry.*

- ***Bituminous*** *coal contains 45% 86% carbon. Bituminous coal in the United States is between 100 million and 300 million years old. Bituminous coal is the most abundant rank of coal found in the United States, and it accounted for about 44% of total U.S. coal production in 2020. Bituminous coal is used to generate electricity and is an important fuel and raw material for making coking coal or use in the iron and steel industry. Bituminous coal was produced in at least 18 states in 2020, but five states accounted for about 74% of total bituminous production: West Virginia (28%), Pennsylvania (14%), Illinois (13%), Kentucky (10%), and Indiana (8%).*

- ***Subbituminous*** *coal typically contains 35% 45% carbon, and it has a lower heating value than bituminous coal. Most subbituminous coal in the United States is at least 100 million years old. About 46% of total U.S. coal production in 2020 was subbituminous and about 88% was produced in Wyoming and 8% in Montana. The remainder was produced in Alaska, Colorado, and New Mexico.*

- ***Lignite*** *contains 25% 35% carbon and has the lowest energy content of all coal ranks. Lignite coal deposits tend to be relatively young and were not subjected to extreme heat or pressure. Lignite is crumbly and has high moisture content, which contributes to its*

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[1] Ref. 232

> *low heating value. Lignite accounted for 9% of total U.S. coal production in 2020. About 54% was mined in North Dakota and about 39% was mined in Texas. The other 7% was produced in Louisiana, Mississippi, and Montana. Lignite is mostly used to generate electricity. A facility in North Dakota also converts lignite to synthetic natural gas that is sent in natural gas pipelines to consumers in the eastern United States.*

38. Coals may also be graded based on SO_2 content:[2]

SO_2 Grade	SO_2 Content Range (lbs/MMBtu)
A	0.00 – 0.80
B	0.81 – 1.20
D	1.21 – 1.66
E	1.67 – 3.34
G	3.35 - 5.00
H	> 5.00

Thus, for example, a high sulfur bituminous coal may be classified as 'BG.'

39. Power plants may also blend coals of different ranks, or coals of the same rank from different mines. Coals of different ranks, from different mines, and even from different seams in a mine may differ by heating value and also by chemical composition. Accordingly, power plants must consider the heating value and chemical composition of the coal being combusted when designing and operating pollution control equipment. A power plant must also be permitted to burn a particular type of coal. The type of coal burned can significantly impact mercury speciation, emissions, and the technology required to control emissions.

2.2. Overview of EPA Regulations and Permitting

40. In order for coal burning power plants to operate, they must comply with Title V of the Clean Air Act (CAA).[3] Permits are issued to coal-fired power plants, which are considered to be "major sources" of pollutants by the federal Environmental Protection Agency in (EPA). Most such permits are issued by state or local agencies. The permit is a legally-enforceable document that requires compliance by clarifying what the power plants must do to

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[2] Ref. 70

[3] Ref. 86

control emissions that contribute to air pollution.[4] A Title V permit is enforceable for five years and generally renewable after

41. These permits identified required pollution control equipment and testing requirements. Failure to comply with the permit requirements can result in significant fines or shut down of the power plant.

42. Testing is typically conducted over a set period of time. For example. a power plant may be required to limit a particular pollutant emission over a 30 day period. During that time, the plant could shut down some piece of equipment for maintenance purposes while the plant is still burning coal, but it would otherwise need to ensure that overall emissions during that time period do not exceed the limits specified in its operating permit.

43. Some operating permits may allow power plants to use some pollution control equipment intermittently. For example, power plants burning bituminous coal and equipped with an SCR may only need to use activated carbon injection a few days out of the year.[5]

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44. On the other hand, some pollution control equipment may need to be operated continuously or with only short term stoppages. If a power plant wants to shut down the equipment for more than a limited time it would need to seek a revision to its operating permit and provide assurance that it could comply with regulations. For example, if a power plant wanted to shut down its required activated carbon system and use some other pollution control approach, it would need to apply and seek approval to do so.[6]

[redacted]

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2.3. Development of Mercury Capture Technology, Regulations, and Tax Credits

45. In 1990, Congress amended the Clean Air Act to better address toxic air pollutants. That law required the EPA to prepare regulations addressing a number of potential air pollutants, including mercury. It also required the EPA to identify Maximum Achievable Control Technology (MACT) standards based on the best demonstrated control technology or practices within an industry.[7]

46. In 1997 and 1998, the EPA issued two reports to Congress: *Mercury Study Report to Congress* (issued December 1997)[8] and *Study of Hazardous Air Pollutant Emissions from Electric Utility Steam* (issued February 1998)[9] related to the risks of mercury pollution and potential technologies for capturing mercury. Over the next several years, the EPA would issue a number of additional reports regarding mercury and potential technologies that could be used to achieve mercury capture.

[redacted]

[8] Ref. 17

[9] Ref. 234

47. During this time, the industry spent millions of dollars seeking to develop mercury capture technologies. Much of the focus of this research was on retrofit technologies. That is, technology that could increase mercury capture at already existing power plants at a relatively low cost, and with relatively limited changes to plant operation.[10]

2.4. The Inventors' Development of the Patents-in-Suit.

48. The inventors of the patents-in-suit were researching the issue of mercury capture at the EERC. Through their work, they uncovered some of the complex chemistry that occurs in a coal-fired boiler. They further discovered a number of methods for improving mercury capture. In particular, they found that applying a halogen additive such as bromine, and bromide compounds, onto coal prior to combustion, when combined with activated carbon injection into the combustion gas stream, could dramatically reduce the mercury content of coal-fired power plant emissions.[11]

49. In 2004, the inventors filed a provisional patent application that would lead to the patents in suit. This application, and the subsequently issued patents, cover some of their discoveries and various applications of their discoveries. In particular, the inventors discovered, and ultimately proved, the benefits of combining halogen treatments (e.g., bromine containing materials) in-flight with backend sorbents (e.g., activated carbon).

2.5. EPA Finalizes Mercury Regulation.

50. The EPA finalized the first national standards to reduce mercury and other toxic air pollution from coal-fired plants (the Mercury and Air Toxics Standards or "MATS"). Most power plants were required to comply with this rule by 2015, unless they were granted a one-

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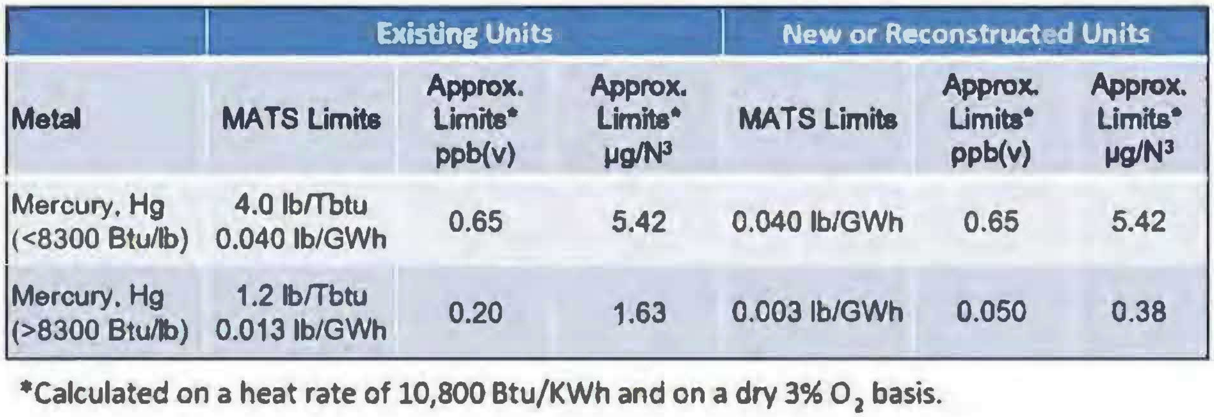
[10] Ref. 64, Pp. 3-4 ('114 prosecution history)

[11] Ref. 64, Pp. 8-9 ('114 prosecution history)

[redacted]

year extension.[12] Plants must obtain a Title V operating permit from the EPA, state, or local agency disclosing their procedures for complying with MATS.

51. The goal of MATS was to reduce mercury emissions from coal-fired power plants by at least 90%. The final MATS limits depend on the type of coal burned by the power plant, i.e., lignite-burning power plants are allowed to emit more mercury than power plants burning bituminous or sub-bituminous coals, as shown below:[13]



	Existing Units			New or Reconstructed Units		
Metal	MATS Limits	Approx. Limits* ppb(v)	Approx. Limits* µg/N³	MATS Limits	Approx. Limits* ppb(v)	Approx. Limits* µg/N³
Mercury, Hg (<8300 Btu/lb)	4.0 lb/Tbtu 0.040 lb/GWh	0.65	5.42	0.040 lb/GWh	0.65	5.42
Mercury, Hg (>8300 Btu/lb)	1.2 lb/Tbtu 0.013 lb/GWh	0.20	1.63	0.003 lb/GWh	0.050	0.38

*Calculated on a heat rate of 10,800 Btu/KWh and on a dry 3% O_2 basis.

2.6. Refined Coal Tax Credits.

52. In 2004, Congress created a refined-coal tax credit (Section 45 tax credits) to promote the production of refined coal.[14] Taxpayers that opened refined-coal production

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[12] Ref. 71, Pg. 12.

[13] Ref. 71, Pg. 16.

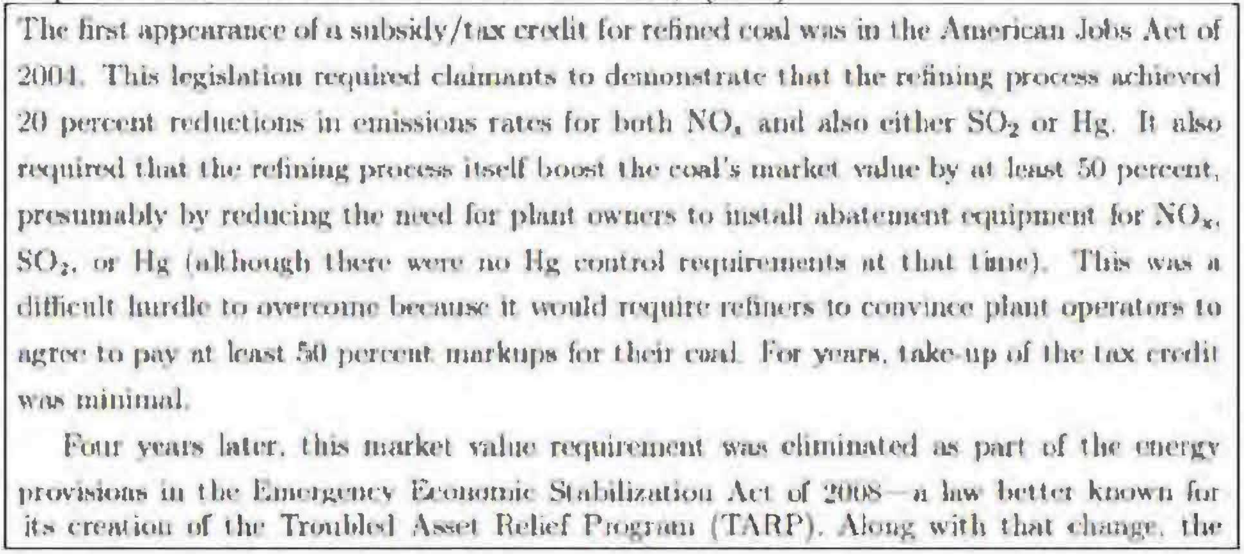
[14] Ref. 72, 26 U.S.C. § 45(c)(7)(A):
(7) Refined coal
 (A)In general - The term "refined coal" means a fuel—
  (i)which—
   (I)is a liquid, gaseous, or solid fuel produced from coal (including lignite) or high carbon fly ash, including such fuel used as a feedstock,
   (II)is sold by the taxpayer with the reasonable expectation that it will be used for the purpose of producing steam, and
   (III)is certified by the taxpayer as resulting (when used in the production of steam) in a qualified emission reduction, or
  (ii)which is steel industry fuel.

facilities before 2012 could claim a tax credit for each ton sold over the following ten years. Initially, a producer could only receive the credit if they sold the refined coal for 50% more than the market value of unrefined coal. However, Arthur J. Gallagher & Co. lobbied congress to remove that requirement from the law.[15] In 2008, as part of legislation related to the 2008 financial crisis, Congress ultimately adopted the Gallagher proposal.[16]

(B) Qualified emission reduction - The term "qualified emission reduction" means a reduction of at least 20 percent of the emissions of nitrogen oxide and at least 40 percent of the emissions of either sulfur dioxide or mercury released when burning the refined coal (excluding any dilution caused by materials combined or added during the production process), as compared to the emissions released when burning the feedstock coal or comparable coal predominantly available in the marketplace as of January 1, 2003.

[redacted]

[16] Ref. 225, ME2C-RC-00279293, B. Prest & A. Krupnick, "How Clean is "Refined Coal"? An Empirical Assessment of a Billion-Dollar Tax Credit," (2020)



The first appearance of a subsidy/tax credit for refined coal was in the American Jobs Act of 2004. This legislation required claimants to demonstrate that the refining process achieved 20 percent reductions in emissions rates for both NO_x and also either SO_2 or Hg. It also required that the refining process itself boost the coal's market value by at least 50 percent, presumably by reducing the need for plant owners to install abatement equipment for NO_x, SO_2, or Hg (although there were no Hg control requirements at that time). This was a difficult hurdle to overcome because it would require refiners to convince plant operators to agree to pay at least 50 percent markups for their coal. For years, take-up of the tax credit was minimal.

Four years later, this market value requirement was eliminated as part of the energy provisions in the Emergency Economic Stabilization Act of 2008—a law better known for its creation of the Troubled Asset Relief Program (TARP). Along with that change, the

53. To qualify for a section 45 tax credit, a refined coal producer must sell refined coal that meets the emission reduction requirements of Section 45 of the tax code, and with the expectation that the refined coal will be used for producing steam. This requires a reduction of 20 percent from NOx and 40 percent from either mercury or SOx. Moreover, the refined coal producer must be "unrelated" to the purchaser of the refined coal. Thus, an owner of a power plant could not obtain Section 45 tax credits by selling refined coal to itself.

2.7. Mechanisms of Mercury Capture.

54. The EPA, DOE, and others have continued to study mercury capture for coal-fired power plants, and the industry has obtained a greater understanding of the mechanisms and available technology for mercury capture.

55. During combustion, the mercury (Hg) in coal is volatilized and converted to elemental mercury (Hg^0) vapor in the high temperature regions of coal-fired boilers. As the flue gas is cooled, a series of complex reactions begin to convert Hg^0 to ionic mercury (Hg^{2+}) compounds and/or Hg compounds (Hg^P) that are in a solid-phase at flue gas cleaning temperatures or Hg that is adsorbed onto the surface of other particles. The presence of chlorine gas-phase equilibrium favors the formation of mercuric chloride ($HgCl_2$) at flue gas cleaning temperatures. However, Hg^0 oxidation reactions are kinetically limited and, as a result, Hg enters the flue gas cleaning device(s) as a mixture of Hg^0 , Hg^{2+}, and Hg^P. This partitioning of Hg into Hg^0 , Hg^{2+}, and Hg^P is known as mercury speciation, which can have considerable influence on selection of mercury control approaches.[17] In general, the majority of gaseous mercury in

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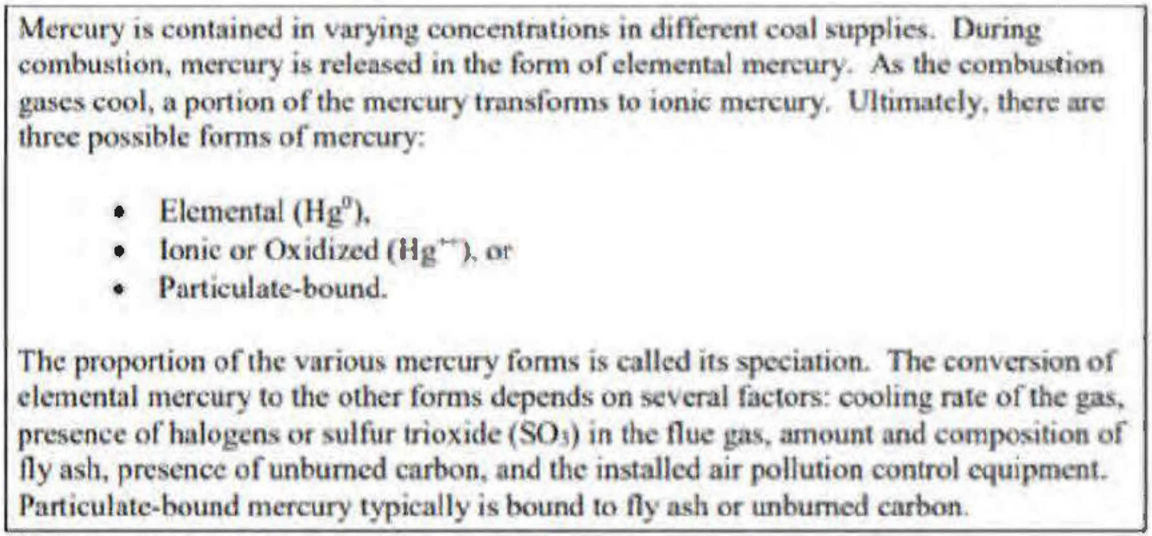
[17] Ref. 75 at pg. 2:

bituminous coal-fired boilers is Hg^{2+}. On the other hand, the majority of gaseous mercury in subbituminous- and lignite-fired boilers is Hg^0.[18]

56. If a plant is equipped with a scrubber, oxidized mercury may be captured in dry or wet FGD systems. Because oxidized mercury is water soluble, it may be dissolved and captured in the slurry.[19]

57. Oxidized mercury may also be converted to particle bound mercury if it comes into contact with suitable particles, e.g., in flight or in the filter cake of a fabric filter. Such particles may be injected, e.g., activated carbon injection, or produced through the combustion process, e.g., pyrolysis char and reactive ash.

58. Particle bound mercury may be captured in traditional particulate matter control devices, i.e., bag houses and ESPs, as these devices capture the mercury-bound particles.



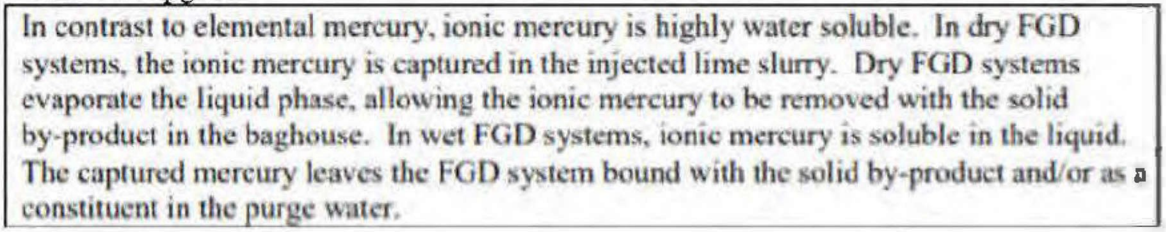
Mercury is contained in varying concentrations in different coal supplies. During combustion, mercury is released in the form of elemental mercury. As the combustion gases cool, a portion of the mercury transforms to ionic mercury. Ultimately, there are three possible forms of mercury:

- Elemental (Hg^0),
- Ionic or Oxidized (Hg^{++}), or
- Particulate-bound.

The proportion of the various mercury forms is called its speciation. The conversion of elemental mercury to the other forms depends on several factors: cooling rate of the gas, presence of halogens or sulfur trioxide (SO_3) in the flue gas, amount and composition of fly ash, presence of unburned carbon, and the installed air pollution control equipment. Particulate-bound mercury typically is bound to fly ash or unburned carbon.

[18] Ref. 226, ME2C-RC-00279374

[19] Ref. 75 at pg. 3:



In contrast to elemental mercury, ionic mercury is highly water soluble. In dry FGD systems, the ionic mercury is captured in the injected lime slurry. Dry FGD systems evaporate the liquid phase, allowing the ionic mercury to be removed with the solid by-product in the baghouse. In wet FGD systems, ionic mercury is soluble in the liquid. The captured mercury leaves the FGD system bound with the solid by-product and/or as a constituent in the purge water.

