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STEVEN E. EDWARDS
President and CEO

October 1, 2005

State of North Dakota
The Industrial Commission
State Capitol
Bismarck, North Dakota 58505

Dear Technical Review Committee members:

I am pleased to submit a grant application to the Lignite Research, Development and Marketing Program on behalf of Mazyck Technology Solutions, LLC. Our project, titled "**Silica-Titania Coated Packing for Superior Hg Capture; A Tailored Technology for Lignite-Fired Power Plants**", will employ a technology with the potential to: (a) provide an economical solution that can more efficiently capture various species of mercury compared to existing technologies, (b) significantly decrease the estimated costs to meet pending regulations, (c) be regenerated and reused multiple times, (d) not deleteriously impact fly ash quality, and (e) be engineered for easy implementation in existing lignite-fired power plants.

Our proprietary technology has been extremely successful for mercury removal in both the bench scale and the pilot scale, achieving about 99% Hg removal. The novel material combines a high surface area sorbent with the photocatalytic properties of titania to achieve efficient oxidation and adsorption of mercury in a cost-effective manner. The adsorption capacity of your material (300 mg/g) is far greater than that of other sorbents.

If the Lignite Research Council chooses to award this grant to our team, we will commit to successfully completing this project in the manner described in this application, in the amount of time designated, and for the project costs defined within. We hope that you will recognize the benefits that the results of our project will bring to the lignite industry and consequently to the state of North Dakota.

Sincerely,

Steven Edwards

Steven E. Edwards
President and CEO

Title: “**Silica-Titania Coated Packing for Superior Hg Capture; A Tailored Technology for Lignite-Fired Power Plants**”

Applicants: Mazyck Technology Solutions, LLC, MicroEnergy Systems, Inc., University of Florida

Principal Investigator: David W. Mazyck, Ph.D.

Date of Application: October 1, 2005

Amount of request: $752,030

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ABSTRACT

In response to the limitations of existing control technologies, Mazyck Technology Solutions, LLC (MTS), Gainesville, Florida, has formed a team to demonstrate a unique and innovative technology for mercury capture from lignite-fired power plants. In addition to MTS, the team includes the University of Florida Department of Environmental Engineering Sciences (UF), Gainesville, Florida and MicroEnergy Systems, Inc (MSI), Oakland, Maryland. The technology, silica-titania coated packing (STCP) was specifically designed for Lignite-fired power plants, and has the potential to: (a) provide an economical solution that can more efficiently capture various species of mercury compared to existing technologies, (b) significantly decrease the estimated costs to meet pending regulations, (c) be regenerated and reused multiple times, (d) not deleteriously impact fly ash quality, and (e) be engineered for easy implementation in existing Lignite-fired power plants.

The program objective is to design, fabricate, and test a pilot-scale mercury control system based on bench-scale tests completed during the past several years and our experience in capturing elemental Hg from chlor-alkali facilities. We anticipate greater than 90 % mercury capture using our technology. The ultimate goal is to develop the commercialization of said technology for this application. We propose to complete this program in 18 months. In this period of time the STCP will be optimized and its capacity for mercury capture from an air stream containing only Hg vapor will be assessed, a pilot reactor will be designed and fabricated, and the effectiveness of STCP in the pilot reactor fed by flue gas from MSI’s Combustion Test Facility boiler using Lignite as the feedstock will be studied. The total project cost is estimated to be $1,504,060, of which $752,030 is requested in funding.

PROJECT SUMMARY

Mazyck Technology Solutions, LLC (MTS), Gainesville, Florida, the University of Florida Department of Environmental Engineering Sciences (UF), Gainesville, Florida, and MicroEnergy Systems, Inc (MSI), Oakland, Maryland have come together to propose the demonstration of a unique and innovative technology for mercury capture. The technology has the potential to: (a) provide an economical solution that can more efficiently capture various species of mercury compared to existing technologies, (b) significantly decrease the estimated costs to meet pending regulations, (c) be regenerated and reused multiple times, (d) not deleteriously impact fly ash quality, and (e) be engineered for easy implementation in existing lignite-fired power plants. (Although regeneration is possible, it appears that the more feasible option, as discussed herein, would be to pulverize our catalyst and then dispose of this material in an appropriate landfill facility. We anticipate that the catalyst will be in service for numerous years before regeneration is required. This, accompanied by the fact that large volumes of acid used for regeneration would require treatment, and storage of the acid would be required, leads us to believe that regeneration is not the most practical or feasible option.)

The technology, silica-titania coated packing (STCP), focuses on the combination of photocatalytic oxidation and adsorption to convert elemental Hg to a more adsorbable species (e.g., mercuric oxide, HgO). We have designed a silica gel impregnated with titanium dioxide that has demonstrated mercury capture orders of magnitude greater (**300 mg/g**) than achievable by activated carbon (**5 mg/g**). The silica-titania sol can be formed into various shapes and sizes or coated on commercially available chemical packing material to optimize mercury capture while maintaining low pressure drop. The technology can be used to *oxidize and adsorb all species of mercury (including elemental mercury)*, has been successfully demonstrated in bench-scale tests and in pilot tests at a chlor-alkali facility, is patent pending at the U.S. Patent and International Patent Offices and addresses the research priorities identified by the Lignite Research Council, as well as the objectives of the Electric Power Research Institute (EPRI).

The pilot study recently completed at a chlor-alkali manufacturing facility applied the silica-titania technology in the shape of cylindrical pellets. This experience provided valuable information that will be used to design a mercury control system for the treatment of flue gas from lignite-fired power plants expected to achieve greater than 90 % mercury removal at a cost ***below*** the average baseline cost of mercury removal per pound ($60,000/lb Hg based on powdered activated carbon injection costs) (DOE, 2005). Since the contamination of fly ash will be avoided, the implementation of our technology provides an even greater economic benefit.

With confidence that the technology will be successful once again, the program objective is to design, fabricate, and test a pilot-scale mercury control system to demonstrate greater than 90 % mercury capture by STCP, and to ultimately develop the commercialization of said technology for this application. We propose to complete this program in three phases that will require 18 months. Phase I will focus on the optimization of the STCP (i.e., the core silica-titania sol coated on chemical packing) and preliminary design of a pilot reactor. Phase II will focus on the acquisition of preliminary data to assess the capacity of the STCP for Hg capture in an air stream containing only Hg vapor. The program will conclude with the implementation of the STCP technology in a specifically designed pilot reactor fed by flue gas from MSI's Combustion Test Facility boiler using lignite as the feedstock.

INTRODUCTION

The economy of the state of North Dakota relies heavily on the lignite industry as both an energy and an employment resource. As such, active research is encouraged by the state to enhance the use of lignite. An issue surrounding the use of lignite for energy production is the control of emissions of hazardous pollutants resulting from the combustion process. One of such hazardous pollutants is mercury.