59. Bag houses are more effective at capturing mercury than ESPs because they provide a more effective and longer contact time as the mercury laden gas passes through the filter cake. Oxidized mercury is more easily captured in a baghouse due to the increased residence and contact time with the filter cake. Because oxidized mercury adsorbs more readily to carbon, as the oxidized mercury passes through the filter cake on the baghouse fabric filter, the mercury becomes bound to particles of carbon or ash particles that have collected on the filter cake. The effectiveness of this approach depends on the amount of unburned carbon, activated carbon, and reactive ash present in the filter cake as well as the flue gas velocity. Mercury is not captured as effectively in an ESP due to the very limited (short) residence and contact time that ESPs provide. Thus, there are very limited interactions that occur with the mercury and material in the flue gas (e.g ash, carbon, etc) on the plates of the ESP. Most of the interaction with the mercury and material (e.g ash, carbon, etc) in the flue gas therefore must occur inflight in a very short period of time (seconds). Consequently, mercury is not captured unless that mercury is bound to particles inflight that can be captured by the ESP, i.e., carbon.[20]

60. Elemental mercury is the most difficult form of mercury to capture. It must be converted into oxidized or particle-bound mercury to be captured effectively.[21]

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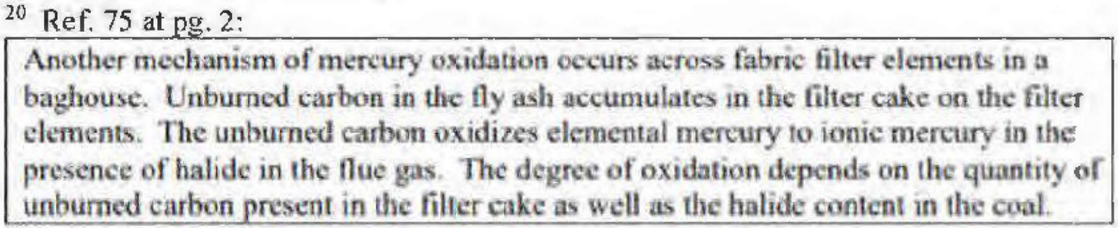
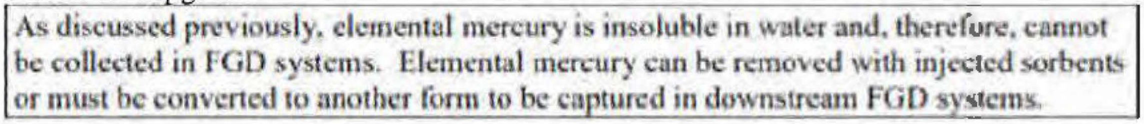
[20] Ref. 75 at pg. 2:



Another mechanism of mercury oxidation occurs across fabric filter elements in a baghouse. Unburned carbon in the fly ash accumulates in the filter cake on the filter elements. The unburned carbon oxidizes elemental mercury to ionic mercury in the presence of halide in the flue gas. The degree of oxidation depends on the quantity of unburned carbon present in the filter cake as well as the halide content in the coal.

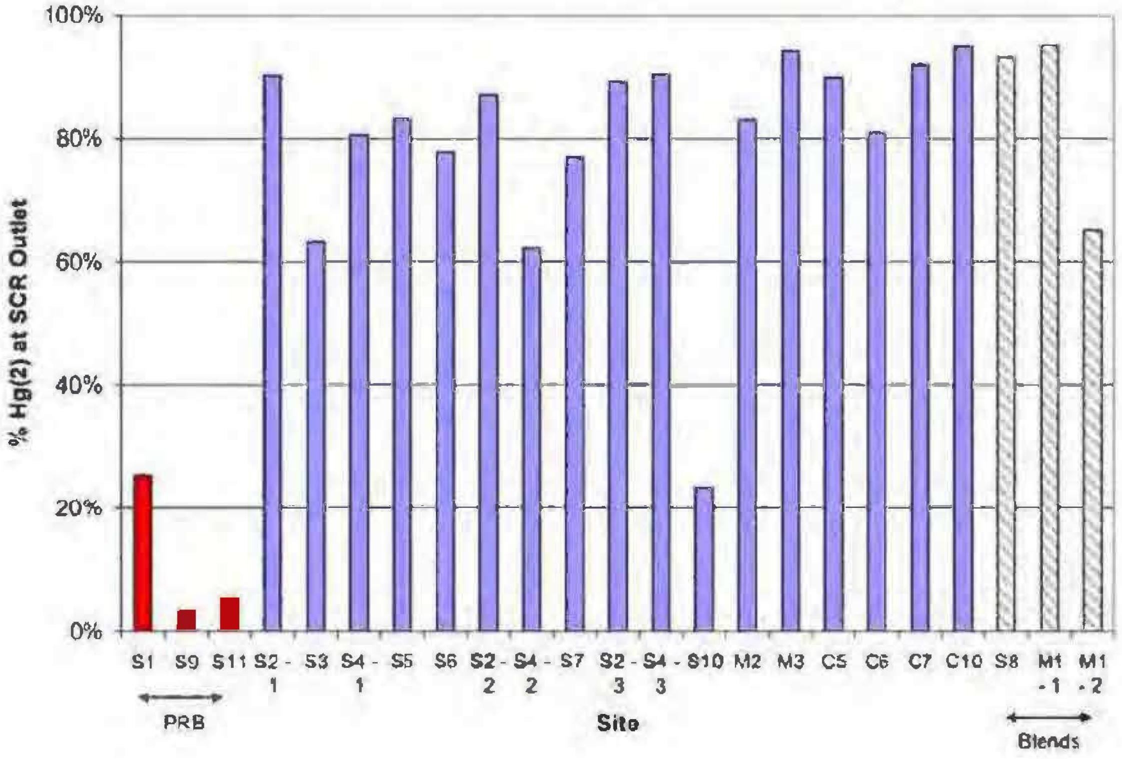
[21] Ref. 75 at pg. 3:



As discussed previously, elemental mercury is insoluble in water and, therefore, cannot be collected in FGD systems. Elemental mercury can be removed with injected sorbents or must be converted to another form to be captured in downstream FGD systems.

[redacted]

61. As discussed more below, elemental mercury may be oxidized through reactions with halogens and activated carbon. In addition, to control NOx, many plants have installed selective catalytic reduction (SCR) technology. SCRs can have a significant impact on mercury oxidation and subsequent removal in downstream equipment. As show below, the impact that SCRs have on mercury oxidation is coal dependent.[22] Plants that burn PRB subbituminous coal have minimal mercury oxidation as compared to plants that burn bituminous or blends of bituminous/subbituminous coal. Thus, controlling mercury in plants that burn PRB subbituminous coal is much more difficult.



2.8. Mercury Capture Differences Between Coal Ranks.

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[22] Ref. 235

[redacted]

62. Mercury in coal can vary significantly by coal rank and coal from different regions of the country.[23] For example, lignite coal from the Gulf Coast region has a very high mercury content when compared to other coals on a lb/TBtu basis. When burned in power plants, these lignites will generate large amounts of mostly elemental mercury, which is the most difficult to control/remove.

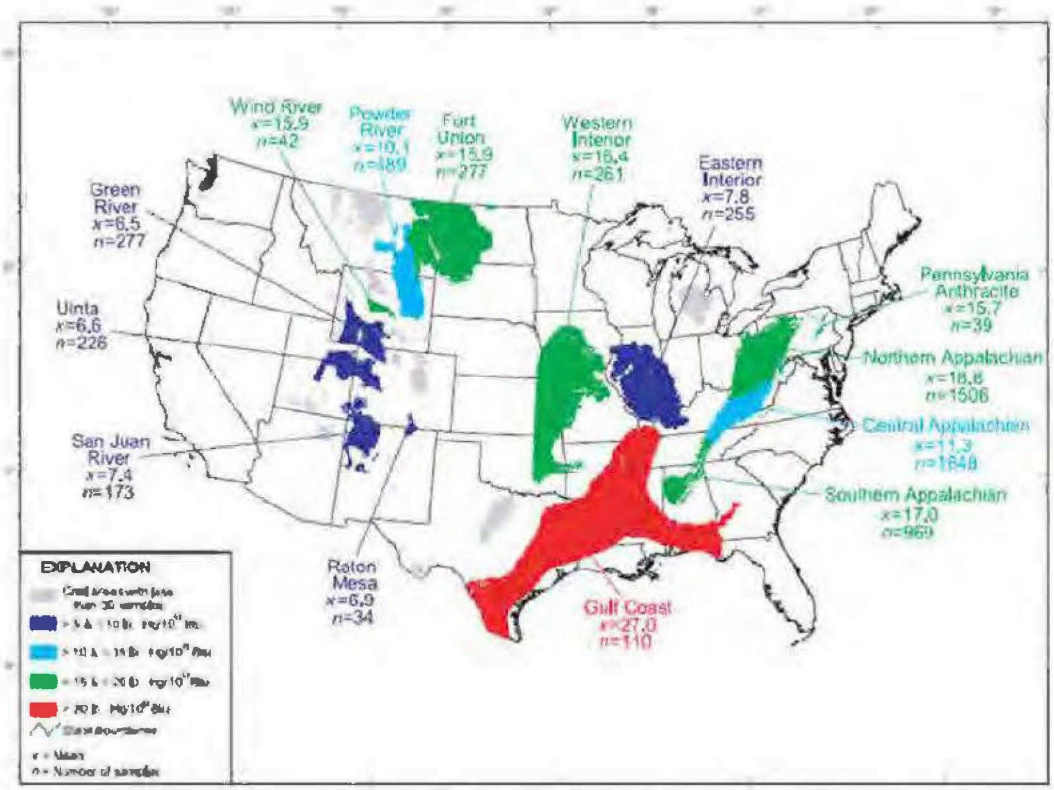

Figure 3. Mercury input loadings (in pounds of mercury per 10^{12} British thermal units (lb Hg/10^{12} Btu)) of in-ground coal for selected U.S coal-producing regions.

63. Mercury capture techniques can vary significantly for bituminous versus sub-bituminous or lignite coals.[24] Bituminous coals typically have higher chlorine content compared

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[23] Ref. 87

[24] Ref. 80, Pg. 49, Lines1-16:

[redacted]

to sub-bituminous or lignite coals. The presence of this chlorine can result in an increased proportion of oxidized mercury, i.e., $HgCl_2$. In addition, bituminous coal combustion tends to result in a greater proportion of unburned carbon in the fly ash. This unburned carbon, in combination with the chlorine present in the flue gas, can also result in a higher proportion of oxidized mercury.[25] Moreover, because bituminous coal has less mercury on a lb/btu basis, bituminous coal combustion is more likely to have a higher proportion of particle bound carbon bound to unburnt carbon in the fly ash. In contrast, for low rank coals (sub-bituminous and lignite), most of the mercury will remain in elemental form without the use of mercury capture systems such as activated carbon injection.[26]

[redacted]

64. As a result, capturing mercury from power plants that burn sub-bituminous or lignite coals presents a more significant challenge than capturing mercury from bituminous coal-fired power plants. For example, the EPA has reported that some plants burning bituminous coals with a fabric filter installed may be able to achieve 90% or greater mercury capture without installing new mercury removal systems. However, no power plants burning sub-bituminous or lignite coals could achieve that level of mercury capture without the installation of additional mercury capture systems.[27]

65. The table below shows the average reduction in total mercury (Hg^T) emissions developed from EPA's Information Collection Request (ICR) data on U.S. coal-fired boilers. In general, the amount of Hg captured by a given control technology is greater for bituminous coal than for either subbituminous coal or lignite. For example, the average capture of Hg in plants equipped with a cold side ESP (CS-ESP) is 36 percent for bituminous coal, 3 percent for

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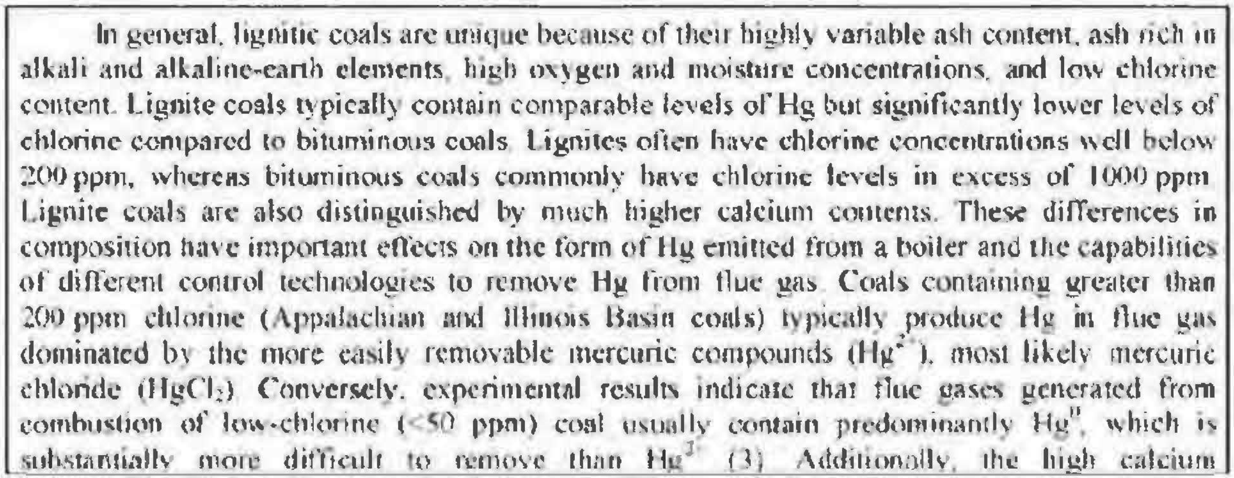
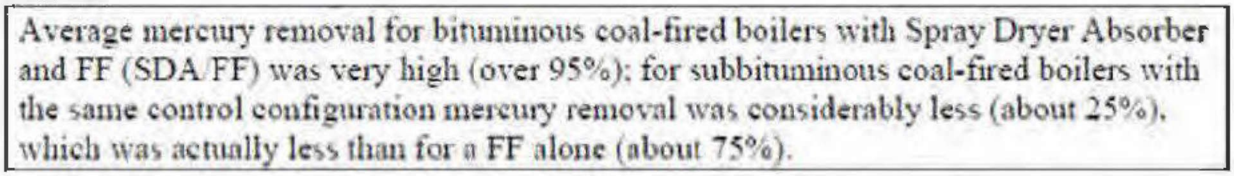


In general, lignitic coals are unique because of their highly variable ash content, ash rich in alkali and alkaline-earth elements, high oxygen and moisture concentrations, and low chlorine content. Lignite coals typically contain comparable levels of Hg but significantly lower levels of chlorine compared to bituminous coals. Lignites often have chlorine concentrations well below 200 ppm, whereas bituminous coals commonly have chlorine levels in excess of 1000 ppm. Lignite coals are also distinguished by much higher calcium contents. These differences in composition have important effects on the form of Hg emitted from a boiler and the capabilities of different control technologies to remove Hg from flue gas. Coals containing greater than 200 ppm chlorine (Appalachian and Illinois Basin coals) typically produce Hg in flue gas dominated by the more easily removable mercuric compounds (Hg^{2+}), most likely mercuric chloride ($HgCl_2$). Conversely, experimental results indicate that flue gases generated from combustion of low-chlorine (<50 ppm) coal usually contain predominantly Hg^0, which is substantially more difficult to remove than Hg^{2+} (3). Additionally, the high calcium

[27] Compare Ref. 76, Table 1 and Table 2.

Ref. 76:



Average mercury removal for bituminous coal-fired boilers with Spray Dryer Absorber and FF (SDA/FF) was very high (over 95%); for subbituminous coal-fired boilers with the same control configuration mercury removal was considerably less (about 25%), which was actually less than for a FF alone (about 75%).

[redacted]

subbituminous coal, and 0 percent for lignite coal.[28] The data shows that controlling mercury from plants burning subbituminous and lignite coal equipped with cold-side ESPs is most difficult.

Post-combustion Control Strategy	**Post-combustion Emission Control Device Configuration**	**Average Mercury Capture by Control Configuration**		
		Coal Burned in Pulverized-coal-fired Boiler Unit		
		Bituminous Coal	**Subbituminous Coal**	**Lignite**
PM Control Only	**CS-ESP**	36 %	3%	0 %
	HS-ESP	9 %	6 %	not tested
	FF	90 %	72 %	not tested
	PS	not tested	9 %	not tested
PM Control and Spray Dryer Adsorber	**SDA+CS-ESP**	not tested	35 %	not tested
	SDA+FF	98 %	24 %	0 %
	SDA+FF+SCR	98 %	not tested	not tested
PM Control and Wet FGD System[(a)]	**PS+FGD**	12 %	0 %	33%
	CS-ESP+FGD	75 %	29 %	44 %
	HS-ESP+FGD	49 %	29 %	not tested
	FF+FGD	98 %	not tested	not tested

CS-ESP = cold-side electrostatic precipitator
HS-ESP = hot-side electrostatic precipitator
FF = fabric filter
PS = particle scrubber
SDA = spray dryer absorber system

(a) Estimated capture across both control devices

66. Various groups have investigated whether mercury capture techniques that work for bituminous coals could be employed for sub-bituminous or lignite coals if additional halogen, e.g., chlorine, bromine, iodine, is added to the coal. However, these studies have shown that while mere addition of halogen to the coal can improve mercury capture somewhat, it alone is not a viable strategy for MATS compliance.[29]

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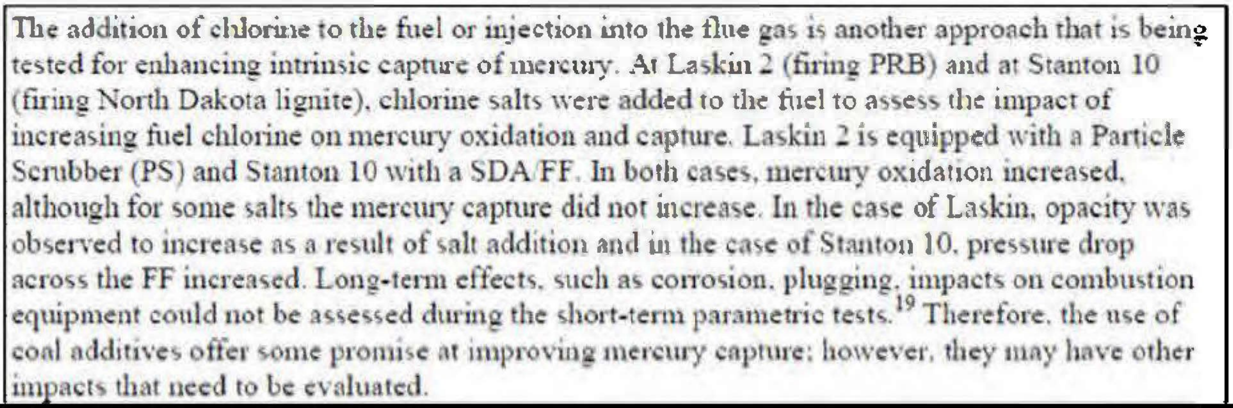
[28] Ref. 226

[29] Ref. 76:

[redacted]

67. Similarly, Chem-Mod found that its system was not a viable MATS compliance strategy and that activated carbon injection was necessary for power plants with ESPs that burn PRB coal.[30]



The addition of chlorine to the fuel or injection into the flue gas is another approach that is being tested for enhancing intrinsic capture of mercury. At Laskin 2 (firing PRB) and at Stanton 10 (firing North Dakota lignite), chlorine salts were added to the fuel to assess the impact of increasing fuel chlorine on mercury oxidation and capture. Laskin 2 is equipped with a Particle Scrubber (PS) and Stanton 10 with a SDA/FF. In both cases, mercury oxidation increased, although for some salts the mercury capture did not increase. In the case of Laskin, opacity was observed to increase as a result of salt addition and in the case of Stanton 10, pressure drop across the FF increased. Long-term effects, such as corrosion, plugging, impacts on combustion equipment could not be assessed during the short-term parametric tests.[19] Therefore, the use of coal additives offer some promise at improving mercury capture; however, they may have other impacts that need to be evaluated.

[redacted]

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[redacted]

3. The Patented Technology

69. The patents-in-suit are US Patent Nos. 8,168,147 (the '147 Patent to Olson), 10,343,114 (the '114 to Olson), 10,589,225 (the '225 Patent to Olson), 10,596,517 (the '517 Patent to Olson), and 10,668,430 (the '430 Patent to Olson). These five patents relate back to a common provisional application.

70. In general, the specifications of the '147 Patent, the '114 Patent, the '225 Patent, the '517 Patent, and the '430 Patent, describe the use of halogen additives (e.g., bromine) and sorbents (e.g., activated carbon) that can be used to capture mercury in the emissions from coal-fired power plants.

71. The patents explain that mercury in flue gas may be present in oxidized or elemental forms.[33] It also explains that sorbents could be used to bind with the mercury so that it can be captured in particulate matter devices such as ESPs and bag houses.[34] However, the patents note that when activated carbon or other sorbents are injected into flue gas, they have very limited time to react with mercury in the flue gas.[35] This requires large quantities of activated carbon sorbent to be injected to achieve mercury capture.[36] The patents identify

[redacted]

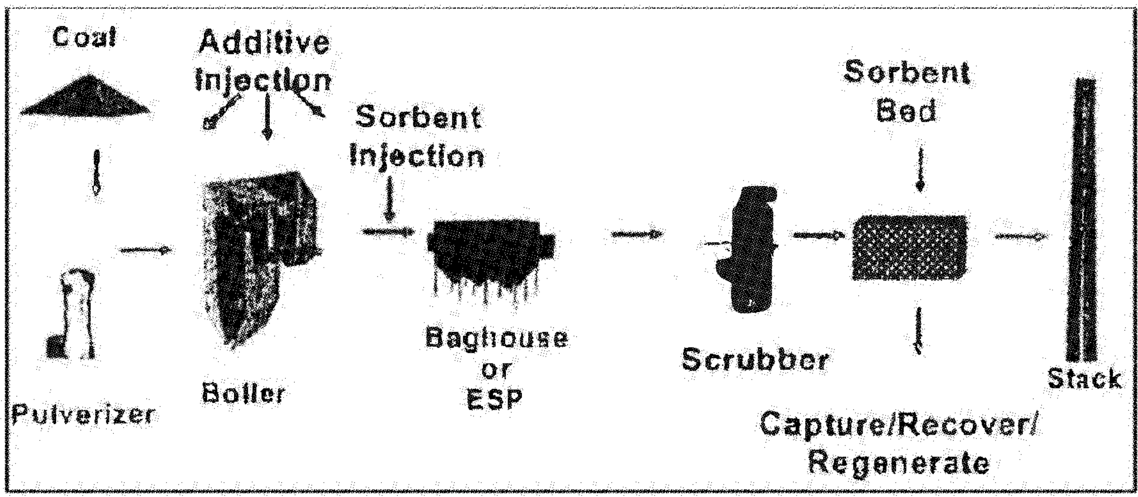
[34] Ref. 7, Col. 1, Lines 55-65.

[35] Ref. 7, Col. 1, Lines 65-2:9.

[36] Ref. 7, Col. 2, Lines 10-19.

various approaches that had been attempted to solve that problem, but ultimately note that they were unsuccessful.[37]

72. The patents describe ways of solving this problem by improving the effectiveness of sorbents. Of particular relevance to this case, are embodiments where bromine or bromide is added to coal or into the combustion chamber. These additives will enter the combustion chamber with the coal, and exit in the flue gas. Activated carbon is then injected into the flue gas. An activated carbon injection system provides a constant flow of activated carbon particles into the post-combustion gas. This flow is typically measured in lbs/hr or lbs/mmacf. This approach allows the bromine and carbon to bind to the mercury so that it can be captured in an ESP or bag house. An example of this system is depicted below:[38]



73. The inventors have further explained that, merely adding halogens to coal may not achieve the necessary level of mercury oxidation. This is because other gases resulting from coal combustion can interfere with the oxidation process.[39] The inventors overcame this

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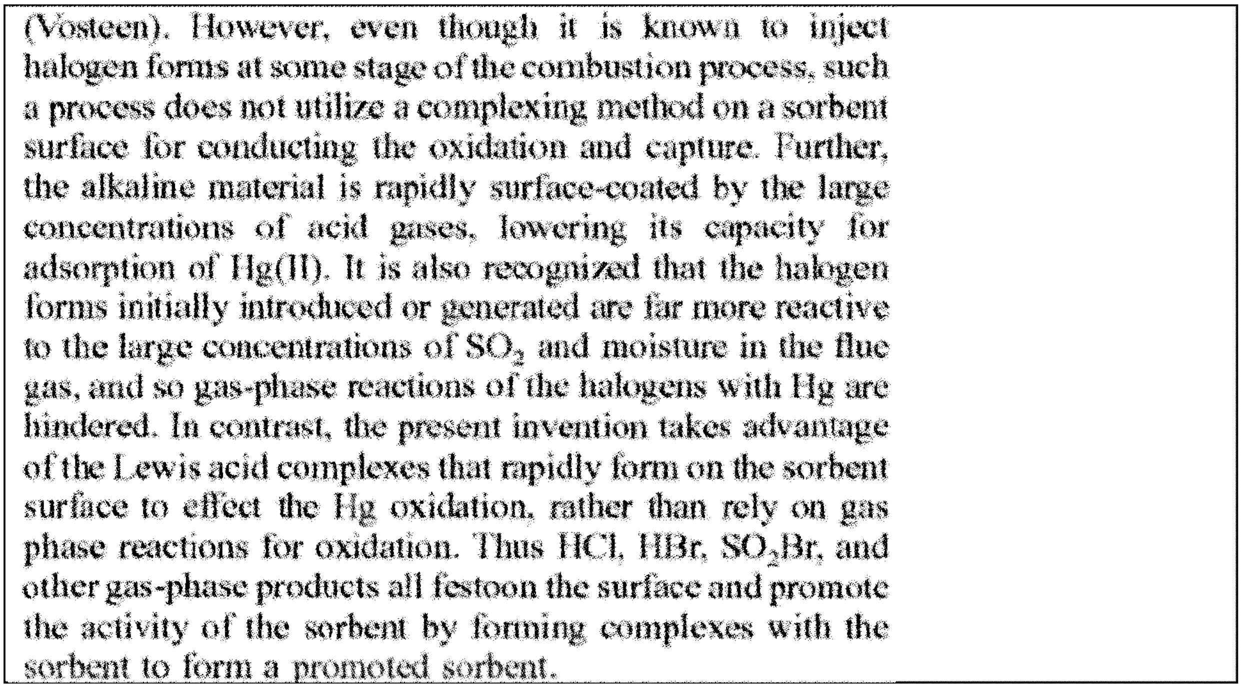
[37] Ref. 7, Col. 2, Line 20- Col. 3, Line 20.
[38] Ref. 7, Figure 6. (This figure is also contained in the provisional application.)
[39] Ref. 6, Pg. 3, Line 5 -21:

problem by recognizing that bromine can react with activated carbon to promote mercury oxidation. This is explained in the model shown in the patents:[40]



(Vosteen). However, even though it is known to inject halogen forms at some stage of the combustion process, such a process does not utilize a complexing method on a sorbent surface for conducting the oxidation and capture. Further, the alkaline material is rapidly surface-coated by the large concentrations of acid gases, lowering its capacity for adsorption of Hg(II). It is also recognized that the halogen forms initially introduced or generated are far more reactive to the large concentrations of SO_2 and moisture in the flue gas, and so gas-phase reactions of the halogens with Hg are hindered. In contrast, the present invention takes advantage of the Lewis acid complexes that rapidly form on the sorbent surface to effect the Hg oxidation, rather than rely on gas phase reactions for oxidation. Thus HCl, HBr, SO_2Br, and other gas-phase products all festoon the surface and promote the activity of the sorbent by forming complexes with the sorbent to form a promoted sorbent.

[40] Ref. 6, PG.17, Lines 4-36:

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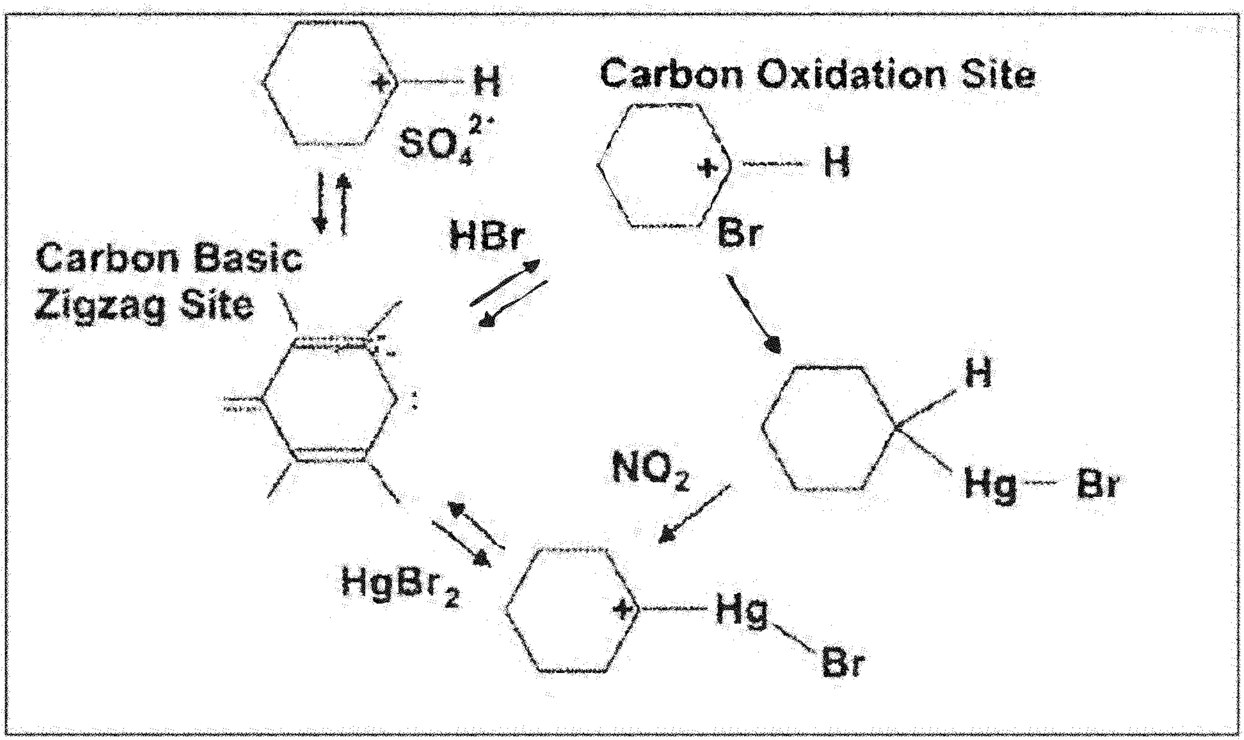

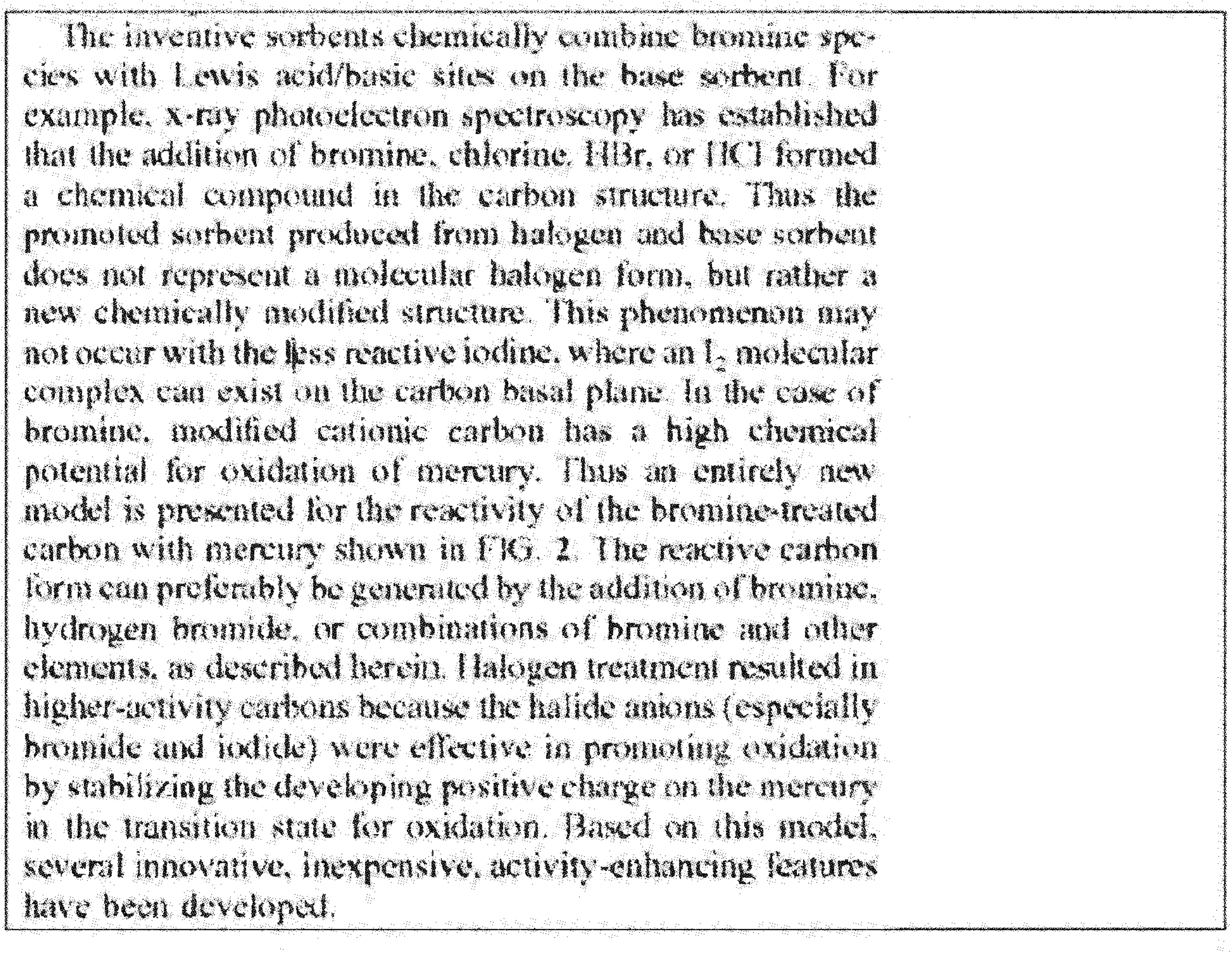

The inventive sorbents chemically combine bromine species with Lewis acid/basic sites on the base sorbent. For example, x-ray photoelectron spectroscopy has established that the addition of bromine, chlorine, HBr, or HCl formed a chemical compound in the carbon structure. Thus the promoted sorbent produced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

[redacted]

74. Work by the inventors and others have explained how this technology works.[41] When a bromine additive, e.g., NaBr or CaBr, is added to coal, it is combusted with the coal. The heat from this combustion converts the bromide to a gaseous form and the bromine reacts to form HBr and other compounds.[42] However, HBr is a relatively non-reactive form of bromine that does not effectively oxidize mercury.[43] To oxidize the mercury a further catalyst is

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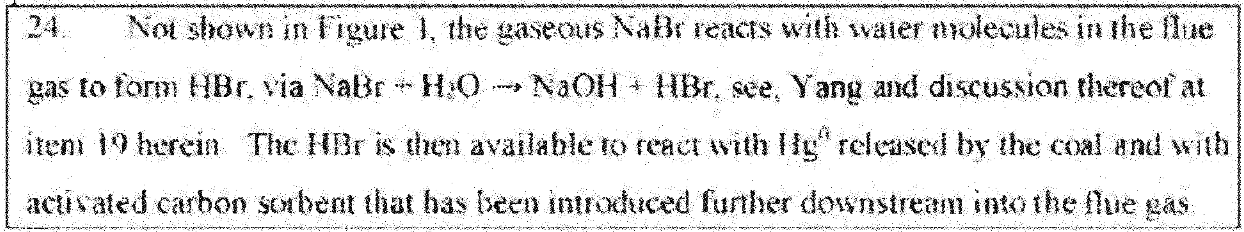
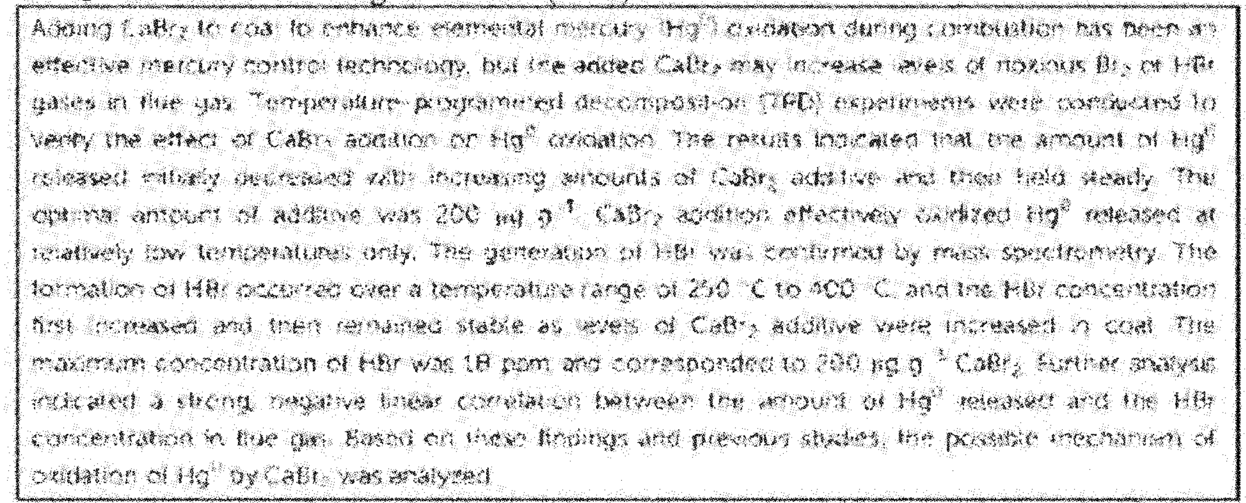
[41] See generally Declaration C of inventor John Pavlish submitted during prosecution of the '114 patent.



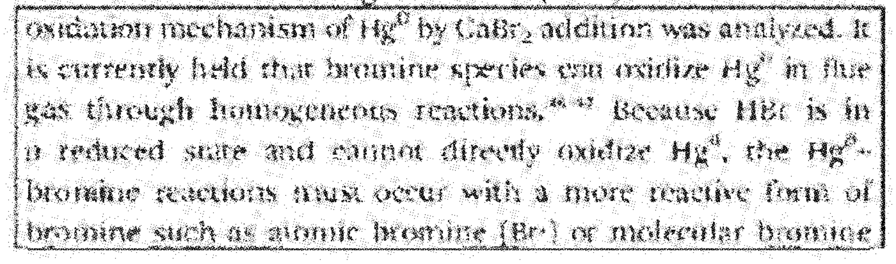
24. Not shown in Figure 1, the gaseous NaBr reacts with water molecules in the flue gas to form HBr, via $NaBr + H_2O \rightarrow NaOH + HBr$, see, Yang and discussion thereof at item 19 herein. The HBr is then available to react with Hg^0 released by the coal and with activated carbon sorbent that has been introduced further downstream into the flue gas.

[42] Ref. 14, Yang et al., Effect of HBr formation on mercury oxidation via $CaBr_2$ addition to coal during combustion (2016):



Adding $CaBr_2$ to coal to enhance elemental mercury (Hg^0) oxidation during combustion has been an effective mercury control technology, but the added $CaBr_2$ may increase levels of noxious Br_2 or HBr gases in flue gas. Temperature-programmed decomposition (TPD) experiments were conducted to verify the effect of $CaBr_2$ addition on Hg^0 oxidation. The results indicated that the amount of Hg^0 released initially decreased with increasing amounts of $CaBr_2$ additive and then held steady. The optimal amount of additive was 200 μg g^{-1}. $CaBr_2$ addition effectively oxidized Hg^0 released at relatively low temperatures only. The generation of HBr was confirmed by mass spectrometry. The formation of HBr occurred over a temperature range of 250 °C to 400 °C, and the HBr concentration first increased and then remained stable as levels of $CaBr_2$ additive were increased in coal. The maximum concentration of HBr was 18 ppm and corresponded to 200 μg g^{-1} $CaBr_2$. Further analysis indicated a strong negative linear correlation between the amount of Hg^0 released and the HBr concentration in flue gas. Based on these findings and previous studies, the possible mechanism of oxidation of Hg^0 by $CaBr_2$ was analyzed.