Powdered activated carbon (PAC) injection for the capture of mercury from flue gas is currently the most feasible and effective control technology available. However, both fundamental research at the bench scale and pilot studies around the United States have confirmed that PAC injection has limitations. For example, its adsorption capacity is low (ca. 0.2 to 5 mg/g according to Pavlish et al., 2003) unless tailored via impregnation with sulfur or halogens. Furthermore, the efficiency for Hg capture is much greater when the PAC is collected via a baghouse versus removed in an electrostatic precipitator. Additionally, waste PAC accumulates in fly ash, a product of combustion commonly sold for the manufacturing of concrete and other materials. Revenue generation from selling of fly ash is compromised by the presence of waste PAC.

PAC injection may provide a suitable Hg control strategy for some coal-fired power plants, but may not likely be a viable option for lignite-fired power plants, since activated carbon's capacity for elemental Hg is considerably less than for ionic Hg. Therefore, other solutions are required for those that burn lignite, or for those that deem it unfeasible to install a baghouse, which can be in the neighborhood of $10 M (Johnson and Cummings, 2005). The issue surrounding lignite is that elemental mercury (Hg^0) generation is favored vs. the more readily adsorbed oxidized mercury compounds. Therefore, a technology that is robust and capable of capturing Hg regardless of its speciation, can be easily added to the existing air pollution control process train, and does not negatively impact the quality of fly ash for potential resale is definitely required. As such, the objective of this proposal is to enhance the readiness level of a catalytic technology originally developed at the University of Florida (UF) in Gainesville, Florida that we anticipate will achieve over 90% mercury removal in a cost-effective manner.

BACKGROUND

In recent years, numerous studies for enhanced mercury removal from combustion sources have been undertaken. Generally the effectiveness of the methods used in these studies varies greatly depending on mercury speciation (Pavlish et al., 2003). A control technology that can remove all forms of mercury has yet to be identified (EPA, 2005). The Energy & Environment Research Center (EERC) at the University of North Dakota is currently conducting research to develop and evaluate cost-effective sorbent technologies to reduce mercury emissions specifically from plants burning lignite coal. These technologies include sorbent injections coupled with particulate control devices (EERC, 2005). The patented THIEF process utilizes a thermally activated sorbent consisting of semi-combusted coal extracted from the furnace and injected into the flue gas upstream of a particulate control device. The sorbent is less effective than commercially available activated carbon, achieving up to 70% removal in pilot studies (Feeley et al., 2003). Powerspan Corporation has licensed a promising technology (Photochemical Oxidation) developed by the U.S. Department of Energy and initiated the development of its commercial application with sub-bituminous and lignite coals (Granite and Pennline, 2003). Their technology uses 254 nm ultraviolet light to oxidize elemental mercury upstream of a baghouse or electrostatic precipitator and relies on other control strategies (e.g., scrubbers) to subsequently remove the oxidized mercury. Therefore, the technology does not complete total oxidation and removal in a single step. Powerspan is also developing their Electrocatalytic Oxidation technology, capable of achieving 80-90% mercury removal, which is less than what we believe our technology can achieve. Other technologies focus either on adsorption using various sorbents (i.e., metal oxides, impregnated activated carbons, iron chloride, palladium chloride, etc.), or oxidation upstream of scrubbers (or other existing particulate removal devices) using different catalysts (Pavlish and Holmes, 2005). Activated carbon injection is the most developed sorbent technology available for mercury control, but its commercial experience has primarily been for waste incinerators with very high levels of chlorine present, which is not the case for coal-fired power plants; particularly for those utilities that burn lignite (Benson, 2003).

In response to the limitations of existing mercury control technologies, Dr. David Mazyck and some colleagues at the University of Florida (UF) developed an innovative material and process for mercury capture. Originally, the technology was developed for NASA for water recovery and air revitalization (Grant No. NCC 9-110) and then investigated for Hg capture via the US EPA's Future's program (Grant No. R-82960201).

Silica-Titania Composites (STC)

The technology, silica-titania composites (STC), involves removal of mercury via adsorption and/or either simultaneous or subsequent photo-oxidation using titania-impregnated silica-gels. (Herein, the focus is on the use of continuous UV, but the technology can be operated in the dark intermittently.) Adsorption on the composite material allows mercury to be concentrated while exposure to ultraviolet (UV) radiation ensures the oxidation of adsorbed mercury (Pitoniak et al., 2003, 2005).

The porous composite material consists of a high surface area substrate (> 600 m^2/g), for example, a silica-gel, which is transparent to UV light and is impregnated with photocatalyst particles, such as titanium dioxide (TiO_2). Indeed, as the mass loading of TiO_2 increases, the transparency of the silica decreases and more UV lamps are required to fully illuminate the catalyst/sorbent bed. Recognizing this limitation, a modified STC approach is discussed below to reduce the UV lamp requirements.

<u>Bench-Scale Testing</u>

The efficacy of this technology has been tested at the bench scale at the University of Florida and Mazyck Technology Solutions, LLC (MTS). Mercury removal as a function of adsorption and oxidation was monitored.

<u>Experimental Setup</u>:

A packed-bed reactor system was used to characterize the mechanisms and efficiency for mercury removal. The reactor system included a supply of elemental mercury vapor, a mercury analyzer (VM 3000, Mercury Instruments), and appropriate appurtenances for measuring total Hg (i.e., elemental and oxidized Hg) via the Ontario Hydro Method (ASTM D6784-02). Mercury-laden air was introduced into the system by passing purified air above liquid mercury in a reservoir. The flow rate of mercury-laden air and the amount of STC were manipulated to provide residence times varying from 0.1 to 0.78 s. The temperatures used in the reactor ranged from 28 to 200°C, and the initial mercury concentrations ranged from 7 to 40 ppb (59 to 334 $\mu g/m^3$).

A stainless steel mesh (64 µm opening) was used to hold the STC cylindrical pellets, which were approximately 3 x 5 mm. A UV lamp (365 nm, 4W) was placed at the center of the packed-bed reactor, and the pellets were randomly packed around the lamp. The cross-sectional area of the reactor was 26.5 cm^2.

Mercury Removal as a Function of Adsorption and Oxidation:

In the absence of UV light, the only function of the STC is to adsorb mercury. When UV light is present, adsorption and oxidation may occur. In order to differentiate between adsorption and adsorption/oxidation, UV light was turned on and off at various intervals. During experiments, the effluent concentration of mercury would start at zero and slowly increase until complete breakthrough when the UV light was off. Upon turning the UV light on after a period of no UV, and in experiments where UV was on from the beginning, the effluent mercury concentration was zero and remained there for the duration of the experiment. Figures 1a and 1b show the results of two experiments. Experiments similar to that of Figure 1b were carried out for almost 500 hours with the same results. At the end of each run, pellets had a black and/or yellow coating on their surfaces, which is indicative of the capture of oxidized mercury. This also provided an indication that the majority of the reactions are taking place on the surface of the composite; a phenomenon that is used advantageously in the design of the second generation STC discussed below.