[43] Ref. 14, Yang et al., Effect of HBr formation on mercury oxidation via $CaBr_2$ addition to coal during combustion (2016):



oxidation mechanism of Hg^0 by $CaBr_2$ addition was analyzed. It is currently held that bromine species can oxidize Hg^0 in flue gas through homogeneous reactions.[40,42] Because HBr is in a reduced state and cannot directly oxidize Hg^0, the Hg^0–bromine reactions must occur with a more reactive form of bromine such as atomic bromine (Br·) or molecular bromine

[redacted]

necessary. In the absence of a catalyst, the oxidizing effect from bromine is limited.[44] Injected activated carbon provides that catalyst.[45]

75. Oxidation of mercury by a reaction of mercury with a gas (e.g., gaseous bromine) is referred to as homogeneous oxidation. Oxidation of mercury through a reaction involving gas and surface interactions (e.g. with activated carbon and bromine) is referred to as heterogeneous

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[44] Ref. 14, Yang et al., Effect of HBr formation on mercury oxidation via $CaBr_2$ addition to coal during combustion (2016). In describing the effect of calcium bromide in the absence of fly ash or activated carbon, Yang explained that as more calcium bromide was added, the oxidation rate increased, but only up to a maximum of 40%:

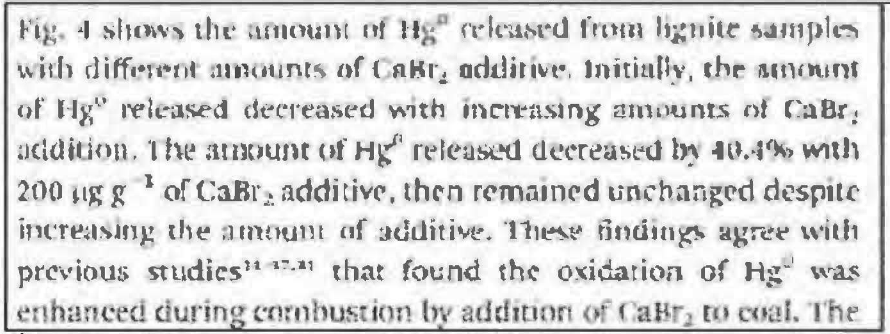
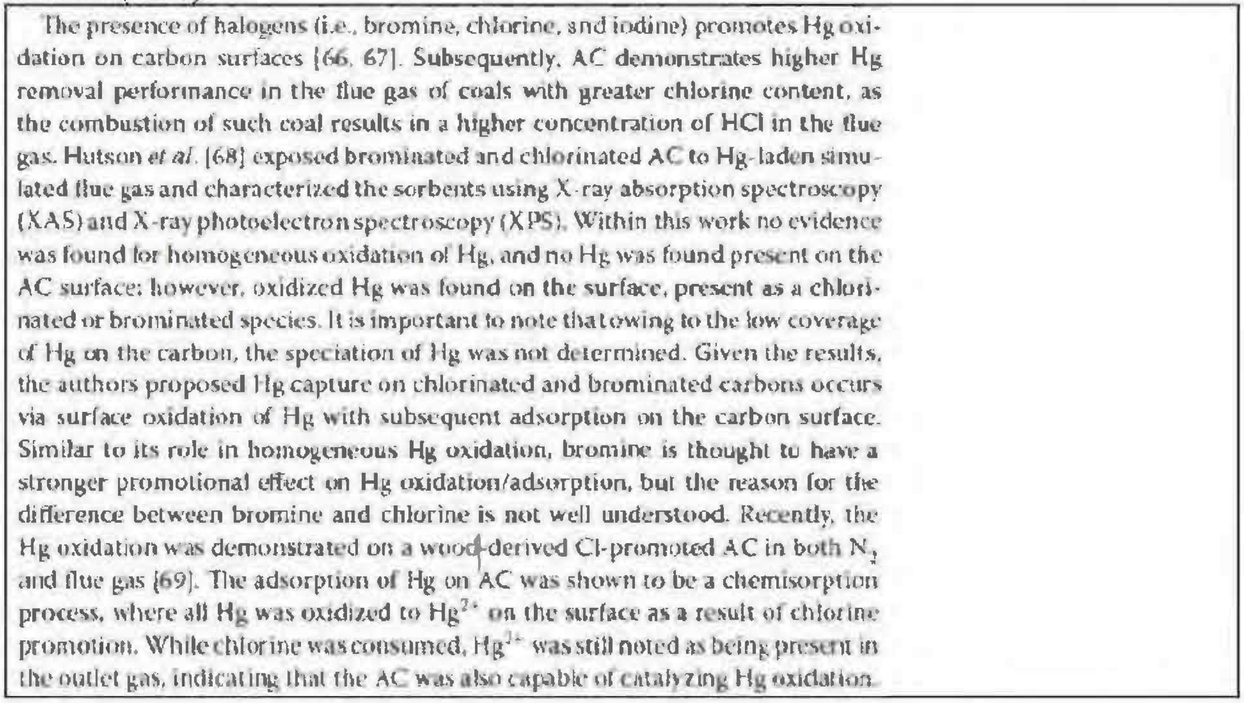


Fig. 4 shows the amount of Hg^0 released from lignite samples with different amounts of $CaBr_2$ additive. Initially, the amount of Hg^0 released decreased with increasing amounts of $CaBr_2$ addition. The amount of Hg^0 released decreased by 40.4% with 200 $\mu g\ g^{-1}$ of $CaBr_2$ additive, then remained unchanged despite increasing the amount of additive. These findings agree with previous studies[11,37-41] that found the oxidation of Hg^0 was enhanced during combustion by addition of $CaBr_2$ to coal. The

[45] Ref. 89, J. Wilcox, Atomistic-Level Models from Mercury Control: for Coal-Derived Gas Streams (2015):



The presence of halogens (i.e., bromine, chlorine, and iodine) promotes Hg oxidation on carbon surfaces [66, 67]. Subsequently, AC demonstrates higher Hg removal performance in the flue gas of coals with greater chlorine content, as the combustion of such coal results in a higher concentration of HCl in the flue gas. Hutson *et al.* [68] exposed brominated and chlorinated AC to Hg-laden simulated flue gas and characterized the sorbents using X-ray absorption spectroscopy (XAS) and X-ray photoelectron spectroscopy (XPS). Within this work no evidence was found for homogeneous oxidation of Hg, and no Hg was found present on the AC surface; however, oxidized Hg was found on the surface, present as a chlorinated or brominated species. It is important to note that owing to the low coverage of Hg on the carbon, the speciation of Hg was not determined. Given the results, the authors proposed Hg capture on chlorinated and brominated carbons occurs via surface oxidation of Hg with subsequent adsorption on the carbon surface. Similar to its role in homogeneous Hg oxidation, bromine is thought to have a stronger promotional effect on Hg oxidation/adsorption, but the reason for the difference between bromine and chlorine is not well understood. Recently, the Hg oxidation was demonstrated on a wood-derived Cl-promoted AC in both N_2 and flue gas [69]. The adsorption of Hg on AC was shown to be a chemisorption process, where all Hg was oxidized to Hg^{2+} on the surface as a result of chlorine promotion. While chlorine was consumed, Hg^{2+} was still noted as being present in the outlet gas, indicating that the AC was also capable of catalyzing Hg oxidation.

oxidation. It is well accepted that both homogeneous and heterogeneous reactions must take place.[46]

76. ME2C has implemented this technology by selling front end additives containing bromine and backend sorbents containing activated carbon. ME2C provides the front-end additives to be applied to pulverized coal[47] or injected into the boiler,[48] and it provides backend sorbents to be injected downstream of the boiler.[49] Each of ME2C's power plant customers also

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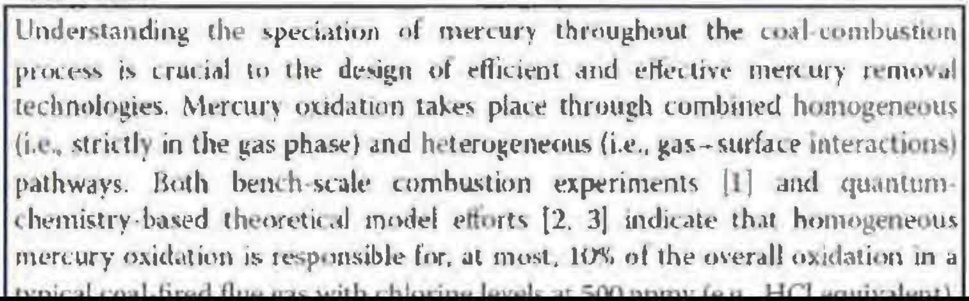
[46] Ref. 179:



Understanding the speciation of mercury throughout the coal-combustion process is crucial to the design of efficient and effective mercury removal technologies. Mercury oxidation takes place through combined homogeneous (i.e., strictly in the gas phase) and heterogeneous (i.e., gas–surface interactions) pathways. Both bench-scale combustion experiments [1] and quantum-chemistry-based theoretical model efforts [2, 3] indicate that homogeneous mercury oxidation is responsible for, at most, 10% of the overall oxidation in a

[redacted]

[redacted]

employ at least baghouses or ESPs to capture mercury. While they may adjust application rates from time to time based on mercury emission levels, they rely on daily application of these sorbents and additives to comply with mercury regulations. Those customers are:[50]

[redacted]

[redacted]

77. For the same reasons that the directly infringing power plants in this case infringe by employing calcium bromide to coal and injecting activated carbon, ME2C's US[51] customers have used the patented technology by using ME2C's front-end additives and back-end activated carbon sorbents.[52]

4. The Court's Constructions

78. The parties have agreed, or the Court has construed, some terms in the patent claims. For terms that have not been construed, I have applied the plain and ordinary meaning of those terms as would be understood by a person of ordinary skill in the art. For terms that have been construed or for which the parties have agreed to a construction I have applied the following constructions:

Claim Term	Claim Term	Construction
'114 Patent, Claims 1 and 23-25 '430 Patent, Claims 1, 28, and 29	injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber	injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of, and from outside, the combustion chamber

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[51] The Centralia and Keephills power plants are located in Canada.
[52] Conversation with John Pavlish.

5. Defendants 'Accused Conduct

5.1. Defendant's Process for Preparing, Testing, and Supplying Refined Coal

79. The Defendants in this case can be classified into three general groups based on the parent organization they operate under: Arthur J. Gallagher & Co.("AJG"), DTE, and CERT. Each group has one or more parent organizations that operate a set of limited liability companies ("LLCs"). For each power plant that receives refined coal from a Defendant in this case, AJG, DTE, or CERT created an LLC (referred to as a REFCO or RC LLC) to contract with the power plant to provide the refined coal. AJG, DTE, and CERT have also operated other entities that oversee these RC LLCs, or otherwise participated in operating refined coal facilities.

80. Each RC LLC Defendant obtained a license from Chem-Mod LLC to prepare refined coal using what Chem-Mod describes as the Chem-Mod process. This process generally involves a refined coal operator leasing space at a power plant to install sprayer equipment. The refined coal operator purchases coal from the power plant operator. The refined coal then takes possession of the purchased coal, applies Chem-Mod licensed sorbents to the coal, and sells the coal back to the power plant. This now refined coal is transferred back to the power plant on-site, e.g., on the conveyor belt leading the refined coal to the combustion chamber.[53] The power plant can then combust the refined coal using the same process and equipment it uses for non-refined coal.

[redacted]

81. To ensure that the refined coal supplied by Defendants will qualify for Section 45 tax credits, each RC LLC Defendant contracted with the EERC to perform refined coal testing. This testing involved obtaining a sample of non-refined coal obtained from the feedstock of the power plant at issue. The EERC would mix a portion of this feed stock coal with the Chem-Mod additives to be used for that power plant to produce refined coal. The EERC would then combust the non-refined coal and measure the mercury emissions at an outlet. The EERC would also combust the refined coal and measure the mercury emissions at the same outlet. Using these measurements, the EERC would calculate the difference in mercury emissions between the two samples. The EERC provided reports to each of the RC LLC Defendants informing them of a minimum additive rate suitable for achieving mercury emissions reductions that qualify for Section 45 tax credits. The Defendants relied on those rates, unless a power plant requested a different rate be used.[54]

[redacted]

Ref. 80, Pg. 107, Lines 3-21:

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

83. Mer-Sorb is a halide salt solution consisting of calcium bromide and water. This is a liquid containing calcium (Ca^{2+}) and bromine ions (Br^{-}).[57] S-Sorb is a combination of calcium compounds, also referred to as cement kiln dust.[58]

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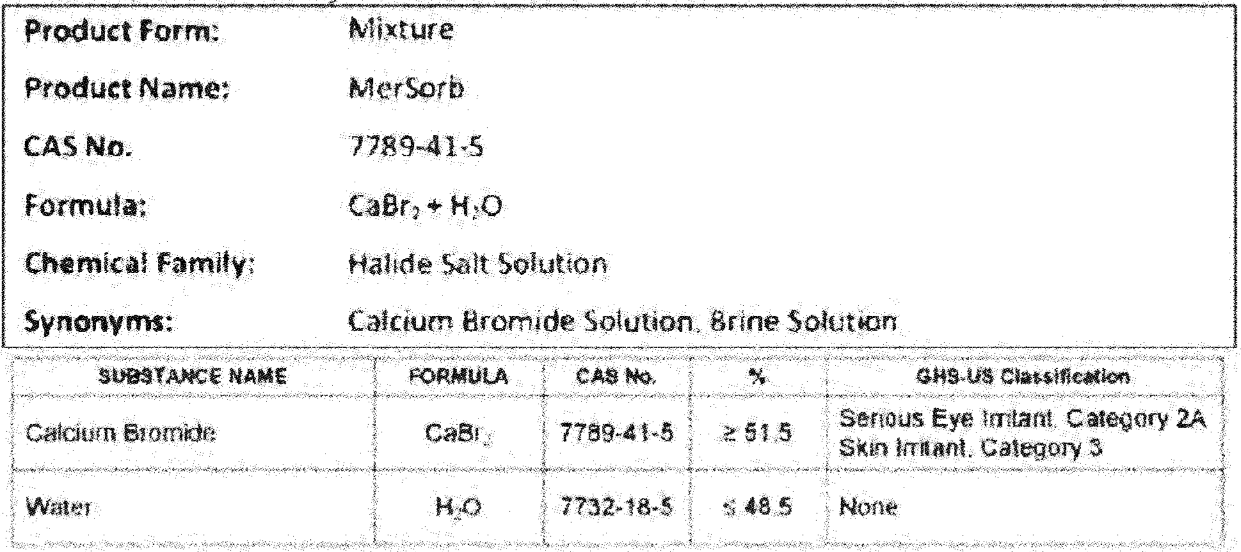
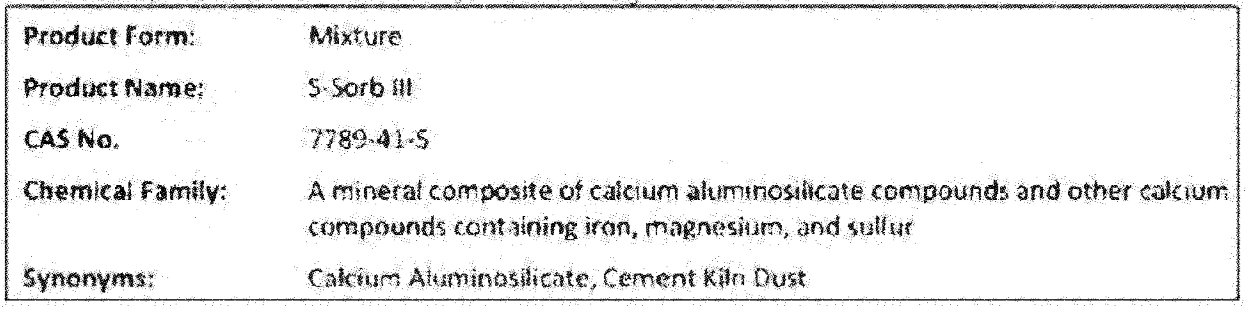
[57] Ref. 81, MerSorb Safety Data Sheet.



Product Form:	Mixture
Product Name:	MerSorb
CAS No.	7789-41-5
Formula:	$CaBr_2 + H_2O$
Chemical Family:	Halide Salt Solution
Synonyms:	Calcium Bromide Solution, Brine Solution

SUBSTANCE NAME	FORMULA	CAS No.	%	GHS-US Classification
Calcium Bromide	$CaBr_2$	7789-41-5	≥ 51.5	Serious Eye Irritant, Category 2A Skin Irritant, Category 3
Water	H_2O	7732-18-5	≤ 48.5	None

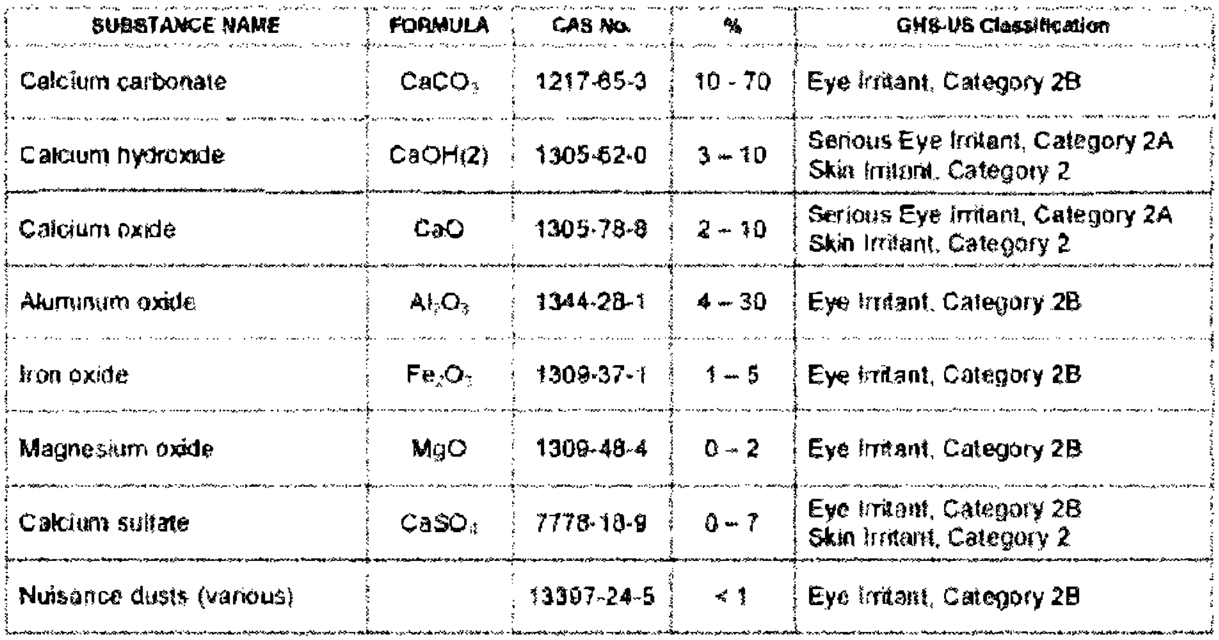
[58] Ref. 230, Arbor Fuels_00067779, S-Sorb Safety Data Sheet:



Product Form:	Mixture
Product Name:	S-Sorb III
CAS No.	7789-41-5
Chemical Family:	A mineral composite of calcium aluminosilicate compounds and other calcium compounds containing iron, magnesium, and sulfur
Synonyms:	Calcium Aluminosilicate, Cement Kiln Dust

84. The products sold by Defendants to power plants are refined coals that have been sprayed with these additives. Defendants generally distinguish between refined bituminous, refined subbituminous, and refined lignite.[59] However, as explained above, each refined coal is actually produced from the feedstock coal located at a particular plant.