Preliminary bench-scale experiments with simulated flue gas, at various temperatures, containing varying amounts of SO_2, NO, NO_2, and HCl have been run with promising results. In fact, presence of these compounds enhanced performance of the STC (Pitoniak, 2004).

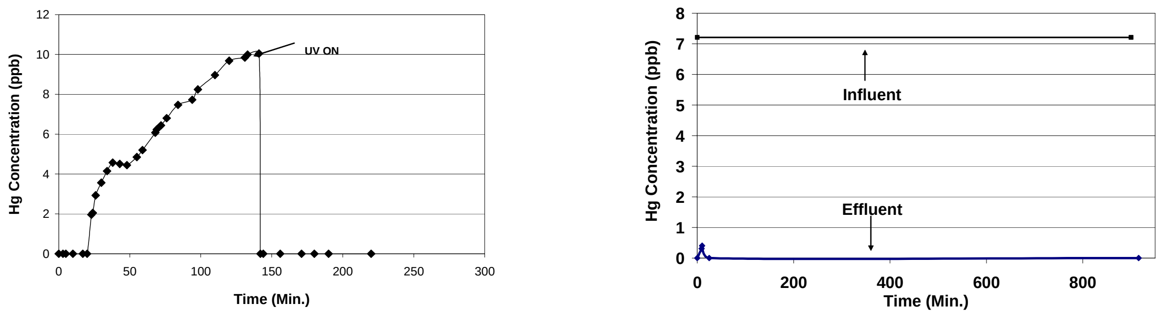

Figure 1: (a) (left) Mercury removal by adsorption alone, followed by adsorption and oxidation. (b) (right) Mercury removal via simultaneous adsorption and oxidation. (Temperature was 175 °C.) (Note: 0 to 12 ppb = 0 to 100 µg/m^3, 0 to 8 ppb = 0 to 67 µg/m^3).

Key lessons learned from these bench-scale studies were that a residence time of 0.1 s is satisfactory for capture efficiencies of 99%, ***the STC technology works equally well at flue gas temperatures*** compared to ambient temperatures, and 254 nm lamps are preferred versus 365 nm lamps. (All data not shown to conserve writing space.)

Formation of Mazyck Technology Solutions, LLC (MTS)

Intrigued by the bench scale testing, Sol-gel Solutions, LLC licensed the technology from UF. Since Sol-gel Solutions primarily consisted of research engineers (i.e., they lacked experience with the installation of equipment in industrial settings), they partnered with one of the country's most successful engineering, procurement, and construction firms (Ford, Bacon, and Davis, LLC) to provide assistance with scale-up of the technology and field installation. Sol-gel Solutions and FBD are each 50% owners and decided to name their joint venture Mazyck Technology Solutions, LLC (MTS), after Dr. Mazyck.

Pilot Study at a Chlor-Alkali Plant

During the formation of MTS, prior to the coming-together of Sol-gel and FBD, pilot studies of the STC technology began in the chlor-alkali industry focusing on the recovery of mercury from caustic exhaust/end-box treatment at Olin Chlor-Alkali Products (Augusta, Georgia). MSI was called upon to assist with the design and construction of the pilot reactor. It contained two chambers (A and B), which could be run independently of each other. Two Teflon-coated 254 nm UV lamps were positioned vertically down the center of each chamber. The total volume of each chamber (excluding the space occupied by UV lamps) was approximately 0.2 ft^3. The 254 nm lamps were positioned such that no STC pellet was greater than 1” from UV light.

The temperature of the caustic exhaust, containing elemental mercury and saturated with water vapor, was between 6 and 8 ºC. The temperature was raised to roughly 50 ºC (inlet temperature to pilot reactor) after passing through two blowers in series used to push the exhaust through the reactor.

Various trials were run with flow rates varying between 1.8 and 6.8 acfm. Although the influent mercury concentrations were highly variable (between 400 and 1600 micrograms/ft^3) (1710 to 6837 ppb), the reactor was able to handle these fluctuations and achieve greater than 95% removal for extended periods of time, as shown in Figure 2. At the end of one run, pellets were removed from Chamber A and regenerated by soaking in a concentrated HCl bath for one hour, followed by a water rinse and overnight drying. The regenerated pellets were then placed into Chamber B. The experiment was run until breakthrough (21-33 days). Figure 2 shows that prior to breakthrough the regenerated pellets performed similarly to virgin pellets, indicating that regeneration had no negative effect on pellet performance. Prior to regeneration, a mass balance on the pilot unit was performed and Hg loading was approximately **300 mg/g.**

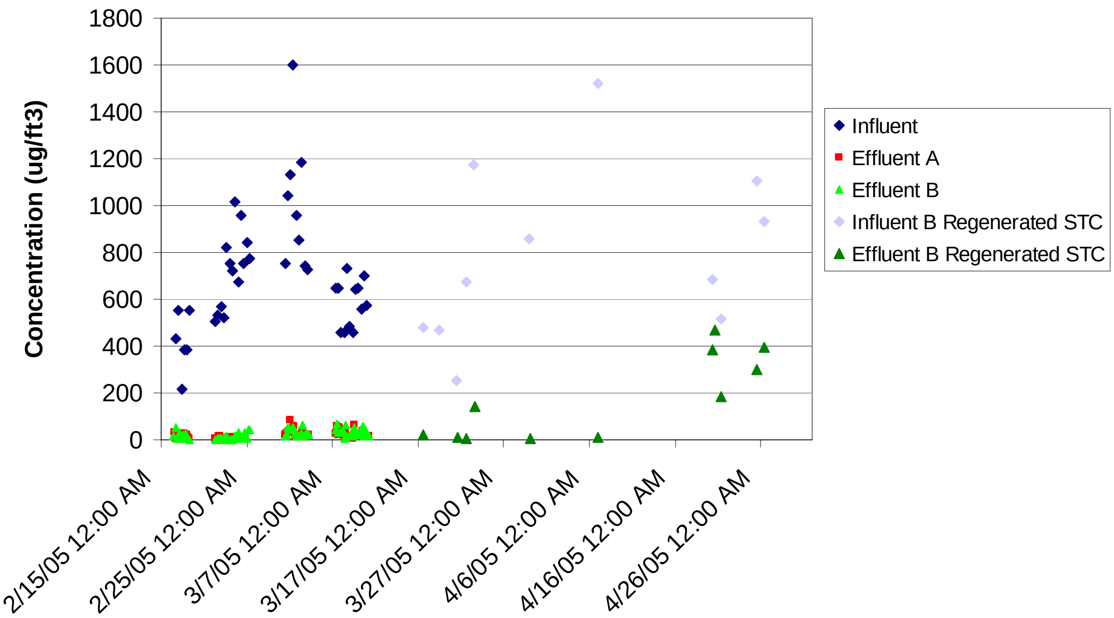

Figure 2: Results from pilot study at Olin Chlor-Alkali. (Note: 0 to 1800 μg/ft^3 = 0 to 7692 ppb).

Due to the success of the pilot study, design and fabrication of a full-scale unit (Mercury Recovery Unit, MRU) for Olin is in progress and scheduled to be completed by November 11, 2005. After the first month of successful demonstration, Olin will proceed with the purchase of several additional MRUs for recovering Hg from different air streams at two of their facilities. All nine of the chlor-alkali facilities in the US have expressed interest in the technology and pilot tests are currently planned for two additional sites. A contract for manufacturing the STC for these full-scale units is in place with Advanced Catalyst Systems, LLC (ACS). Furthermore, ACS will provide consulting support on this project and hereafter (Letter of support included in appendix).

PROJECT DESCRIPTION

Concept

The pilot testing in the chlor-alkali industry provided some valuable lessons that we can apply to better design a system for lignite-fired power plants. Indeed, the concentration of Hg in the chlor-alkali exhaust is far greater than what is present at lignite-fired power plants, but as was shown in Figures 1a and 1b, the technology worked just as well for typical flue-gas Hg concentrations as it did for the higher chlor-alkali concentrations, if not better.

Based on our design values, the approximate size of a MRU for a 100 MWe lignite-fired power plant would be 612 ft^3, and would require hundreds of UV bulbs if we simply scaled the chlor-alkali reactor (1200 cfm) up to meet the much larger flow rates. However, based on the fact that only the very outer edge of the STC was used for Hg capture, as verified via visual inspections and SEM images, we are herein proposing to use coated chemical packing material in a fixed bed. An example of such packing material is shown in Figure 3. Since our silica-titania composites formula begins as a liquid sol, we can coat the packing material via a sol-gel process, with which we have years of experience. We will call the packing Silica-Titania Coated Packing (STCP). As Figure 3 indicates, the packing material, which individually are approximately the size of a ping-pong ball, has a large void space. Thus, UV penetration through the STCP will be much greater than what it was for the STC pellets; hence drastically reducing the number of UV lamps that would be required. Furthermore, this approach will ensure that pressure drop is minimal. As an aside, we have compared commercially-available titania and titania synthesized from various precursors to our STC formula, and have proven numerous times that the STC formula is much more effective for Hg capture.

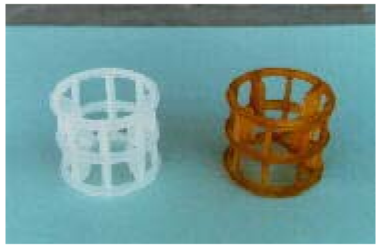

Figure 3: Examples of packing material (http://www.csubak.edu/~mevans/stowe/as.htm).

The Appendix section includes Figure A-1, which illustrates a confidential conceptual plan for an MRU suitable for a nominal 100 MWe lignite-fired power plant, based on the following assumptions (Table 1):

Table 1: Assumptions for conceptual plan for MRU for lignite-fired power plant.

POWER OUTPUT	100 MWe
Heat rate	10,500 BTU/KWh
Lignite energy content	6,950 BTU/lb
Gas flow rate	425,000 acfm
Residence time	0.1 s
Bed dimensions	10 ft wide x 7.5 ft deep x 25 ft high

Methodology

As expressed before, the program goal is to design, fabricate, and test a pilot-scale system to demonstrate the efficiency of STCP in removing mercury from flue gas that will be generated by burning lignite at MSI's Combustion Test Facility. We propose to complete this program in 18 months. The first 3 to 6 months will be employed in the optimization of the STCP for this application. The goal will be to achieve low cost and high mercury capture simultaneously.

During the final 12 to 15 months, fieldwork will be conducted at MSI's Combustion Test Facility to study the effectiveness of the STCP in removing mercury from flue gas.

Refinement of the chemical packing material (e.g., selection of geometry and material (e.g., thermoplastic, metal, etc.) and bench testing will proceed at MTS. Dr. David Mazyck will provide oversight of this work, provide characterization analyses (e.g., SEM, TEM, XRD, TGA, BET, etc.) at the University of Florida (UF), assist with the design of the pilot reactor and experiments, and oversee the QA/QC program.

Work Breakdown Structure

The work for this project can be broken down into the following Tasks.

Task 1.0 PROGRAM MANAGEMENT, COORDINATION & COMMUNICATION

Project management activities, including: Coordination, communication, scheduling, data acquisition management, budget and project reporting.

Task 2.0 STCP DESIGN, CHARACTERIZATION & ANALYSES

Optimization of STCP by introducing different manufacturing methods and/or raw materials (i.e., chemical packing) for purposes of laboratory analyses to quantify key parameters, such as surface area, pore size, loading of titania, durability, coating strategy, and preferred chemical packing (e.g., percent void space and construction material). The optimization period will make use of the consulting services of ACS. Analyses will be performed at MTS and UF. In conjunction with the above analyses, another set of tests will be conducted to quantify UV radiation intensities through a STCP bed by use of a unique test system collaboratively developed by MTS and MSI. The system includes a series of varying-sized test "boxes" fabricated with Alzack aluminum, which reflects UV light. A 254 nm UV bulb will be center-mounted within a box, and the box will be filled with STCP. By use of a UV radiometer "looking" through various "port-holes" on the box sides, intensity of UV radiation passing through the STCP bed can be measured. This will be repeated with the boxes of various sizes in order to correlate intensity vs. lamp distance (i.e., spacing of UV lamps in pilot reactor) in the packed bed with STCP.

Task 3.0 ACQUISITION OF TEST LIGNITE

Identification, procurement, and characterization of lignite for tests purposes. The test lignite will be analyzed for chemical and physical characteristics including: (a) ultimate analyses, (b) proximate analyses, (c) ash composition, with emphasis on mercury content, (d) Hardgrove Index, and (e) ash fusion temperatures.

Task 4.0 MANUFACTURING OF COMPOSITE MATERIALS

Manufacture of sufficient quantities of STCP at MTS, based on appropriate "recipes" and procedures for manufacturing defined by MTS with consulting from Advanced Catalyst Systems.

Task 5.0 MODIFICATIONS TO EXISTING REACTOR

MSI has developed a pilot scale UV Photocatalytic Fixed Bed Reactor as part of its contract responsibilities with Dr. Mazyck and UF under USDOE Contract DE-FC36-03ID14437. The project is titled: ***"An Innovative Titania-Activated Carbon System for Removal of VOC's & HAP's from Pulp, Paper, Paperboard Mills, and Wood Products Facilities with In-Situ Regeneration Capabilities".*** The reactor was developed for testing the recovery of methanol from an industrial gas stream; however, it can be modified into a small-scale Mercury Recovery Unit (MRU). Upon modification, utilizing the analysis results developed by MTS and UF in Task 2.0, preliminary mercury recovery efficiencies and "fine-tuning" of system criteria can be carried out by MSI at its Combustion Test Facility. Figure 4 illustrates key components of the existing reactor. Modifications would primarily include a reorientation of UV bulbs to correspond to bulb spacing developed by MTS and UF in Task No. 2. Likewise, inlet and outlet duct sizing must be increased, primarily to accommodate a higher gas flow for mercury recovery, due to a shorter required residence time for mercury, as compared to methanol.