[redacted]



SUBSTANCE NAME	FORMULA	CAS No.	%	GHS-US Classification
Calcium carbonate	$CaCO_3$	1217-65-3	10 - 70	Eye Irritant, Category 2B
Calcium hydroxide	CaOH(2)	1305-62-0	3 – 10	Serious Eye Irritant, Category 2A Skin Irritant, Category 2
Calcium oxide	CaO	1305-78-8	2 – 10	Serious Eye Irritant, Category 2A Skin Irritant, Category 2
Aluminum oxide	Al_2O_3	1344-28-1	4 – 30	Eye Irritant, Category 2B
Iron oxide	Fe_2O_3	1309-37-1	1 – 5	Eye Irritant, Category 2B
Magnesium oxide	MgO	1309-48-4	0 – 2	Eye Irritant, Category 2B
Calcium sulfate	$CaSO_4$	7778-18-9	0 – 7	Eye Irritant, Category 2B Skin Irritant, Category 2
Nuisance dusts (various)		13397-24-5	< 1	Eye Irritant, Category 2B

[59] Ref. 181, email chain distributing Safety Data Sheets for Chem-Mod, AJG, DTE, and CERT:

Also attached are SDS for Refined Coal products. These have been requested by some of the utility clients. There are three SDS, one each for refined coal produced from bituminous, subbituminous, and lignite coals. The revision to the

[60] This chart is Exhibit 3 to the Inendino deposition (Ref. 182).

material to control NOx and halogen material to control mercury emissions from coal-fired combustion chambers. ADA-ES claims that it uses this process to create and sell refined coal.[156] Similar to the ME2C patents, it describes the use of a halogen additive to assist with mercury control. Although, I note that this patent also post-dates the ME2C patents at issue in this case.

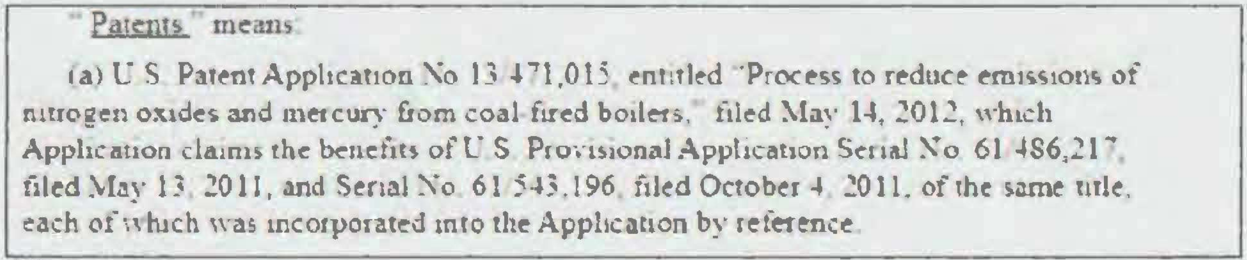
157. The '692, '083, '170, and '986 patents all describe technology related to mercury capture for use with coal-fired combustion chambers. Thus, they are technically comparable to the ME2C patents at issue in this case, at least in the sense that they are drawn toward the same field of technology. Although, as noted above, ME2C's patents are more applicable to the Defendants' refined coal process or have an earlier priority date.

158. If called upon to testify at trial, I expect to prepare additional demonstrative materials reflecting the opinions in this report. In doing so, I may rely upon documents identified in this report.

EXECUTED ON:

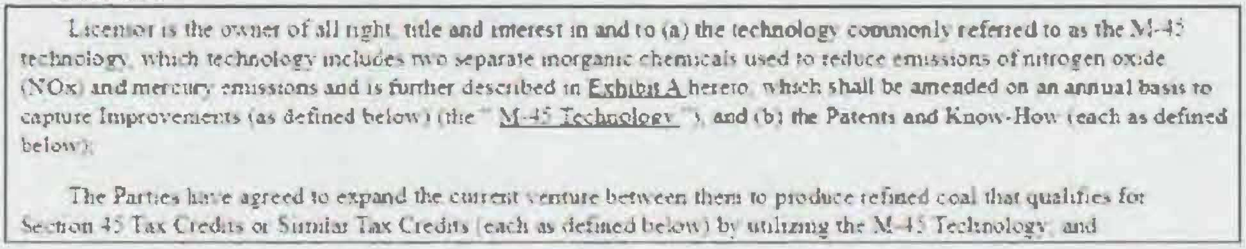
Philip J. O'Keefe, PE

10-25-2022


"Patents" means:

(a) U.S. Patent Application No 13/471,015, entitled "Process to reduce emissions of nitrogen oxides and mercury from coal-fired boilers," filed May 14, 2012, which Application claims the benefits of U.S. Provisional Application Serial No. 61/486,217, filed May 13, 2011, and Serial No. 61/543,196, filed October 4, 2011, of the same title, each of which was incorporated into the Application by reference.

[156] Ref. 237


Licensor is the owner of all right, title and interest in and to (a) the technology commonly referred to as the M-45 technology, which technology includes two separate inorganic chemicals used to reduce emissions of nitrogen oxide (NOx) and mercury emissions and is further described in Exhibit A hereto, which shall be amended on an annual basis to capture Improvements (as defined below) (the "M-45 Technology"), and (b) the Patents and Know-How (each as defined below);

The Parties have agreed to expand the current venture between them to produce refined coal that qualifies for Section 45 Tax Credits or Similar Tax Credits (each as defined below) by utilizing the M-45 Technology; and

[redacted]

Appendix A - Infringement Claim Charts

The '114 Patent to Olson

No.	'114 Claim Element	Accused Conduct
1a	A method of separating mercury from a mercury-containing gas, the method comprising:	Each infringing power plant (see section 6.1) has performed this method using refined coal supplied by one or more of the Defendants. Each of ME2C's customers has performed this method as well (see section 3).
1b	combusting coal in a combustion chamber, to provide the mercury-containing gas,	Each infringing power plant burned the refined coal in the combustion chambers of their steam generator furnaces. When this coal is burned, it releases mercury-containing gas. See section 2. Information regarding the amount of refined coal burned by these power plants is identified in response to ME2C interrogatory 19 and is available at https://www.eia.gov/electricity/data/eia923/
1c	wherein the mercury-containing gas comprises a halogen or halide promoter comprising HBr, Br, or a combination thereof, wherein the coal comprises added Br , HBr, Br^-, or a combination thereof, added to the coal upstream of the combustion chamber, or the combustion chamber comprises added Br , HBr, Br^-, or a combination thereof, or a combination thereof;	Each infringing power plant has coal handling systems to transport refined coal received from Defendants. The Defendants additive equipment added MerSorb to the coal before it reached the power plants' combustion chambers. MerSorb contains calcium bromide ($CaBr_2$), which is a bromide. When Calcium bromide is dissolved in water, the solution contains Calcium ions (Ca^{++}) and Bromine ions (Br^-). See section 5.1. When combusted with the coal the resulting gas contains bromine (Br). In addition, this bromine reacts with hydrogen to produce HBr. See sections 2, 3. Thus, the coal combusted by each infringing power plant comprises added Br^- and the combustion chamber comprises added Br^- and the resulting mercury-containing gas contains HBr and Br. See sections 2, 3.
1d	injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber;	Each infringing power plant injected a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber. See sections 5.4, 6.

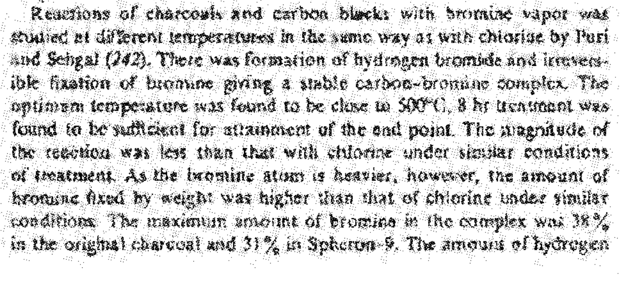
[redacted]

1e	contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition;	At each infringing power plant, in the mercury-containing gas with the sorbent, the activated carbon sorbent contacts the mercury to form a mercury/sorbent composition. Activated carbon functions by adsorbing mercury to convert it into particle-bound mercury that can be captured in downstream pollution control equipment. See sections 2, 3.
1f	separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas;	Each infringing power plant operates and ESP, bag house, and/or filter separator devices downstream of their combustion chambers. These devices separated the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas. See sections 2, 3, 6.
1g	monitoring the mercury content of the cleaned gas; and	Each infringing power plant monitors the mercury content of the cleaned gas. This is required as per their operating permits and to ensure compliance with MATS.
1h	controlling, in response to the monitored mercury content of the cleaned gas, an injection rate of injecting the sorbent into the mercury containing gas, the sorbent composition, or a combination thereof, so that the mercury content of the cleaned gas is maintained at or below a desired level.	Each infringing power plant controlled, in response to the monitored mercury content of the cleaned gas, an injection rate of injecting the sorbent into the mercury containing gas, the sorbent composition, or a combination thereof, so that the mercury content of the cleaned gas is maintained at or below a desired level. See sections 2, 3. Each power plant may adjust the activated carbon injection rate (sections 5.4, 6), or ask Defendants to adjust the MerSorb injection rate(see section 5.4), to ensure that they comply with MATS.

[redacted]

2	The method of claim 1, comprising removing greater than 70 wt % of the mercury in the mercury-containing gas.	Each infringing power plant, except Antelope Valley, must remove greater than 70 wt % of the mercury in the mercury-containing gas, otherwise they would not be able to comply with MATS regulations. For sub-bituminous and bituminous coals, MATS requires reduction of mercury emissions to of 1.2 lbs hg/TBtu. Thus, if the power plant meets this regulation by burning coal that naturally contains 4lbs hg/TBtu or greater, then it has performed this step. Based on EERC test reports, each of the power plants burning sub-bituminous or bituminous coal burns coal with greater than 4lbs hg/TBtu. For lignite coals, MATS requires reduction of mercury emissions to of 4.0 lbs hg/TBtu. Thus, if the power plant meets this regulation by burning coal that naturally contains 13.3lbs hg/TBtu or greater, then it has performed this step. Based on EERC test reports, [redacted]

[redacted]

4	The method of claim 1, wherein the sorbent in the mercury-containing gas comprises about 1 g to about 30 g of the halogen or halide promoter per 100 g of the sorbent material.	Each infringing power plant injected activated carbon sorbent such that the sorbent in the mercury-containing gas comprises about 1 g to about 30 g of the added bromine in the mercury-containing gas per 100 g of the sorbent material. This limitation requires that, the combined bromine/activated carbon sorbent comprise a ratio of 1 – 30 parts bromine to 100 parts activated carbon. As Defendants have explained, it has been known in the art that the saturation limit for bromine on activated carbon is 31 parts bromine to per 100 parts carbon: "a POSITA would have known that the saturation limit of activated carbon for bromine (i.e., the amount of bromine activated carbon can actually hold at equilibrium), was up to 31 grams per 100 grams of activated carbon" See Defendants' invalidity contentions Exhibit A. See also, Declaration of Stephen Niksa at VIII.C.5: "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. A person of ordinary skill in the art would expect that in an actual industrial application, the amount of Br actually bound would be less than the saturation limit." Thus, 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. See also ME2C-RC-00064769, Philip Walker, Chemistry and Physics of Carbon at 260.  Reactions of charcoals and carbon blacks with bromine vapor was studied at different temperatures in the same way as with chlorine by Puri and Sehgal (242). There was formation of hydrogen bromide and irreversible fixation of bromine giving a stable carbon-bromine complex. The optimum temperature was found to be close to 500°C, 8 hr treatment was found to be sufficient for attainment of the end point. The magnitude of the reaction was less than that with chlorine under similar conditions of treatment. As the bromine atom is heavier, however, the amount of bromine fixed by weight was higher than that of chlorine under similar conditions. The maximum amount of bromine in the complex was 38% in the original charcoal and 31% in Spheron-9. The amount of hydrogen

[redacted]

5	The method of claim 1, wherein the combustion chamber comprises the halogen or halide promoter.	Each infringing power plant had furnaces with combustion chambers burning refined coal treated with a bromide compound. The bromine in this compound is a halogen promoter.
6	The method of claim 1, wherein the coal comprises added Br , HBr, Br$^-$, or a combination thereof, added to the coal upstream of the combustion chamber.	Each infringing power plant burned coal with a bromide compound added upstream of the combustion chambers. Thus, this coal comprises added Br$^-$
7	The method of claim 1, wherein the promoter is contacted with the sorbent in vapor form, gaseous form, liquid form, or in an organic solvent.	Each infringing power plant burned coal with an added bromide compound in liquid form. Because water boils at 100 degrees Celsius and the combustion chambers maintain heat far above that temperature, the Br$^-$ exits the combustion chamber and contacts the sorbent in a gaseous state.
12	The method of claim 1, wherein the activated carbon comprises powdered activated carbon, granular activated carbon, or a combination thereof.	Each infringing power plant injected powdered activated carbon into the gas downstream of their furnace combustion chambers.
15	The method of claim 1, wherein the combustion chamber comprises a boiler.	Each infringing power plant had furnace combustion chambers within their boilers.
16	The method of claim 1, wherein the mercury-containing gas is a flue gas.	Each infringing power plant generated mercury-containing gas during combustion of coal. The mercury-containing gas is a flue gas as gas leaving the combustion chamber at each power plant exits through the flue.
18	The method of claim 1, wherein the injection of the sorbent material into the mercury-containing gas occurs upstream of a particulate separator or a scrubber.	Each infringing power plant injected activated carbon sorbent into the flue gas upstream of a particulate separator or a scrubber.
20	The method of claim 1, wherein the combustion chamber comprises added Br , HBr, Br , or a combination thereof. 2	Each infringing power plant received coal treated with a bromide compound upstream of the combustion chambers. The treated coal, a.k.a. refined coal, was then burned in the clients' combustion chambers. Thus, the combustion chamber comprises added Br$^-$.

[redacted]

23a	A method of separating mercury from a mercury-containing gas, the method comprising:	See '114 1a.
23b	combusting coal in a combustion chamber, to provide the mercury-containing gas, wherein the mercury-containing gas comprises a halogen or halide promoter comprising HBr, Br , or a combination thereof, wherein	See '114 1b, 1c.
23c	the mercury-containing gas comprises a halogen or halide promoter comprising HBr, Br , or a combination thereof, wherein the coal comprises added Br , HBr, Br , or a combination thereof, added to the coal upstream of the combustion chamber, or the combustion chamber comprises added Br , HBr, Br , or a combination thereof, or a combination thereof;	See '114 1c.
23d	injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber;	See '114 1d.
23e	contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition; and	See '114 1e.
23f	separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas.	See '114 1f.
24a	A method of separating mercury from a mercury-containing gas, the method comprising:	See '114 1a.
24b	combusting coal in a combustion chamber, to provide the mercury-containing gas, wherein the mercury-containing gas comprises a halogen or halide promoter comprising HBr, Br , or a combination thereof, wherein	See '114 1b, 1c.

[redacted]

24c	the mercury-containing gas comprises a halogen or halide promoter comprising HBr, Br , or a combination thereof, wherein the coal comprises added Br , HBr, Br , or a combination thereof, added to the coal upstream of the combustion chamber, or the combustion chamber comprises added Br , HBr, Br , or a combination thereof, or a combination thereof;	See '114 1c.
24d	injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber	See '114 1d.
24e	such that the activated carbon reacts with the halogen or halide promoter in the mercury- containing gas to form a promoted sorbent;	All of the defendants constructed equipment in their clients' power plant coal handling systems to produce refined coal. The equipment added MerSorb to the coal before it reached the clients' combustion chambers. MerSorb contains calcium bromide ($CaBr_2$) dissolved in water. When calcium bromide is dissolved in water, the solution contains calcium ions (Ca^{++}) and bromine ions (Br^-). Moreover, because water boils at 100 degrees Celsius and the combustion chambers maintain heat far above that temperature, the Br^- exits the combustion chamber in a gaseous state. Each infringing power plant injected a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber. Thus, this activated carbon and the bromine come into contact and form a promoted brominated sorbent, i.e., a sorbent particle that is bound with the bromine.
24f	contacting mercury in the mercury-containing gas with the promoted sorbent, to form a mercury/sorbent composition;	See '114 1e.

24g	separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas;	See ‘114 1f.
24h	monitoring the mercury content of the cleaned gas; and	See ‘114 1g.
24i	controlling, in response to the mercury content of the cleaned gas, an injection rate of injecting the sorbent into the mercury-containing gas, a rate of addition to the coal or the combustion chamber of the added Br , HBr, the bromide compound, or a combination thereof, or a combination thereof, so that the mercury content of the cleaned gas is maintained at or below a desired level.	See ‘114 1h.
25a	A method of separating mercury from a mercury-containing gas, the method comprising:	See ‘114 1a.
25b	combusting coal in a combustion chamber, to provide the mercury-containing gas, wherein	See ‘114 1b.
25c	the coal comprises added Br , HBr, a bromide compound, or a combination thereof, added to the coal upstream of the combustion chamber, or the combustion chamber comprises added Br , HBr, a bromide compound, or a combination thereof, or a combination thereof,	See ‘114 1c.
25d	injecting a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber;	See ‘114 1d.
25e	contacting mercury in the mercury-containing gas with the sorbent, to form a mercury/sorbent composition; and	See ‘114 1e.

[redacted]

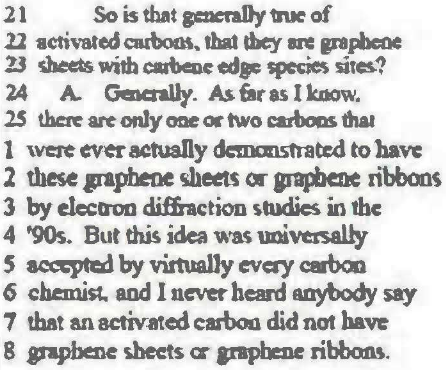
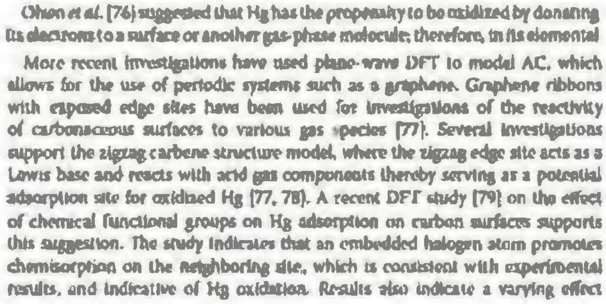
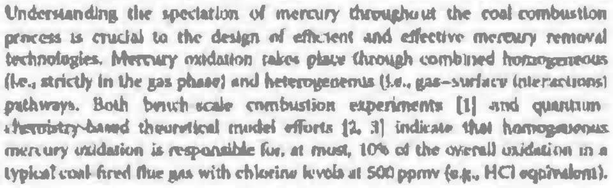
25f	separating the mercury/sorbent composition from the mercury-containing gas, to form a cleaned gas.	See ‘114 1f.
26	The method of claim 25, wherein the coal comprises the added Br , HBr, the bromide compound, or a combination thereof, added to the coal upstream of the combustion chamber.	See 1c.
27	The method of claim 25, wherein the combustion chamber comprises the added Br , HBr, the bromide compound, or a combination thereof.	See 1c.
28a	The method of claim 25, further comprising monitoring the mercury content of the cleaned gas; and	See ‘114 1g.
28b	controlling, in response to the mercury content of the cleaned gas, an injection rate of injecting the sorbent into the mercury-containing gas, a rate of addition to the coal or the combustion chamber of the added Br , HBr, the bromide compound, or a combination thereof, or a combination thereof, so that the mercury content of the cleaned gas is maintained at or below a desired level.	See ‘114 1h.
29	The method of claim 25, wherein the mercury- containing gas comprises about 1 g to about 30 g of the element bromine per 100 g of the sorbent.	See ‘114 4.
30	The method of claim 25, wherein the mercury/sorbent composition comprises the element bromine, the sorbent material, and mercury.	Each infringing power plant produced mercury/sorbent composition in the mercury-containing flue gas. This composition comprises bromine, sorbent material, and mercury. See ‘114 1e.

[redacted]

<u>The '147 Patent to Olson</u>

No.	'147 Claim Element	Accused Conduct
1a	A method for separating mercury from a mercury containing gas comprising:	Each infringing power plant has performed this method using refined coal supplied by one or more of the Defendants. Each of ME2C's customers has performed this method as well (see section 3).
1b	promoting at least a portion of a particulate sorbent material comprising activated carbon by chemically reacting the sorbent material with a bromine containing promoter to form a promoted brominated sorbent, wherein the bromine containing promoter is in gaseous form, vapor form, or non-aqueous liquid form,	Each infringing power plant has coal handling systems to receive and transport refined coal. This refined coal included feedstock coal with added MerSorb. MerSorb contains calcium bromide ($CaBr_2$) dissolved in water. When calcium bromide is dissolved in water, the solution contains calcium ions (Ca^{++}) and bromine ions (Br^-). These atoms of bromine are the promoter. Moreover, because water boils at 100 degrees Celsius and the combustion chambers maintain heat far above that temperature, the Br^- exits the combustion chamber in a gaseous state. All defendants engaged power plant clients who injected a sorbent material comprising activated carbon into the mercury-containing gas downstream of the combustion chamber. Thus, this activated carbon and the bromine come into contact and form a promoted brominated sorbent, i.e., a sorbent particle that is bound with the bromine.