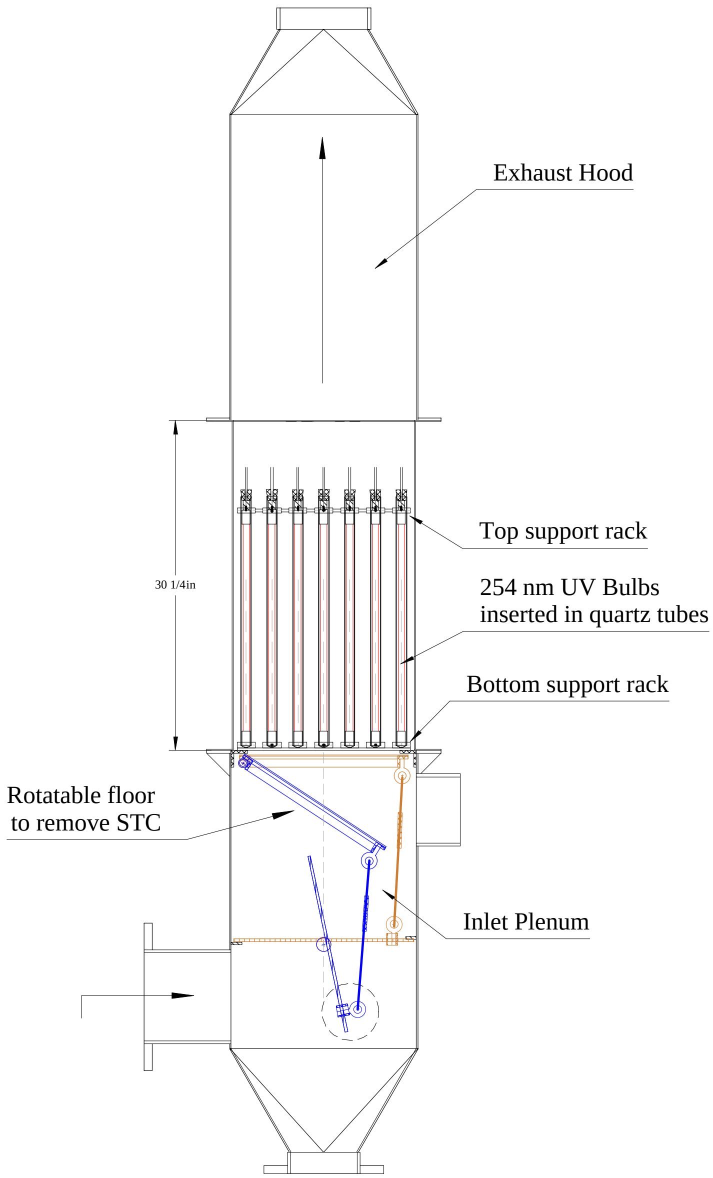

Figure 4: Schematic of existing reactor chamber.

<u>**Task 6.0** MERCURY RECOVERY TESTING WITH EXISTING REACTOR</u>

After completing modifications to the existing reactor, a test program will be conducted to determine the efficiency of mercury removal in order to optimize key engineering design criteria and parameters. Figure 5 illustrates a conceptual plan of the proposed test program.

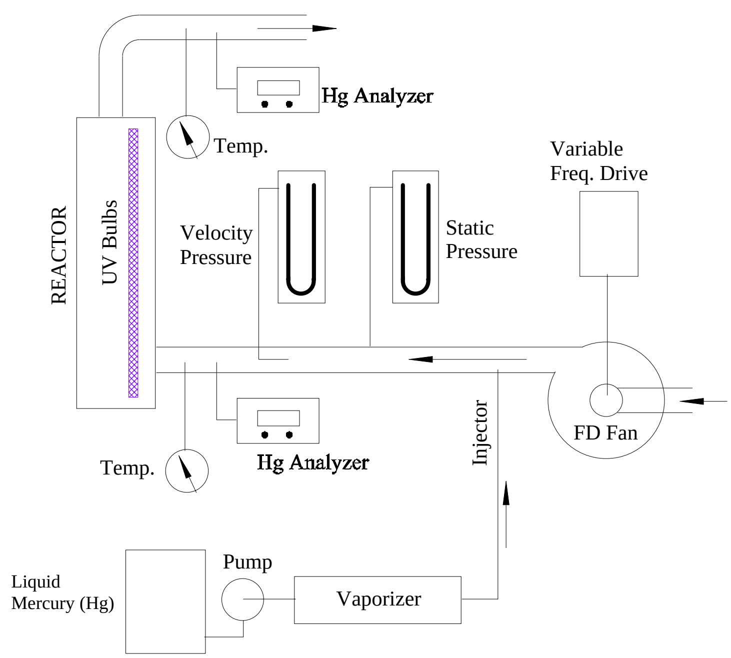

Figure 5: Conceptual plan of test with existing modified reactor.

In addition to the modified reactor described above, MSI possesses in-house equipment components necessary to complete a comprehensive test program, including: (a) forced draft (FD) fan, equipped with a variable frequency drive to supply a controlled airflow to the reactor, (b) connecting ducts mounted with pitot tubes linked with manometers to measure static and velocity pressures between the FD fan and reactor, and (c) thermocouples to monitor temperatures on the reactor’s inlet and outlet for mass flow corrections. To simulate a surrogate gas flow containing mercury, MSI will fabricate an electric heat exchanger capable of inputting an accurately measured liquid mercury flow and heating it to a temperature greater than its boiling point (i.e., higher than 360°C). The resulting mercury vapor will then be injected into the inlet gas duct upstream of the reactor, thus creating a controlled mercury concentration. MSI developed a similar vaporizer system for methanol, which was successfully utilized during tests it conducted under the previously mentioned USDOE Contract DE-FC36-03ID14437. MSI has developed a mass-flow computer program, which inputs designated test program criteria that will be used to ensure the proper mix ratio of mercury to airflow entering the reactor. Based on its results, a variable speed, positive displacement pump will be calibrated prior to testing to ensure the proper quantity of mercury is injected into the air stream to produce the desired mercury concentration (10 $\mu g/m^3$ = 1.19 ppb). As a double check, the liquid mercury container will be located on a highly accurate weigh scale. During testing, the rate of weight reduction of the mix will be measured over time to confirm that the proper injection rate is being achieved. The test reactor will be filled with STCP material, as developed in previous tasks, at sufficient quantities to achieve the desired residence time (0.1 second).

The test protocol will include: (a) inlet and outlet **TOTAL** mercury concentrations measured using a Lumex Portable Mercury Vapor Analyzer Model RA-915 with MiniCEM and validated (e.g., once per hour) via the Ontario Hydro Method for QA/QC purposes for the duration of 8-hour tests, (b) airflows controlled using variable frequency drive on the FD fan supplying air to the reactor, (c) airflows measured using pitot tubes linked with manometers to measure static and velocity pressures in the connecting duct between the FD fan and reactor, (d). thermocouple to monitor temperatures on the inlet and outlet for mass flow corrections, (e) variable speed, positive displacement pump calibrated to ensure the proper quantity of mercury vapor injection into the air stream, and (f) high accuracy scale to monitor over time the weight distribution of mercury input to the system. MSI’s in-house Allen Bradley SLC-5/04 controller can be utilized during testing to automatically control mass-flows and test related equipment in response to varying conditions (i.e., temperature, relative humidity, barometric pressure, monitored static and velocity pressures, etc.) and provide data logging acquisition of necessary test data.

Task 7.0 DESIGN AND FABRICATION OF A NEW TEST-MRU FOR STCP TESTING

Based on results of tests and analyses acquired in previous tasks, the objective of this task will be the design and fabrication of a new Test-MRU parametrically-scaled after the conceptual plan of the MRU indicated in Figure A-1. Its capacity size will be "matched" with the output gas-flow capacity of MSI's in-house Babcock & Wilcox Model FMD-9-34 "D"-Pattern test boiler (i.e., 15,000 pph-steam @ 150 ºF/SAT). Based on the same system criteria indicated in Table 1, dimensions of the Test-MRU would approximate 2 ft wide x 2 ft deep x 5 ft high. The lignite energy content will approximate 7,000 BTU/lb and the gas flow rate will approximate 6500 acfm. A Test-MRU with these criteria is indicated in Figure A-2 in the Appendix (confidential information). This task will also involve procurement of off-the-shelf equipment and design and fabrication of system components currently not available at MSI's Test Facility, but necessary to complete the program objectives for STCP testing (e.g., primarily ducting to incorporate new Test-MRU, dampers, etc.).

Task 8.0 EQUIPMENT INSTALLATION

Installation of the new Test-MRU and all equipment for the STCP test applications and interface with existing system test components at MSI's Test Facility, including data acquisition and control systems. Other than the Test-MRU, MSI possesses mostly all other necessary equipment to complete the test program described below.

Task 9.0 MERCURY RECOVERY TESTING WITH NEW TEST-MRU

The objective of this Task will be to conduct a test program consisting of ten boiler runs to determine the efficiency of mercury removal by STCP by directing the flue gas flow from actual combustion of the lignite identified in Task 3.0. Existing MSI in-house systems and components available for use in testing the Test-MRU program include: (a) lignite storage and handling, (b) variable speed screw conveyor to feed lignite to MSI micronization mill, (c) MSI Model 24-C micronization mill, (d) Babcock & Wilcox Model FMD-9-34 "D"-Pattern test boiler, (e) B&W XCL Low-NO_x burner, modified for micronized lignite firing, (f) all necessary air emission control systems as authorized by the State of Maryland, (g) "catch-system" for acquiring ash samples during testing, (h) all necessary FD and ID fans, equipped with variable speed controls, (i) complete array of monitoring and control systems to measure and control all parameters necessary for a complete mass-energy input/output analyses, (j) Allen Bradley SLC-5/04 controller, with capabilities of automatically controlling combustion and test related equipment and data logging acquisition of necessary test data, (k) proprietary MSI computer model that simulates boiler operations by quantifying and analyzing all mass-energy input and output parameters, which can be integrated into, and with, the SLC-5/04 control system, and (l) LAND Series II Combustion Analyzer System to monitor air emissions, including Temperature, CO, CO_2, O_2, SO_x, and NO_x. Figure A-3 in the Appendix illustrates a conceptual diagram of the proposed test plan with the Test-MRU. The test protocol described in Task 6.0 will likewise be utilized in this task. All key operational and performance test parameters will be monitored and data logged.

Task 10.0 TEST SAMPLE ANALYSES

Before, during and after all test programs, samples of STCP materials and ash, will be acquired and sent to MTS and UF for laboratory analyses and characterization.

Task 11.0 COMPILATION AND ASSESSMENT OF ALL ACQUIRED DATA

All acquired data will be compiled, analyzed, and condensed into a series of charts and graphs that "tell the story" of the various test procedures, results and conclusions. Likewise, text will discuss potential impacts of the technology on related balance of power plant issues. All results, illustrations, diagrams, procedures, and conclusions will be integrated into various periodic and final reports.

Task 12.0 VERIFICATION OF STCP PERFORMANCE

Utilization of MTS's lab-scale test bed with simulated flue gas compositions to test materials synthesized at MTS for mercury capture efficiency, utilizing MTS's test bed to simulate various constituents of flue gas. Verification and evaluation of data during the test program, and assistance with final design, troubleshooting, and implementation. Concurrent with test program, MTS will continue to focus on test results developed at MSI, and assess methodologies to improve efficiencies of the sorbent. Significant efforts will be directed to characterizing full-scale methods to produce the STCP via the most economical method.

Task 13.0 COMMERCIALIZATION POTENTIAL

Compilation of results and conclusions of the various test results, cost estimates, system performance, and institutional and environmental issues learned during the implementation of the program. This information will be expanded into a discussion of the commercialization potential of utilizing STCP, in context of the population and profile of the U.S. lignite-fired utility industry.

Task 14.0 REPORTS

Preparation of all required interim, special, and final reports.

Facilities and Resources

The participants of the proposed program include: (1) **Mazyck Technology Solutions, LLC (MTS),** (2) **MicroEnergy Systems, Inc. (MSI),** and (3) the **University of Florida (UF).** Dr. Mazyck will serve as the program principal investigator and will work very closely with Richard Sheahan, VP of MSI during the test program. Besides the Olin pilot study, Dr. Mazyck and MSI have been successful on various other projects including a $2.1 M DOE-AFPA project that focuses on control of VOCs/HAPs from pulp and paper mills. This project is scheduled to be completed in 2006 and results to date were recently presented at the AWMA 2005 conference (Stokke et al., 2005). MSI will take the lead on fabricating the Test-MRU (Figure A-2) and conducting the pilot studies via their state-of-the-art Combustion Test Facility.

MicroEnergy Systems, Inc. (MSI)

MicroEnergy Systems, Inc., established in 1986, is the world's leader in the development of micronized coal technology and systems. Likewise, since 1997, it has been actively involved in the development and testing of specialty activated carbon products, and is noted for its unprecedented advanced "first-of-a-kind" and commercial energy and environmental systems.