[redacted]

1c	and wherein the activated carbon contains graphene sheets having carbene species edge sites which react with the bromine containing promoter to form a carbocation paired with a bromide anion in the promoted brominated sorbent for oxidation of the mercury;	Activated carbon contains graphene sheets having carbene species edge sites. See deposition of E. Olson at Pg. 201, Line 21- Pg. 202, Line 8:  So is that generally true of activated carbons, that they are graphene sheets with carbene edge species sites? A. Generally. As far as I know, there are only one or two carbons that were ever actually demonstrated to have these graphene sheets or graphene ribbons by electron diffraction studies in the '90s. But this idea was universally accepted by virtually every carbon chemist, and I never heard anybody say that an activated carbon did not have graphene sheets or graphene ribbons. Ref. 238, Declaration of Stephen Niksa discussing structure of activated carbon and citations to Bansal, section VII.C.2 . That this claimed reaction occurs has been demonstrated by the inventors and others. See section 3 explaining that activated carbon provides a catalyst for mercury oxidation. Ref. 179:  Olson *et al.* [76] suggested that Hg has the propensity to be oxidized by donating its electrons to a surface or another gas-phase molecule; therefore, in its elemental More recent investigations have used plane-wave DFT to model AC, which allows for the use of periodic systems such as a graphene. Graphene ribbons with exposed edge sites have been used for investigations of the reactivity of carbonaceous surfaces to various gas species [77]. Several investigations support the zigzag carbene structure model, where the zigzag edge site acts as a Lewis base and reacts with acid gas components thereby serving as a potential adsorption site for oxidized Hg [77, 78]. A recent DFT study [79] on the effect of chemical functional groups on Hg adsorption on carbon surfaces supports this suggestion. The study indicates that an embedded halogen atom promotes chemisorption on the neighboring site, which is consistent with experimental results, and indicative of Hg oxidation. Results also indicate a varying effect Oxidation of mercury by a reaction of mercury with a gas (e.g., gaseous bromine) is referred to as homogeneous oxidation. Oxidation of mercury through a reaction involving gas and surface interactions (e.g. with activated carbon and bromine) is referred to as heterogeneous oxidation. It is well accepted that both homogeneous and heterogeneous reactions must take place. Thus, for example, mercury leaving the combustion chamber would not be fully oxidized by the time it reaches the activated carbon. Ref. 179:  Understanding the speciation of mercury throughout the coal combustion process is crucial to the design of efficient and effective mercury removal technologies. Mercury oxidation takes place through combined homogeneous (i.e., strictly in the gas phase) and heterogeneous (i.e., gas–surface interactions) pathways. Both bench scale combustion experiments [1] and quantum chemistry-based theoretical model efforts [2, 3] indicate that homogeneous mercury oxidation is responsible for, at most, 10% of the overall oxidation in a typical coal-fired flue gas with chlorine levels at 500 ppmv (e.g., HCl equivalent).

[redacted]

1d	chemically reacting elemental mercury in the mercury containing gas with the promoted brominated sorbent to form a mercury/sorbent chemical composition; and	As explained above in 1c, the elemental mercury in the mercury containing gas chemically reacts with the promoted brominated sorbent to form a mercury/sorbent chemical composition
1e	separating particulates from the mercury containing gas, the particulates including ash and the mercury/sorbent chemical composition.	Each of the infringing power plants employed devices that separated mercury/sorbent chemical composition from the mercury-containing gas, i.e., the fabric filter baghouse or ESP.
17a	A method according to claim 1, further comprising 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, wherein the promoter is reacted in the gas phase or as a vapor,	Each of the infringing power plants that burn pulverized coal, (i.e., all of the power plants except for Newton) pulverized the refined coal received by Defendants. Pulverized coal is transported out of the pulverizer by blowing air into the pulverizer such that it transports the coal to the combustion chamber. Thus, the coal and bromine containing promoter (the bromine in the MerSorb) are injected into a gas stream. This gas stream continues through the combustion chamber and out through the flue toward the pollution control equipment. Each power plant also injects activated carbon into that same gas stream. All but one of ME2C's US customers all use coal pulverizers for coal that has been treated with SF20 (which contains a bromide compound). For the one customer that has a cyclone furnace, SF10 is injected into the furnace above the re-entrant throat. SF 10 is also contains a bromide compound. As a result, the bromine, mercury, and sorbent all come into contact in the same gas stream to form the promoted brominated sorbent. Moreover, because water boils at 100 degrees Celsius and the combustion chambers maintain heat far above that temperature, the Br^- exits the combustion chamber and contacts the sorbent in a gaseous state.

[redacted]

17b	wherein the promoter is added at from about 1 to about 30 grams per 100 grams of the sorbent material.	See '114 4.
18	A method according to claim 17, wherein the gas stream is a mercury containing gas.	Each of the infringing power plants burned refined coal. This refined coal contains mercury. Thus, the gas stream from the pulverizer through the combustion chamber, to the point where activated carbon is injected is a mercury containing gas stream.
19	A method according to claim 18, wherein the gas stream is a transport gas.	Each of the infringing power plants burned refined coal to produce a gas stream. This gas stream transports the pulverized coal and resulting emissions, thus it is a transport gas.
20	A method according to claim 17, wherein the promoter injection rate and the sorbent injection rate into the gas are determined at least in part on the monitored mercury content of the cleaned gas.	See '114 1g, 1h.

[redacted]

The ‘225 Patent to Olson

No.	‘225 Claim Element	Accused Conduct
1a	A method for treating a mercury-containing gas, the method comprising:	See ‘114 1a.
1b	combusting a mixture comprising coal, pyrolysis char, and an additive comprising HBr, a bromide compound, or a combination thereof, to form the mercury-containing, gas; and	See ‘114 1b, 1c. In addition, when coal is combusted, it produces some amount of pyrolysis char. For example, the EERC test reports identify the amount of carbon captured in the fly ash when that refined coal is burned. This carbon is pyrolysis char.
1c	adding a particulate sorbent material comprising activated carbon into the mercury-containing gas.	See ‘114 1d.
2	The method of claim 1, wherein the pyrolysis char is a promoted pyrolysis char.	The pyrolysis char forms in the presence of bromine that has been added to the coal. Thus, it is promoted pyrolysis char.
5	The method of Claim 1, further comprising using a particle separation device to remove mercury from the flue gas and comprising collecting greater than 70 wt % of the mercury in the mercury-containing gas to produce a cleaned gas.	See ‘114 4.
6a	The method of Claim 5, further comprising:	
6b	measuring the mercury content of the mercury-containing gas; and	See ‘114 1g.
6c	modifying, in response to the measured mercury content:	See ‘114h.

[redacted]

6d	an injection rate of injecting the sorbent into the mercury-containing gas,	See '114 1h.
6e	an amount of the additive in the mixture, or	See '114 1h.
6f	a combination thereof.	See '114 1h.
8	The method of claim 1 , wherein the sorbent material is chosen from powdered activated carbon, granular activated carbon, carbon black, carbon fiber, aerogel carbon, pyrolysis char, and combinations thereof.	See '114 12.
9	The method of claim 1 , further comprising adding an alkaline component to the mercury-containing gas, the alkaline component chosen from alkali elements, alkaline earth elements, alkali salts, alkaline earth salts, and combinations thereof.	All defendants provided their power plant clients with refined coal comprising S-Sorb as well as MerSorb. S-Sorb contains calcium compounds also referred to as cement kiln dust. See section 5.1. Calcium is in group 2 of the periodic table, also referred to as the alkaline earth elements. Thus, by combusting the refined coal, each of the infringing power plants added an alkaline component to the mercury-containing gas.
14a	A method for treating a mercury-containing gas, the method comprising:	See '225 1a.
14b	combusting coal in a combustor comprising pyrolysis char and an additive comprising HBr, a bromide compound, or a combination thereof, to form the mercury-containing gas; and	See '225 1b.
14c	adding a particulate sorbent material comprising activated carbon into the mercury-containing gas.	See '225 1c.
15	The method of claim 14, wherein the pyrolysis char is a promoted pyrolysis char.	See '225 2.

[redacted]

17a	A method for treating a mercury-containing gas, the method comprising:	See '225 1a.
17b	combusting a mixture comprising coal, pyrolysis char, and an additive comprising HBr, a bromide compound, or a combination thereof, to form the mercury-containing gas; and	See '225 1b.
17c	adding a sorbent material comprising activated carbon into the mercury-containing gas.	See '225 1c.
18a	The method of claim 1, further comprising	See '225 6a.
18b	modifying, in response to a measured mercury content,	See '225 6c.
18c	an injection rate of injecting the sorbent into the mercury-containing gas,	See '225 6d.
18d	an amount of the additive in the mixture, or	See '225 6e.
18e	a combination thereof.	See '225 6f.
20	The method of claim 1, wherein the coal is combusted in a combustion chamber at a coal-combustion facility, wherein the HBr, bromide compound, or combination thereof, is added to the coal before the coal enters the combustion chamber, wherein the addition of the HBr, bromide compound, or combination thereof, to the coal is performed at the coal-combustion facility.	Prior to combustion, all defendants provided their power plant clients with refined coal comprising a bromide compound ($CaBr_2$) additive. The refined coal was burned in the clients' furnace combustion chambers. Moreover, the bromide additive was applied on-site at each power plant. Thus, each infringing power plant combusted coal in a combustion chamber where bromide was added to the coal before it entered the combustion chamber and where the addition of the bromide was performed at the coal combustion facility.

[redacted]

22	The method of claim 1, wherein the sorbent is contacted with a halogen or halide promoter prior to the addition of the sorbent to the mercury-containing gas.	As shown in Section 6, Powerton, WA Parish, Limestone, and Labadie used brominated or iodinated activated carbon. Thus, this sorbent is contacted with a halogen prior to the addition of the sorbent to the mercury-containing gas.,
23	The method of claim 1, wherein the sorbent is free of contact with a halogen or halide promoter prior to the addition of the sorbent to the mercury-containing gas.	As shown in Section 6, with the exception of Powerton, WA Parish, Limestone, and Labadie, which used brominated or iodinated activated carbon, all defendants engaged power plant clients who injected activated carbon sorbent into the mercury-containing gas. Prior to injection, the sorbent was free of contact with the halogen promoter.
25	The method of claim 1, wherein the coal comprises subbituminous coal.	With the exception of Williams, Cope, Oak Grove and Antelope Valley, all of the infringing power plants burned subbituminous coal. See section 6.1.
27	The method of claim 1, wherein the mixture is combusted in a combustion chamber of a coal-combustion facility upstream of a scrubber, a particulate control system, or a combination thereof, wherein the particulate sorbent is added to the mercury-containing gas before the mercury-containing gas encounters the scrubber, the particulate control system, or the combination thereof.	Prior to combustion, all defendants provided their power plant clients with refined coal comprising a bromide compound ($CaBr_2$) additive. The refined coal was burned in the clients' furnace combustion chambers. The combustion chambers were upstream of a scrubber and a particulate control system. The clients added powdered activated carbon sorbent to the mercury-containing gas after the combustion chambers and before the scrubbers and particulate control systems.
28	The method claim 26, wherein the particulate control system comprises an electrostatic precipitator, a baghouse, a fabric filter, or a combination thereof.	Each infringing power plant had particulate control system comprising an electrostatic precipitator, a baghouse, a fabric filter, or a combination thereof. See section 6.1.

[redacted]

The '517 Patent to Olson

No.	'517 Claim Element	Accused Conduct
1a	A method for reducing mercury in a mercury-containing gas, the method comprising:	See '114 1a.
1b	combusting coal in a combustion chamber, the coal comprising an additive comprising Br_2, HBr, a bromide compound, or a combination thereof, to form the mercury-containing gas; and	See '114 1b, 1c.
1c	collecting mercury in the mercury-containing gas with a sorbent added to the mercury-containing gas, the sorbent comprising activated carbon.	See '114 1d, 1f.
2	The method of claim 1, further comprising injecting an alkaline sorbent into the mercury-containing gas stream.	All defendants provided their power plant clients with refined coal comprising S-Sorb as well as MerSorb. S-Sorb contains calcium compounds also referred to as cement kiln dust. Calcium is in group 2 of the periodic table, also referred to as the alkaline earth elements. When refined coal is pulverized, it is blown out of the pulverizer and injected into the combustion chamber. Thus, each infringing power plant (except Newton which does not use pulverized coal) injected an alkaline sorbent into the mercury-containing stream.
3	The method of claim 2, wherein the alkaline sorbent is selected from the group consisting of alkali elements, alkaline earth elements, alkali salts, alkaline earth salts, and combinations thereof.	See '517 2.
4	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.	Each infringing power plant injected powdered activated carbon into the gas downstream of their furnace combustion chambers. See sections 5.4, 6.

[redacted]

5	The method of claim 1, wherein the sorbent has a composition comprising from about 1 to about 30 grams of the element bromine per 100 grams of activated carbon.	See '114 4.
6	The method of claim 1, comprising collecting greater than 70 wt % of the mercury in the mercury-containing gas.	See '114 2
8a	The method of claim 1, further comprising:	See '114 1g.
8b	measuring mercury content of the mercury-containing gas; and	See '114 1g.
8c	modifying, in response to the measured mercury content,	See '114 1h.
8d	an injection rate of injecting the sorbent comprising activated carbon into the mercury-containing gas,	See '114 1h.
8e	n amount of the additive comprising the Br_2, HBr, bromide compound, or a combination thereof, added to the coal, or	See '114 1h.
8f	a combination thereof.	See '114 1h.
10a	The method of claim 1, further comprising:	See '114 1g.
10b	modifying, in response to a measured mercury content,	See '114 1h.

[redacted]

10c	an injection rate of injecting the sorbent comprising activated carbon into the mercury-containing gas,	See '114 1h.
10d	an amount of the Br_2, HBr, bromide compound, or a combination thereof, added to the coal, or	See '114 1h.
10e	or a combination thereof.	See '114 1h.
11	The method of claim 1, wherein the coal comprises a subbituminous coal.	See '225 23.
13	The method of claim 1, wherein the coal comprises the added Br_2, HBr, the bromide compound, or a combination thereof, added to the coal before the coal enters the combustion chamber.	See '114 6.
14	The method of claim 1, wherein the combustion chamber comprises the added Br_2, HBr, the bromide compound, or a combination thereof.	See '114 6.
15	The method of claim 1, wherein the coal is combusted in the combustion chamber at a coal-combustion facility, wherein the Br_2, HBr, bromide compound, or combination thereof, is added to the coal before the coal enters the combustion chamber, wherein the addition of the Br_2, HBr, bromide compound, or combination thereof, to the coal is performed at the coal-combustion facility.	See '225 20.
17	The method of claim 1, wherein the combustion chamber is an electric utility coal combustion chamber.	Each infringing power plant had combustion chambers inside electric utility boilers as evidenced by their operating permits.
18a	The method of claim 1, further comprising:	
18b	measuring mercury content of the mercury-containing gas; and	See '114 1g.

[redacted]

18c	modifying, in response to the measured mercury content, an injection rate of injecting the sorbent comprising activated carbon into the mercury-containing gas.	See '114 1h.
19	The method of claim 1, wherein the mercury-containing gas comprises about 1 g to about 30 g of the element bromine per 100 g of the sorbent.	See '114 4.
21	The method of claim 1, wherein the sorbent in the mercury-containing gas comprises about 1 g to about 30 g of the added Br , HBr, the bromide compound, or a combination thereof, per 100 g of the sorbent.	See '114 4.
22	The method of claim 1, wherein the Br , HBr, or the bromide compound is contacted with the sorbent in vapor form, gaseous form, liquid form, or in an organic solvent.	See '114 7.
23	The method of claim 1, wherein the sorbent injected into the mercury-containing gas is a sorbent obtained by contacting a base sorbent with a halogen or halide promoter prior to injection of the sorbent to the mercury-containing gas.	See '225 20.
24	The method of claim 1, wherein the sorbent injected into the mercury-containing gas is free of contact with a halogen or halide promoter prior to injection of the sorbent into the mercury-containing gas.	See '225 22.
25	The method of claim 1, wherein the injection of the sorbent into the mercury- containing gas occurs upstream of a particulate separator or a scrubber.	See '114 18.

[redacted]

26	The method of claim 25, wherein the particulate separator comprises an electrostatic precipitator, a baghouse, a fabric filter, or a combination thereof.	See '114 18.
29a	A method of separating mercury from a mercury-containing gas, the method comprising:	See '114 1a
29b	combusting coal in a combustion chamber, wherein	See '114 1b
29c	the coal comprises added Br , HBr, bromide compound, or a combination thereof, added to the coal before the coal enters the combustion chamber, or	See '114 1c
29d	the combustion chamber comprises added Br , HBr, bromide compound, or a combination thereof, or	See '114 1c
29e	a combination thereof; and	See '114 1c
29f	collecting mercury in the mercury-containing gas with a sorbent added to the mercury-containing gas, the sorbent comprising activated carbon.	See '114 1e
30a	A method of separating mercury from a mercury-containing gas, the method comprising:	See '114 1a
30b	combusting coal in a combustion chamber, to provide the mercury-containing gas, wherein the mercury-containing gas comprises a halogen or halide promoter comprising HBr, Br , or a combination thereof, wherein	See '114 1b, 1c

[redacted]

30c	the coal comprises added Br , HBr, bromide compound, or a combination thereof, added to the coal before the coal enters the combustion chamber, or	See ’114 1c
30d	the combustion chamber comprises added Br , HBr, bromide compound, or a combination thereof, or 2	See ’114 1c
30e	or a combination thereof.	See ’114 1c
30f	collecting mercury in the mercury-containing gas with a sorbent added to the mercury-containing gas, the sorbent comprising activated carbon;	See ’114 1e
30g	separating the sorbent contacted with the mercury from the mercury-containing gas;	See ’114 1f
30h	measuring the mercury content of the mercury-containing gas; and	See ’114 1g
30i	modifying, in response to the measured mercury content of the mercury-containing gas,	See ’114 1h
30j	an injection rate of injecting the sorbent into the mercury-containing gas,	See ’114 1h
30k	an amount of the Br_2, HBr, bromide compound, or a combination thereof, added to the coal or the combustion chamber, or	See ’114 1h
30l	a combination thereof.	See ’114 1h

[redacted]

The '430 Patent to Olson

No.	'430 Claim Element	Accused Conduct
1a	A method of separating mercury from a mercury-containing gas, the method comprising:	See '114 1a
1b	combusting coal in a combustion chamber, to provide the mercury-containing gas, wherein	See '114 1b
1c	the coal comprises an additive comprising Br_2, HBr, a bromide compound, or a combination thereof, wherein the additive is added to the coal before the coal enters the combustion chamber, or	See '114 1c
1d	the combustion chamber comprises an additive comprising Br_2, HBr, a bromide compound, or a combination thereof or	See '114 1c
1e	a combination thereof;	See '114 1c
1f	injecting a sorbent comprising activated carbon into the mercury-containing gas downstream of the combustion chamber;	See '114 1d
1g	contacting mercury in the mercury-containing gas with the sorbent; and	See '114 1e
1h	separating the sorbent contacted with the mercury from the mercury-containing gas.	See '114 1f

[redacted]

2	The method of claim 1, wherein the coal comprises the additive comprising the Br2, HBr, the bromide compound, or a combination thereof, wherein the additive is added to the coal before the coal enters the combustion chamber.	See '114 claim 6
3	The method of claim 1, wherein the combustion chamber comprises the additive comprising the Br2, HBr, the bromide compound, or a combination thereof.	See '114 1c
4	The method of claim 1, wherein the coal is combusted in the combustion chamber at a coal-combustion facility, wherein the additive comprising the Br2, HBr, bromide compound, or combination thereof, is added to the coal before the coal enters the combustion chamber, wherein the addition of the additive comprising the Br2, HBr, bromide compound, or combination thereof, to the coal is performed at the coal-combustion facility.	See '114 claim 6
6	The method of claim 1, wherein the combustion chamber is an electric utility coal combustion chamber.	See '517 17.
7	The method of claim 1, wherein the combustion chamber is a coal combustion furnace.	See '114 claim 1b
8	The method of claim 1, wherein the coal comprises a subbituminous coal.	See '225 claim 25
10a	The method of claim 1, further comprising	
10b	measuring the mercury content of the mercury-containing gas; and	See '114 1g
10c	modifying, in response to the measured mercury content of the mercury-containing gas,	See '114 1h