A recent example of MSI's activities associated with commercial development of an innovative "first-of-a-kind" environmental program, beginning from a conceptual plan, through engineering design, prototype development, testing and demonstration, and finally to commercial application relates to a program completed for the U.S. Army Chemical Demilitarization Program under contract to Bechtel and Raytheon. A byproduct of the Army's program, is production of a highly contaminated activated carbon which is utilized as part of an elaborate air pollution control filter system. After extensive evaluation, the Army concluded that MSI’s micronization combustion system was the best solution to dispose of the contaminated carbon. During system development and testing, the MSI combustion system demonstrated an unprecedented carbon combustion conversion efficiency of 99.7 percent.

In addition, MSI has participated in several programs involving USDOE, including: (1) Innovative Titania-Activated Carbon System for Removal of VOC's & HAP's from Pulp, Paper, Paperboard Mills, and Wood Products Facilities with In-Situ Regeneration Capabilities in collaboration with Dr. Mazyck at UF, (2) Krackow (Poland) Clean Coal Program, (3) Low-NOx micronized coal burner development at Penn State University Energy Technology Center, and (4) Diesel-Engine micronized coal combined-cycle demonstration – White Sulfur Springs, WV.

MSI’s Combustion Test Facility is licensed by the State of Maryland to conduct research and development activities associated with carbon based fuels and materials. It is one, of a “handful” of such facilities in the United States, and includes 14,000 sq. ft. of work, test and development area adjacent to its two-story office and administration space.

In addition to a well equipped machine shop, it also houses an array of existing test and development equipment that is available for use in the proposed program, including:

- Babcock & Wilcox Model FMD-9-34 “D”-Pattern test boiler, capable of coal, oil and gas firing, including overfire air capabilities for Low-NOx applications.
- Complete array of conventional and specialty burners, including a B&W XCL Low-NOx burner modified for micronized coal.
- 3 ft. diameter x 20 ft. long <u>externally</u> heated kiln for commercial-scale production of specialty activated carbon.
- 2.5 ft. diameter x 4 ft. long <u>externally</u> heated research kiln for prototype manufacturing and/or testing of specialty activated carbon.
- Various sized proprietary and patented MSI coal micronization mills.

- Combustion air fans, solid material handling and storage facilities and equipment.
- Baghouse air emission control system.
- Storage and delivery systems for test support and auxiliary fuels, including: propane, oil, and natural gas.
- Allen Bradley SLC-5/04 controller, with capabilities of: (a) automatically controlling combustion and test related equipment and (b) data logging acquisition of necessary test data.
- Several proprietary MSI computer model's that simulate boiler and kiln operations by quantifying and analyzing all mass-energy input and output parameters, which can be integrated into, and with, the SLC-5/04 control system.
- LAND Series II Combustion Analyzer System to monitor air emissions, including Temperature, CO, CO_2, O_2, SO_x, and NO_x.
- Variety of other test and simulation equipment devices.

More can be learned about MSI at its website: www.microenergysystems.com

Mazyck Technology Solutions, LLC (MTS)

Mazyck Technology Solutions, LLC (MTS) is a research company derived from Sol-gel Technologies, LLC. MTS specializes in sorbent technologies, particularly Silica-Titania Composites (STC), that has been licensed from UF for commercial development. In its own state-of-the-art laboratory in Gainesville, Florida, product research and development is carried out for a variety of applications. During the research program, MTS will serve as the rapid technology development team primarily charged with synthesis of the sorbent for mercury capture. The key technology research team at MTS consists of Dr. David W. Mazyck, Jennifer M. Stokke, and Dr. Anna I. Casasús, along with two laboratory technicians. Their résumés are included in the Qualifications section.

MTS will focus on the synthesis of the STCP, verification of UV irradiation patterns designed by Dr. Mazyck and his team from UF in their Alzack test boxes, bench-scale testing, and provide assistance with field testing at MSI. The state-of-the-art laboratory at MTS was designed especially for testing of sorbent technologies. Its analytical laboratory (500 ft^2) is equipped with an OhioLumex RA-915 Zeeman Mercury Spectrometer, a Hydra AA Atomic Adsorption Spectrometer, a complete test stand for mercury removal from gases, and a fume hood. In the sorbent manufacturing section of the facility (500 ft^2), are 4 programmable Yamato DKN810 ovens (10 ft^3) for STCP manufacturing and various other appurtenances for sorbent synthesis. MTS will soon purchase an OhioLumex MiniCEM system for continuous total mercury analysis.

University of Florida (UF)

The University of Florida will primarily focus on the modeling of UV irradiation, composite selection and coating, and analysis of STCP (e.g., SEM, TEM, BET surface area, etc.)

The University of Florida maintains one of the nation's leading sorbent research facilities under the direction of Dr. David W. Mazyck. Dr. Mazyck's research focuses on the purification of air and water via adsorption, photocatalysis, and/or a combination of the two for maintaining public health. Fundamentals of adsorption are used to tailor adsorbents through the optimization of physical (e.g., pore size distribution) and chemical (e.g., electron density) properties. More specifically, the surface chemistry of carbonaceous (e.g., activated carbon) and silica adsorbents are studied to better understand the adsorbent-adsorbate interface. The robustness of these adsorbents is enhanced through the incorporation of photocatalysts (e.g., TiO_2) to either improve remediation efficiency/capture or to accomplish in-situ regeneration.

In five years, Dr. Mazyck has secured more than $3.6 M is extramural grants and contracts including funding from DOE, NSF, EPA, and NASA. Several of these projects have included industrial partners; including MSI. Since joining the University of Florida in 2000, Dr. Mazyck has published 17 journal articles, more than 10 conference proceedings, has one patent issued and five pending, and has graduated or is advising 8 Ph.D. candidates, 20 MS students, and more than 20 undergraduates.

David Mazyck's research facilities include three 400-square foot laboratories equipped with common laboratory equipment (e.g. analytical balances, pH meters, programmable ovens, UV test stands, etc.), a Perkin Elmer Clarus GC FID/PID, a Zeeman Hg analyzer, and Quantachrome's NOVA 2200E. In addition, data is recorded and analyzed via personal computers. Dr. Mazyck's lab also contains a $20,000 pilot scale fluidized bed intended for creating particles with various properties (e.g., change in pore size distribution, surface chemistry, etc.). This pilot scale fluidized bed in encased in a 4' x 8' x 10' tempered glass closet under continuous vacuum. The lab is also equipped with a fume hood. Dr. Mazyck's additional analytical equipment is continuously maintained at the NSF funded Particle Science Center (less than 50 yards from his lab). For example, Quantachrome's Autosorb 1 with Monte Carlo simulation and DFT package for measuring surface area, pore size distribution, chemisorption capabilities, and a mass-spectroscopy for off gas analysis is used for quality assurance and control for silica manufacturing.