[redacted]

10d	an injection rate of injecting the sorbent into the mercury-containing gas,	See '114 1h
10e	an amount of the Br_2, HBr, the bromide compound, or a combination thereof, added to the coal or the combustion chamber, or	See '114 1h
10f	a combination thereof.	See '114 1h
11	The method of claim 10, wherein the measuring of the mercury content comprises continuous measurement.	See '114 1h
12a	The method of claim 1, further comprising:	See '225 claim 24
12b	modifying, in response to a measured mercury content,	See '114 1h
12c	an injection rate of injecting the sorbent into the mercury-containing gas,	See '114 1h
12d	an amount of the Br2, HBr, the bromide compound, or a combination thereof, added to the coal or the combustion chamber, or	See '114 1h
12e	a combination thereof.	See '114 1h
13	The method of claim 1, wherein the mercury-containing gas comprises about 1 g to about 30 g of the element bromine per 100 g of the sorbent.	See '114 1h
14	The method of claim 1, wherein the sorbent contacted with the mercury comprises the element bromine and mercury.	See '114 4

[redacted]

15	The method of claim 1, comprising removing greater than 70 wt % of the mercury in the mercury-containing gas.	See ’114 1f
16	The method of claim 1, comprising removing greater than 70 wt % of the mercury in the mercury-containing gas with the sorbent.	See ’114 2
17	The method of claim 1, wherein the sorbent in the mercury-containing gas comprises about 1 g to about 30 g of the added Br_2, HBr, the bromide compound, or a combination thereof, per 100 g of the sorbent.	See ’114 3
18	The method of claim 1, wherein the Br_2, HBr, or the bromide compound is contacted with the sorbent in vapor form, gaseous form, liquid form, or in an organic solvent.	See ’114 4
19	The method of claim 1, wherein the activated carbon comprises powdered activated carbon, granular activated carbon, or a combination thereof.	See ’114 7
20	The method of claim 1, wherein the sorbent injected into the mercury-containing gas is a sorbent obtained by contacting a sorbent with a halogen or halide promoter prior to the injection of the sorbent into the mercury- containing gas.	See ’114 12
21	The method of claim 1, wherein the sorbent injected into the mercury-containing gas is free of contact with a halogen or halide promoter prior to injection of the sorbent into the mercury-containing gas.	See ’114 14

[redacted]

22	The method of claim 1, wherein the combustion chamber comprises a boiler.	See ’114 13
23	The method of claim 1, wherein the mercury-containing gas is a flue gas.	See ’114 1
24	The method of claim 1, wherein the injection of the sorbent into the mercury-containing gas occurs upstream of a particulate separator, a scrubber, or a combination thereof.	See ’114 1
25	The method of claim 24, wherein the particulate separator comprises a baghouse, an electrostatic precipitator, a fabric filter, or a combination thereof.	See ’114 18
28a	A method of separating mercury from a mercury-containing gas, the method comprising:	See ’114 18
28b	combusting coal in a combustion chamber, to provide the mercury-containing gas, wherein the mercury-containing gas comprises a halogen or halide promoter comprising HBr, Br^-, or a combination thereof, wherein	See ’114 1a
28c	the coal comprises an additive comprising Br_2, HBr, a bromide compound, or a combination thereof, wherein the additive is added to the coal before the coal enters the combustion chamber, or	See ’114 1b, 1c

[redacted]

28d	the combustion chamber comprises an additive comprising Br_2, HBr, a bromide compound, or a combination thereof, or	See ’114 1c
28e	a combination thereof,	See ’114 1c
28f	injecting a sorbent comprising activated carbon into the mercury-containing gas downstream of the combustion chamber;	See ’114 1c
28g	contacting mercury in the mercury-containing gas with the sorbent; and	See ’114 1d
28h	Separating the sorbent contacted with the mercury from the mercury-containing gas.	See ’114 1e
29a	A method of separating mercury from a mercury-containing gas, the method comprising:	See ’114 1f
29b	combusting coal in a combustion chamber, to provide the mercury-containing gas, wherein the mercury-containing gas comprises a halogen or – halide promoter comprising HBr, Br , or a combination thereof, wherein	See ’114 1a

[redacted]

29c	the coal comprises an additive comprising Br_2, HBr, a bromide compound, or a combination thereof, wherein the additive is added to the coal before the coal enters the combustion chamber, or	See ’114 1b, 1c
29d	the combustion chamber comprises an additive comprising Br_2, HBr, a bromide compound, or a combination thereof, or	See ’114 1c
29e	a combination thereof;	See ’114 1c
29f	injecting a sorbent comprising activated carbon into the mercury-containing gas downstream of the combustion chamber such that the activated carbon reacts with the halogen or halide promoter in the mercury-containing gas to form a promoted sorbent;	See ’114 1c
29g	contacting mercury in the mercury-containing gas with the promoted sorbent;	See ’114 1d
29h	separating the promoted sorbent contacted with the mercury from the mercury-containing gas;	See ’114 1e, f
29i	measuring the mercury content of the mercury-containing gas; and	See ’114 1g
29j	modifying, in response to the measured mercury content,	See ’114 1h

[redacted]

29k	an injection rate of injecting the sorbent into the mercury-containing gas,	See ’114 1h
29l	an amount of the Br_2, HBr, the bromide compound, or a combination thereof, added to the coal or the combustion chamber, or	See ’114 1h
29m	a combination thereof.	See ’114 1h

[redacted]

Appendix B - List of References

1. Deposition transcript of Christopher Berkimer and related exhibits.
2. Deposition transcript of Vincent Inedino and related exhibits.
3. Deposition transcript of George Kotch and related exhibits.
4. Deposition transcript of Vincent Verschueren and related exhibits.
5. Deposition transcript of William Whitney and related exhibits.
6. US Patent No. 8,168,147
7. US Patent No. 10,343,114
8. US Patent No. 10,589,225
9. US Patent No. 10,596,517
10. US Patent No. 10,668,430
11. ME2C Responses to Interrogatories
12. Cert Defendants And Certain Refined Coal Llc Defendants' Responses And Objections To Plaintiffs Midwest Energy Emissions Corp. And Mes Inc.'S First Set Of Common Interrogatories (Nos. 1-17)
13. Deposition transcript of James Landreth and related exhibits.
14. ME2C-RC-00014587
15. https://www.epa.gov/title-v-operating-permits/
16. https://www.epa.gov/clean-air-act-overview/1990-clean-air-act-amendment-summary-title-iii
17. https://www.epa.gov/mercury/mercury-study-report-congress
18. https://www.epa.gov/mats/study-hazardous-air-pollutant-emissions-electric-utility-steam-generating-units-final-report
19. REF-COAL_00000685
20. CERT-0017228
21. SB_00001988
22. SB_00001099
23. SB_00001173
24. SB_00001228 - 1230
25. SB_00002503 – 2506
26. SB00003760
27. SB00002261
28. SB00002510
29. SB_00025047
30. SB_00001630
31. PortageFuels_00069248
32. Belle_00019997
33. Belle_00013373
34. SV_00003746
35. Belle_00018622
36. Belle_00044997
37. Belle_00018121
38. Belle_00018974
39. Coleto_0039
40. CERT-0017228

[redacted]

41. CERT-0034619
42. WHELAN-0000692
43. Deposition of Sally Batanian and related exhibits.
44. WHELAN-0000889
45. Belle_00018066
46. Belle_00063862
47. MIDAMERICAN – 1053
48. MIDAMERICAN – 0935
49. MIDAMERICAN – 0808
50. Belle_00108413
51. CERT-0023675
52. CERT-0022114
53. CERT-0017228
54. ME2C-RC-00209976 - ME2C-RC-00210044
55. ME2C-RC-00210099 - ME2C-RC-00210113
56. COAL_00000685
57. COAL_00000600
58. COAL_00000642
59. COAL_00000596
60. ME2C-RC-00072299 - 306
61. THE MULTIPLE SITE MODEL FOR FLUE GAS— MERCURY INTERACTIONS ON ACTIVATED CARBONS: THE BASIC SITE, Energy & Environmental Research Center University of NorthDakota, 2003.
62. ME2C-RC-00055476 - 479
63. ME2C-RC-00222689 - 696
64. A/N 15/99778,760 PATENT IN THE UNITED STATES PATENT AND TRADEMARK OFFICE , DECLARATION UNDER 37 CFR §1.132, Declaration A, John Pavlish, 5/14/2018.
65. A/N 15/99778,760 PATENT IN THE UNITED STATES PATENT AND TRADEMARK OFFICE , DECLARATION UNDER 37 CFR §1.132, Declaration B, John Pavlish, 5/14/2018.
66. A/N 15/99778,760 PATENT IN THE UNITED STATES PATENT AND TRADEMARK OFFICE , DECLARATION UNDER 37 CFR §1.132, Declaration C, John Pavlish, 5/14/2018.
67. A/N 15/99778,760 PATENT IN THE UNITED STATES PATENT AND TRADEMARK OFFICE , DECLARATION UNDER 37 CFR §1.132, Declaration D, John Pavlish, 5/14/2018.
68. ME2C-RC-00210099 - 113
69. https://www.eia.gov/energyexplained/coal/
70. https://www.epa.gov/sites/default/files/2018-05/documents/epa_platform_v6_documentation_-_chapter_7.pdf
71. ME2C-RC-00169727
72. 26 U.S.C. § 45(c)(7)(A)
73. Deposition transcript of Sally Batanian and related exhibits.

74. B. Prest & A. Krupnick, "How Clean is "Refined Coal"? An Empirical Assessment of a Billion-Dollar Tax Credit," (2020)
75. https://www.epa.gov/sites/default/files/2018-05/documents/attachment_5-6_hg_control_cost_development_methodology.pdf at Pp. 2-3
76. ME2C-RC-00070738
77. Belle_00062312

78. SB_00001195
79. SB-00000917
80. Deposition transcript of Jeff Green and related exhibits
81. ArborFuels_00067791
82. W. Baasel, “Capital and Operating Costs of Wet Scrubbers Installed on Coal-Fired Utilities Impacting the East Coast” (2012)
83. https://www.eescorp.com/solutions/kleenscrub/
84. https://www.eia.gov/energyexplained/coal/
85. https://www.epa.gov/sites/default/files/2018-05/documents/epa_platform_v6_documentation_-_chapter_7.pdf
86. https://www.epa.gov/title-v-operating-permits/
87. https://pubs.usgs.gov/fs/fs095-01/fs095-01.pdf
88. SB_00041379
89. ME2C-RC-00218742
90. COAL_0001392
91. COAL_0001395
92. COAL_0001346
93. COAL_0001350
94. COAL_0001564
95. COAL_0007341
96. COAL_0007338
97. COAL_0007493
98. COAL_0007489
99. COAL_0007296
100. COAL_0007544
101. COAL_0007692
102. COAL_0007630
103. COAL_0007626
104. COAL_0007564
105. COAL_0000453
106. COAL_0000546
107. COAL_0000526
108. COAL_0000543
109. COAL_0000501
110. COAL_0000584
111. COAL_00018816
112. COAL_00019023
113. COAL_00018841
114. COAL_0009715
115. COAL_0009695
116. COAL_0009817
117. COAL_00015250
118. COAL_00015316
119. COAL_00015177
120. COAL_00017498
121. COAL_00017475

122. COAL_00017453
123. COAL_00012434
124. COAL_00012517
125. COAL_00013423
126. COAL_00012986
127. COAL_00012404
128. CGE_00002035
129. COAL_0000038
130. COAL_0000075
131. COAL_0000124
132. COAL_0000207
133. COAL_0000174
134. COAL_0000253
135. COAL_00010970
136. ArborFuels_0005205
137. COAL_0000988
138. COAL_00001048
139. COAL_00001052
140. Belle_00097581
141. COAL_00005641
142. PortageFuels_00050820
143. PortageFuels_00050850
144. COAL_00005672
145. Belle_00064886
146. COAL_00015976
147. COAL_00064812
148. CERT_0007688
149. CERT_0007641
150. CERT_0007240
151. CERT_0009735
152. CERT_0009770
153. CERT_0009823
154. CERT_0007729
155. CERT_0008275
156. CERT_0008315
157. CERT_0012710
158. CERT_0008397
159. CERT_0008446
160. CERT_0007433
161. CERT_0007401
162. CERT_0007346
163. CERT_0036918
164. CERT_0037063
165. CERT_0008039
166. CERT_0007554
167. CERT_0007521

168. CERT_0017134
169. CERT_0007878
170. CERT_0008165
172. CERT_0008205
173. CERT_0007958
174. CERT_0008841
175. CERT_0008871
176. CERT_0020032
177. 26 U.S.C. § 45(c)(7)(A)(i)(II)
178. Belle_00077846
179. ME2C-RC-00218742, J. Wilcox, Atomistic-Level Models from Mercury Control: for Coal-Derived Gas Streams (2015), and supporting references.
180. Declaration of inventor John Pavlish (July 27, 2020).
181. ArborFuels_00045831
182. REF-COAL_00020453
183. GCE_00002311
184. Deposition Transcript of Leah Schatt and related exhibits
185. Deposition Transcript of J. Finlinson and related exhibits
186. CERT_0023314
187. Belle_00052528
188. ArborFuels_0081059
189. ME2C-RC-0041150
190. Belle_0020814
191. ME2C-RC-00174356
192. SB_00026045
193. Belle_00113836
194. ME2C-RC-00172724
195. SB_00001257
196. ME2C-RC-00038657
197. ArborFuels_00080962
198. Belle_00018066
199. CERT-0012805
200. Deposition Transcript of L. Kuennen and related exhibits
201. SB_00041379
202. SB_00001195
203. SB_00041424
204. Deposition Transcript of J. Trettel and related exhibits
205. ArborFuels_00064263
206. CERT-0034624
207. ME2C-RC-00274666
208. DOMINION0000642
209. Belle_00089516
210. DEFTS00000542
211. GCE_00003117
212. GCE_00002311
213. U.S. Patent No. 7,507,083

[redacted]

214. U.S. Patent No. 7,468,170
215. CERT-0006822
216. U.S. Patent No. 6,808,692
217. U.S. Patent No. 8,845,986
218. Defendant Responses to ME2C Requests for Admission
219. Correspondence from J. Evall to J. Nemunaitis (January 28, 2022) ME2C-RC-00279352
220. CERT Responses to ME2C Requests for Admission
221. CERT Responses to ME2C's First Set of Interrogatories
222. MIDAMERICAN – 1142
223. CERT-0012026
224. CERT-0020032
225. ME2C-RC-00279293
226. ME2C-RC-00279374
227. SB_00041379
228. Defendant Responses to ME2C First Set of Interrogatories
229. Defendant Responses to ME2C Third Set of Interrogatories
230. Arbor Fuels_00067779
231. ME2C-RC-00048807
232. https://www.eia.gov/energyexplained/coal/
233. https://www.epa.gov/clean-air-act-overview/1990-clean-air-act-amendment-summary-title-iii
234. United States Environmental Protection Agency, "Study of Hazardous Air Pollutant Emissions from Electric Utility Steam Generating Units -- Final Report to Congress", United States Office of Air Quality EPA-453/R-98-004a, Environmental Protection Planning and Standards, February 1998, https://www.epa.gov/mats/study-hazardous-air-pollutant-emissions-electric-utility-steam-generating-units-final-report
235. https://files.nc.gov/ncdeq/Air%20Quality/permits/psd/docs/cliffside/EPRI_SCR_Mercury_2004.pdf
236. ME2C-RC-00112336
237. https://content.edgar-online.com/ExternalLink/EDGAR/0001193125-12-462616.html?hash=df736b90461a1e917cab80f6fd53fbba63cf04b47b30778cd28cfad418ad29c7&dest=D398286DEX1058_HTM#D398286DEX1058_HTM
238. ME2C-RC-00048867

Appendix C - Curriculum Vitae

Engineering Expert Witness and Litigation Support Services	EngineeringExpert.net Telephone: 630-204-6963 • 612-756-3273 www.engineeringexpert.net

CURRICULUM VITAE

Philip J. O'Keefe, PE

EXPERTISE

Specializing in Intellectual Property, Product Liability, Personal Injury, and Professional Malpractice Matters Involving:

- Medical Devices
- Consumer and Industrial Electronic Products
- Electric Power Tools
- Gasoline Engine Powered Tools
- Turf Care Equipment
- Hand Tools
- Electrical Appliances
- Water Filtration Systems
- Manufacturing Processes and Equipment
- Electric Utility Power Plants
- HVAC Systems
- Process Control Systems and Safety Interlocks
- Railway Equipment and Operations
- Quality Control
- Regulatory Compliance

Fire inspection service:

- Cause and origin determination.
- Evidence collection, preservation, and storage.
- Forensic lab analysis of evidence.
    - Non-Destructive Testing.
    - Destructive Testing.
- Report writing.

EDUCATION

BS Mechanical Engineering - Illinois Institute of Technology, Chicago, Illinois, 1981
MS Electrical Engineering - Iowa State University, Ames, Iowa, (enrolled)

PROFESSIONAL REGISTRATION

Registered Professional Engineer, State of Illinois, License No. 62-058772
Registered Professional Engineer, State of Minnesota, License No. 45527
Model Law Engineer, National Council of Examiners for Engineering and Surveying, Cert. No. 29725

INVENTIONS

Patent No. US 6,623,184 - Low Cost, Upgradeable, Deep Tank Automated X-Ray Film Processor

Patent Application Publication No. US2009/0066486A1 – Modular Signal Device For A Room Occupancy Management System And A Method For Using Same

CERTIFICATIONS

- Basic Instructor - Commonwealth Edison Company, Production Training Department
- Advanced Instructor – Commonwealth Edison Company, Production Training Department
- Problem Solving, Decision Making and Planning Program Instructor – Business Processes, Inc.
- Kepner-Trego Problem Solving/Decision Making Instructor – Kepner-Trego, Inc.
- Systematic Trouble Shooting Instructor – Business Processes, Inc.
- Fossil Power Plant Simulator Training Instructor – Autodynamics, Inc.
- Qualified Vibration Analyst – IRD Mechanalysis, Inc.

PROFESSIONAL EXPERIENCE

North Star Ideations, LLC – Winona, MN 2009 to Present
PRESIDENT

Develop, design, and test digital and analog electronics, embedded systems, and mechanical components for medical device, industrial, and consumer product innovations.

EngineeringExpert.net, LLC – Winona, MN 2000 to Present
PRESIDENT

Provide engineering expert witness and forensic engineering services in legal matters involving intellectual property, product liability, personal injury, and professional malpractice. Provide product development and intellectual property consulting to businesses and inventors. Provide technical training services.

Omni Engineering Services, Inc. – Winona, MN 2006 to 2009
CONSULTING ENGINEERING MANAGER

Developed, designed, and tested digital and analog electronics, embedded systems, industrial control system logic, and mechanical components for the food, consumer product, medical device, transportation, utility, HVAC, and agricultural equipment industries. Managed intellectual property and regulatory compliance matters.

Fischer Industries, Inc. – Geneva, IL 2000 to 2004
DIRECTOR OF ENGINEERING

Developed, designed, and tested new medical devices and accessories, improved existing products, managed quality control, and maintained regulatory compliance.

Echo Incorporated – Lake Zurich, IL/Cape Coral, FL 1997 to 2000
MANAGER OF DEVELOPMENT AND TESTING

Developed, designed, and lab tested gasoline and electric outdoor power tools, improved existing products, managed quality control, and maintained regulatory compliance at the Lake Zurich corporate headquarters. Concurrently managed the Cape Coral prototype product field testing facility.

Richard M. Hansen and Associates – Lombard, IL 1996 to 1997
FORENSIC ENGINEER

Examined, analyzed, photographed, and documented evidence collected at fire scenes.

Karps, Inc. – Elk Grove Village, IL 1995 to 1997
PLANT ENGINEER

Designed machine elements, tooling, and automated control systems for food production lines.

Marker Light Designs – St. Charles, IL 1994 to 2001
PRESIDENT

Designed and constructed scale models and dioramas for museums and corporate clients.

Aurora, Elgin, and Fox River Electric Co. – South Elgin, IL 1984 to 2005
ASSISTANT TRAINMASTER/CAR DEPARTMENT SUPERVISOR/TRAINMAN

Served in various operating and maintenance capacities on a tourist railroad.

Commonwealth Edison Company – Chicago, IL 1981 to 1995
PROJECT MANAGER/CONTROLS ENGINEER/EFFICIENCY ENGINEER

Served in various design, testing, training, and management capacities within utility power plants.

DETAIL OF PROFESSIONAL EXPERIENCE

Medical Device Design, Testing, and Manufacturing Experience:

- Developed and designed new medical products including, electrical/electronic subsystems and mechanical components in accordance with Underwriters Laboratories (UL) and International Electrotechnical Commission (IEC) medical device standards and directives, and Food and Drug Administration (FDA) medical device regulations.
- Conducted lab and clinical studies to evaluate safety and reliability of new product designs.
- Conducted lab tests on defective components for failure mode analysis.
- Wrote engineering bulletins, instruction books, and service manuals for new products.
- Prepared reports, test data, and 510(k) submissions for FDA approval of new products.
- Maintained documentation and quality systems in accordance with FDA Good Manufacturing Practice (GMP) and Quality System Requirements (QSR).
- Drafted specifications, drawings, and claims for utility patent applications.
- Designed manufacturing workstations, hand tools, and assembly fixtures to maximize safety, efficiency, and ergonomics.
- Wrote manufacturing and quality procedures in accordance with FDA regulations.

Power Tool Design and Testing Experience:

- Developed and designed gasoline-powered turf care, horticultural, forestry, and construction tools in accordance with California Air Resources Board and Federal Environmental Protection Agency air pollution regulations. These tools included chain saws, turf and hedge trimmers, leaf blowers, lawn edgers, and rototillers.

- Developed and designed electrically powered products including a line of battery operated turf care, horticultural, and forestry tools.
- Conducted lab and field tests to evaluate the safety, feasibility, and durability of new product designs and design revisions in existing products.
- Conducted lab tests to measure gasoline engine power and exhaust emission levels against regulatory agency emissions standards.
- Prepared compliance test reports for submission to the California Air Resources Board and the Federal Environmental Protection Agency to obtain approval of new product designs and design revisions.
- Conducted forensic analyses for product liability cases.
- Drafted specifications, drawings, and claims for utility patent applications.

Manufacturing/Production Line Design Experience:

- Designed processing machinery, material handling systems, tooling, industrial controls, data acquisition systems, and safety interlocks for manufacturing lines.
- Created mechanical drawings, electrical wiring diagrams, electrical schematics, and control logic.
- Troubleshot electrical systems and mechanical equipment in manufacturing lines.
- Designed manufacturing facilities in accordance with National Electric Code (NEC) requirements and municipal building codes.

Industrial and Consumer Product Development Experience:

- Evaluated electrical components to design printed circuit boards and electro-mechanical devices.
- Designed metal castings, extrusions, and stampings.
- Designed extruded, die-cut, injection molded, blow molded, rotational molded, and vacuum formed plastic parts.
- Created mechanical drawings, electrical wiring diagrams, electrical schematics, printed circuit board layouts, and control logic.

Utility Power Plant Design, Testing, Maintenance, and Operating Experience:

- Designed computerized process control systems for coal-fired boilers, steam turbines, and auxiliary equipment.
- Designed boiler control system safety interlocks in accordance with National Fire Protection Association (NFPA) guidelines regarding furnace explosions.
- Designed equipment control panels and human-machine interface (HMI) stations for safe, ergonomic operation.
- Designed piping systems, storage tanks, and pressure vessels in accordance with rules developed by the American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Committee (BPVC).
- Performed system efficiency tests in accordance with ASME Power Test Codes.
- Wrote power plant procedures regarding equipment operations, maintenance, and safety.
- Designed a computerized power plant simulator to train operating personnel to effectively and safely contend with equipment malfunctions and dangerous conditions.
- Managed overhaul, inspection, and repair of boilers, steam turbines, combustion turbines, pumps, coal pulverizers, coal feeders, burners, gas ignition systems, piping, exhausters, condensers, heat exchangers, fans, ductwork, piping systems, coal handling equipment, ash/clinker handling equipment, electrostatic precipitators, generators, exciters, transformers, and instrumentation.

Railroad Experience:

- Performed inspection and maintenance of electric railway equipment, including multiple-unit controls, automatic air brake systems, PCC-type electric braking systems, traction motors, bearings, current collection devices, door controls, and lighting systems.

- Operated steam, diesel, and electric railway equipment in passenger and freight service.
- Developed operating crew training manuals, training classes, and examinations.
- Maintained track, roadbed, electrical substation, and electrical overhead systems.
- Developed drawings and operating manuals for electrical substation wiring, control systems, and electrical equipment.
- Redesigned diesel locomotive control systems to incorporate a radio remote control option for switching service.

Forensic Engineering Experience:

- Photographed and documented evidence and forensic analysis in accordance with Federal Rules of Evidence (FRE) and the Federal Rules of Civil Procedure and Evidence (FRCPE).
- Performed both destructive and non-destructive examinations to analyze evidence collected at fire scenes to isolate and identify the true cause of onset.
- Reconstructed fire scenes to locate point of origin and cause.

SEMINARS AND COURSES PRESENTED

Coal Power Plant Fundamentals - EUCI, Inc./EngineeringExpert.net, LLC

Developed lesson plans and taught a course that provides an overview of a utility power plant, from the coal pile to the electrical switch yard, illustrating the functions and operations of equipment used to generate electricity.

Arc Flash Fundamentals – EUCI, Inc./EngineeringExpert.net, LLC

Developed lesson plans and taught a course for utility power plant personnel. Course content included a discussion of the hazards of exposure to electrical arc flash incidents, OSHA regulations pertaining to arc flash program requirements, NFPA and IEEE standards for arc flash incident energy calculations and personal protective equipment selection, electrical equipment warning label requirements, and arc flash program maintenance.

Turbine Heat Rate Testing – Commonwealth Edison Production Training Center

Developed lesson plans and taught a course for utility power plant engineers and technicians. Course content included methods for setting up and performing steam turbine efficiency tests in accordance with ASME Power Test Codes and turbine manufacturer guidelines. Taught lessons in practical thermodynamics, heat transfer, and fluid mechanics in the context of power plant efficiency testing.

Transformers – Commonwealth Edison Personnel Development Department

Taught lessons in theory, design, and operation of single phase and three phase high voltage utility transformers.

Problem Solving, Decision Making and Planning Seminar – Commonwealth Edison Personnel Development Department

Developed and presented a series of seminars for supervisory and non-supervisory corporate personnel. Course content included methods to identify true causes of problems and develop decision-making strategies to correct the problems.

First Line Supervisor Training – Commonwealth Edison State Line Station

Developed lesson plans and taught a course for utility power plant management personnel. Course content included lessons in leadership, supervisory skills, administrative procedures, operating procedures, maintenance procedures, and safety procedures.

FILM AND MEDIA EXPERIENCE

Listed as a subject matter expert in the Illinois Film Office, *Film Guide Book.* Listed subject matter expertise includes: power plants, railways, tunnels, bridges, industrial equipment, and industrial archeology. Experience in the following television and radio productions:

Curious and Unusual Deaths, New Road Media/Discovery Channel

Appeared on the television program as a subject matter expert regarding a district heating system steam piping failure; electrocution caused by contacting a high voltage capacitor in a microwave oven; death caused by carbon monoxide emitting from a propane heater; and electrocution caused by an electrical fault in an air conditioning system.

Understanding: Tunnels, Cronkite Ward Television/The Learning Channel

Appeared on the television program as a subject matter expert with regard to the design and operation of Chicago's abandoned narrow gauge freight subway system.

ER, Warner Brothers Entertainment, Inc.

Acted as a technical expert to assist the writers in developing a plot for an episode set in Chicago's abandoned narrow gauge freight subway system.

Urban Explorers, Hoggard Films/Discovery Channel

Acted as a technical expert to assist the writers of this television series in developing a plot for an episode documenting Chicago's abandoned narrow gauge freight subway system.

Cities of the Underworld, Authentic Entertainment, Inc./History Channel

Acted as a technical expert to assist in writing and producing a television series episode documenting the exploration of Chicago's abandoned narrow gauge freight subway system.

History's Mysteries, Lion Television/History Channel

Acted as a technical expert to assist the writers for an episode concerning a Denver Tramways streetcar body that was discovered within the structure of a private home near Denver, Colorado.

PUBLICATIONS

Philip J. O'Keefe, PE, *The Engineering Expert Witness Blog (2008 - Present)* (http://www.engineeringexpert.net/Engineering-Expert-Witness-Blog/)

A weekly blog focused on engineering-related topics. Specific focus is paid to select technical problems and their solutions through a variety of approaches.

Philip J. O'Keefe, PE, *A Case Study of the Systems Engineering Process in FDA Class II Medical Device Design,* Iowa State University of Science and Technology, Ames, Iowa, 2008.

A paper describing how a systems engineering approach was used to develop a new Food and Drug Administration (FDA) Class II medical device. It presented a case study of the systems engineering process and how it was used to ensure that a medical device design met all project stakeholder requirements, including a requirement for regulatory compliance.

P. J. O'Keefe, *Fossil Turbine Heat Rate Testing,* Commonwealth Edison Company, Chicago, 1984.

A manual written to train utility power plant engineers and technicians in setting up and performing steam turbine efficiency tests in accordance with ASME Power Test Codes and turbine manufacturer guidelines. The manual also guides engineers in setting up thermodynamics, heat transfer, and fluid mechanics calculations to process test data, analyze test results, and report test results.

P. J. O'Keefe, J. J. Mulligan, *Technical Staff Handbook*, Commonwealth Edison Company, Chicago, 1983.

A handbook written to guide utility power plant engineers in performing tests, inspections, and analyses of problems on coal fired boilers, steam turbines, blowers, pumps, heat exchangers, piping, coal handling equipment, electrostatic precipitators, dust handling systems, water demineralizers, and chemical injection systems.

P. J. O'Keefe, S. Braun, *Bailey "C" Programming*, Commonwealth Edison Company, Chicago, 1990.

A design guide to provide basic understanding of the "C" programming language and how to upload "C" programs into a Bailey Network 90 Distributed Control System to automatically control utility power plant systems including coal fired boilers, steam turbines, and auxiliary equipment.

P. J. O'Keefe, *State Line Station Locomotive Number 1*, Stateliner Magazine, Commonwealth Edison Company, 1984.

An article describing the construction, specifications, and operating principals of the world's largest and most powerful electric battery operated locomotive and how General Electric based the concept for this locomotive on technology used in World War I submarines.

SEMINARS AND CONTINUING EDUCATION WORKSHOPS

Patent Enforcement and Defense – Minnesota State Bar Association Continuing Legal Education

Guidelines for pre-suit investigations, the impact of KSR v. Teleflex on the TSM Obviousness Test, assessing the impact of statements made during Markman hearings, and trends in claim construction.

Effective Development and Presentation of Expert Witness Testimony – Law Seminars International

Preparing expert reports, retaining files and evidence, using persuasive techniques during testimony, responding to questions of opposing counsel, using graphics and models during testimony, and complying with Federal Rules of Evidence, Federal Rules of Civil Procedure, and ethical standards.

Patent Education Series – Intellectual Properties Enterprises, Inc.

Understanding the regulations, laws, and procedures contained within the Manual for Patent Examining Procedure (MPEP), and how they govern the US Patent and Trademark Office.

Strategies for Successful Presentations – Xerox Learning Systems

Written Communications Seminar - Commonwealth Edison Production Training Department

Basic Instructor Course - Commonwealth Edison Production Training Department

Developing lesson plans and effective presentation skills.

Advanced Instructor Course - Commonwealth Edison Production Training Department

Developing lesson plans and effective presentation skills.

Test Construction Seminar - Commonwealth Edison Production Training Department

Creating effective exams to test and measure students' understanding of training topics.

Interpersonal Management Skills Seminar – Xerox Learning Systems

Systematic Trouble Shooting – Business Processes, Inc.

Applied Systematic Problem Solving, Decision Making and Planning Program – Business Processes, Inc.

Kepner-Trego Problem Solving/Decision Making – Kepner-Trego, Inc.

Stress Management: A Positive Strategy - Commonwealth Edison Personnel Development Department

Situational Leadership/One Minute Manager Training Program – Commonwealth Edison Personnel Development Department

Time Management Seminar - Commonwealth Edison Personnel Development Department

Principles and Fundamentals of Human Relations As Applied To Selling, Supervising, and Managing – Sales Analysis Institute, J. D. Kirk Associates, Inc.

Role of the Manager/Gaining Acceptance - Commonwealth Edison Personnel Development Department

Management Coaching Seminar - Commonwealth Edison Industrial Relations Department

Vibration Monitoring and Analysis Training Program – IRD Mechanalysis, Inc.
Analyzing rotating machinery to identify and eliminate the causes of mechanical vibrations.

Boiler Control Course - Instrument Society of America
Developing control system strategies and designing control logic for coal-fired boilers, oil-fired boilers, gas ignition systems, oil ignition systems, and auxiliary equipment.

Burner Management Seminar – Westinghouse Electric Corporation
Designing fuel system safety interlocks for large utility power plant boilers in accordance with National Fire Protection Association (NFPA) guidelines, for the prevention of explosions.

Pulverized Coal Boiler Design and Operations Seminar - Combustion Engineering, Inc.
Designing and operating utility power plant pulverized coal boiler equipment, including coal pulverizers, exhausters, coal pipes/orifices, coal feeders, burners, gas ignition systems, balanced furnace draft systems, boiler tubes, steam drums, circulating water systems, combustion control systems, and safety interlocks.

Boiler Performance and Maintenance Seminar - Babcox and Wilcox, Inc.
Monitoring and evaluating coal fired boiler performance, conducting inspections, performing equipment tests, and analyzing test data to recommend maintenance procedures.

Systems, Controls, and Operations for Large Steam Turbine Generator Mechanical Hydraulic Control Units – General Electric Apparatus and Engineering Services.
Designing and operating General Electric utility power plant steam turbine equipment including blades, shrouds, diaphragms, nozzle blocks, throttle valves, steam chest, stop valves, intercept valves, hydraulic controls, condensers, extraction lines, generators, and exciters.

Steam Turbine-Generator Maintenance Course – Westinghouse Electric Corporation
Overhauling, inspecting, and repairing Westinghouse utility power plant steam turbines and generators.

Power Plant Performance and Maintenance – Power Safety International
Predicting failure of utility power plant equipment through performance testing and analysis of test results.

Honeywell TDC 2000 Distributed Control Systems – Honeywell Corporation
Designing analog block logic, digital ladder logic, human-machine interface (HMI) graphics, wiring, and hardware for distributed control system (DCS) applications.

Bailey Net 90/Infi 90 Distributed Control Systems – Bailey Controls Corporation
Designing analog block logic, digital ladder logic, HMI graphics, wiring, and hardware for DCS applications.

Westinghouse Distributed Process Family (WDPF) Control Systems – Westinghouse Electric Corp.
Designing analog block logic, digital ladder logic, HMI graphics, wiring, and hardware for DCS applications.

Westinghouse Distributed Process Family (WDPF) Control System Maintenance Course – Westinghouse Electric Corporation

Troubleshooting DCS software and hardware problems.

Westinghouse HPPC Programmable Logic Controllers – Westinghouse Electric Corporation

Designing digital ladder logic for process control applications.

Square D SY/MAX Programmable Logic Controllers – Square D Company

Designing digital ladder logic for process control applications.

Allen-Bradley Programmable Logic Controllers – Allen-Bradley, Inc.

Designing digital ladder logic for process control applications.

Engineering Fluid Mechanics Seminar – Commonwealth Edison Production Training Department

Designing piping systems, determining pump capacity, conducting pump performance tests.

Power Plant Steam and Mechanical Fundamentals - Commonwealth Edison Production Department Training

Operating coal fired boilers, steam turbines, and auxiliary equipment in utility power plants.

Steam Boilers and Auxiliaries - Commonwealth Edison Industrial Relations Department

Operating utility power plant coal and oil fired boilers and auxiliary equipment including coal pulverizers, stokers, cyclone burners, oil atomizers, natural gas ignition systems, coal feeders, induced draft and forced draft systems, boiler tubes, steam drums, circulating water systems, precipitators, coal handling systems, and ash/clinker handling systems.

Power Plant Chemistry Fundamentals – Commonwealth Edison Production Department Training

Designing, operating, and testing water filters, ion exchange systems, chemical injection systems, and acid/caustic storage systems used in treating utility boiler feed water.

Quality Assurance Training - Commonwealth Edison Industrial Relations Department

Understanding quality assurance procedures and auditing methods used in utility power plants.

Electrical Power System Survey Course - Commonwealth Edison Industrial Relations Department

Designing and operating electric utility three-phase high voltage transmission and distribution systems including switching systems, disconnects, circuit breakers, fuses, insulators, protective relay systems, power factor control, transformers, and supervisory control and data acquisition (SCADA) systems.

Computer Training – Various training resources.

Basic and advanced classes in DOS, UNIX, MS Windows, MS Word, MS Excel, MS PowerPoint, MS Access, BASIC, FORTRAN, "C", HTML, Java, Dbase, Word Perfect, AutoCAD 2000, and OrCAD.

OTHER ACCOMPLISHMENTS AND INTERESTS

Professional Scale Model Building:

- Constructed highly detailed, museum quality 1:12 scale model dioramas of a narrow gauge electric railway equipment for display at Chicago's Field Museum of Natural History. The model parts were fabricated from plastic, brass, and wood, based on my personal drawings taken from field measurements.
- Worked with administrators at Chicago's Museum of Science and Industry to repair and restore a large model railroad exhibit and develop new dioramas for the museum's coal mine exhibit.
- Constructed museum quality 1:48 scale models of modern railroad freight cars for display in a traveling exhibit sponsored by Norfolk Southern Corporation. The model parts were fabricated from plastic, brass, and wood, using scale drawings and paint stenciling diagrams supplied by the client.

- Designed, machined, and fabricated brass patterns to manufacture white metal castings for 1:24 scale models of a narrow gauge electric mining locomotive. The patterns were based on my personal drawings developed from field measurements.
- Constructed 1:87 scale model displays of modern railroad freight cars for the Excel Railcar Corporation.
- Received the Dremel Award for authoring an article in *Railroad Model Craftsman Magazine* which describes the construction of a 1:87 scale Chicago streetcar model.

Visual Arts:

- Served as staff artist for the Shore Line Interurban Historical Society magazine, *First and Fastest.*
- Created dust jacket artwork for the book *The "L", The Development of Chicago's Rapid Transit System, 1888-1932,* by Bruce Moffat.
- Produced scale drawings and shot photographs for the book *The Chicago Tunnel Story – Exploring the Railroad Forty Feet Below* by Bruce Moffat.
- Recognized by juried art shows and galleries as a fine artist working in watercolor, pen and ink, and pencil media.
- Designed and created jewelry using various techniques, including photo-chemical etching and lost wax casting.
- Created sculptures using various glass blowing techniques.

Industrial Archeology:

- Recognized as an authority on American railroad artifacts, particularly uniform accoutrements, keys, locks, signal lanterns, and other hardware used on electric railways in the early 20th Century. Authored numerous articles for *Key, Lock, and Lantern Magazine,* a publication for collectors of railroad memorabilia.
- Recognized as an authority on Edison cylinder and disc phonographs and records manufactured between 1900 and 1929. Presented historical lectures and phonograph demonstrations at schools and public events. Created the *Edison Phonology* website to present historical information about Edison phonographs and records. Currently serve as moderator on the *Old Time Victrola Music Message Board,* an internet forum for the discussion of topics regarding acoustical phonographs, acoustical recordings, and early electric recordings manufactured prior to 1935.
- Recognized as an authority on the Chicago Tunnel Company, a common carrier narrow gauge electric freight railway that operated under the streets of downtown Chicago from 1904 until abandonment in 1959. Provided historical and technical information for the book *The Chicago Tunnel Story – Exploring the Railroad Forty Feet Below* by Bruce Moffat. Created the *Chicago Tunnel Company Railroad* website to present historical subject matter. Presented historical lectures and slide presentations on the Chicago Tunnel Company at museums and public events.