The Analytical Support Laboratory (ASL) operated by the Department of Environmental Engineering Sciences has two major tasks: (1) the training of undergraduate and graduate students in the use of environmental analytical methods and techniques, and (2) the analysis of samples in support of departmental research efforts. Equipment is available at ASL for analyzing organic and inorganic compounds in air and water.

The Major Analytical Instrumentation Center (MAIC) provides a wide range of modern analytical instrumentation for materials analysis, including Auger electron spectrometry (AES), electron probe microanalysis (EPMA), Fourier transform infrared spectroscopy (FTIR), electron microscopy (HREM, SEM, TEM), X-ray diffraction (HRXRD, XRD), X-ray photoelectron spectroscopy (XPS, ESCA), inductively coupled plasma (ICP), and scanning probe microscopy (SPM).

The NSF funded Engineering Research Center for Particle Science and Technology (ERC) houses a test bed and six analytical laboratories. It is equipped with state-of-the-art instrumentation for particle size and shape measurements, density, surface area, and porosity, surface charge and surface force measurements, surface and bulk chemical composition, microstructural characterization, particle processing and forming equipment and mechanical properties. Dr. Mazyck is a member of the ERC.

Advanced Catalyst Systems, LLC (ACS) - consultant

Dr. Larry Campbell, President and CEO of Advanced Catalyst Systems, LLC (ACS) in Maryville, Tennessee will act as consultant to MTS for the optimization of the design of STCP for this application. Advanced Catalyst Systems has been involved in the successful development and commercialization of technology for control of pollution and chemical applications. ACS offers more than 100 man-years of catalyst expertise and includes Ph.D. level chemists as well as highly skilled laboratory supervisors and technicians. The 29 US Patents held by ACS are further testament to the accomplishments of the organization and its team members. Their catalyst research and testing group also offers considerable field service experience, catalyst research and testing, and fabrication services.

Project Environmental and Economic Impacts

During the course of the project, each party will take the necessary precautions to avoid any deleterious environmental impacts. As was previously discussed, MSI possesses all the necessary air emission control systems as authorized by the State of Maryland. All parties have years of experience with coal-combustion pilot studies, and environmental safety is paramount to every project. At the conclusion of the program, Hg-laden sorbents will be crushed and then properly disposed of. Proper disposal and routine inspections are customary for UF and MTS. The amount of waste generated will be kept to a minimum. Due to the low concentration of mercury (i.e., low ppb) and the high capacity of the STCP, we do not anticipate the generation of a large amount of STCP containing mercury. MTS and MSI will cover all costs of disposal, which are expected to be very minimal. In addition to the fact that neither the environmental or economic impacts are considered to be significant during the testing program, the success of the research team in acquiring funding from a variety of sources over the past five years have allowed us to reduce the funding requirement to launch this program.

Technology Impact

The technology proposed herein for mercury removal from lignite-fired power plants has enormous potential and could significantly contribute to the reduction of mercury emissions. The efficiency of currently available technologies varies widely depending on coal type and plant configuration. Different types of coal produce different amounts of mercury, sulfur and chlorine, for example. Lignite, in particular, contains levels of mercury comparable to those of other coals, but lower levels of chlorine and higher concentrations of calcium and sodium. This causes much higher concentrations of elemental mercury in combustion emissions. Elemental mercury is less soluble and more difficult to remove than oxidized mercury. The Silica-Titania Composites have proven to be highly effective regardless of influent mercury concentration or speciation. STC have also been proven effective in mercury removal from wastewater with sulfur concentrations as high as 5 ppm. Therefore, we do not envision a problem with sulfur poisoning on our material. High levels of chlorine usually enhance mercury capture, since mercuric chloride is more readily removed than elemental mercury. Low levels of chlorine would not be an issue, since chlorine is not necessary for oxidation of elemental mercury to take place in our system. Presence of NO and NO_2 can enhance or interfere with mercury oxidation depending on their concentration in the flue gas. However, they are not expected to interfere with the MTS technology. We fully recognize that constituents present in the flue gas may decrease the adsorption capacity for Hg, but based on the pilot study in the chlor-alkali facility and the proposed design herein, the expected lifetime of the sorbent could be as long as 60 years. Even if the adsorption capacity were decreased by one order of magnitude, the life expectancy is 6 years. Based on this range, landfilling the sorbent proved to be more viable than regeneration. With this said, regeneration is still an option if for any reason the lifetime of the sorbent is diminished. As stated in the Background section, bench-scale experiments with simulated flue gas, at various temperatures, containing varying amounts of SO_2, NO, NO_2, and HCl have been run, and the results were promising. In fact, presence of these compounds enhanced performance of the STC (Pitoniak, 2004). Because of these reasons, the characteristics of lignite are not expected to affect the system's performance. The MTS technology can be easily tailored to fit into any plant configuration located between the plant's existing baghouse or electrostatic precipitator outlet and its inlet to the stack, and can be used in conjunction with any existing air-pollution control devices. Another advantage of the technology is that its pressure drop requirement is low.

As expressed in the Concept section, for this application we will use a modified version of the STC, which we will call STCP. This modification will require coating packing material with silica-titania sol. The STCP will have the same oxidation and adsorption benefits of the

STC, with lower pressure drop and lower UV requirements. Besides the technological advantages of the STCP, there are economical advantages as will be described below. The factors that will contribute to the cost of using the STCP for mercury removal are: (a) Equipment capital cost, (b) Cost of UV lights, (c) Cost of coated packing material, (d) Electricity Cost, and (e) Cost of Landfilling.

Cost estimates for implementing a MRU in a 100 MWe lignite-fired power plant were developed based on reasonable assumptions. Table 2 indicates capital costs associated with: (a) Fabricating a MRU and (b) Sufficient quantities of STCP to "fill" the MRU. Table 3 presents estimates of mercury recovery based on an expected 90 percent removal efficiency with lignite emitting mercury concentrations of 10, 20, or 30 $\mu g/m^3$ (For a higher mercury influent concentration, our 20-year life cycle cost analysis will result in an even lower cost per pound of mercury removed, since the capital cost will remain the same and the annual amount of mercury removed will be higher). For comparative purposes, the value for 70 percent removal is also indicated. Table 4 shows results of a 20-year life cycle cost analysis for all three mercury concentrations, considering all capital and operating costs, coupled with reasonable assumptions for escalation and discount rates.

Table 2: Cost estimate for 100 MWe Lignite-Fired Power Plant.

A. EQUIPMENT CAPITAL COST		**SOURCE**
Materials		
Stainless steel housing material	$ 20,000	McMasters
Structural supports / ribbing / brackets, etc.	$ 20,000	MSI
Valving, dampers, ducting, mechanical components	$ 50,000	MSI
170 - 254 nm - 75 watt - UV bulbs & ballasts & quartz tube housings	$ 34,000	bulbs.com
Insulation / lagging	$ 30,000	MSI
Control system	$ 40,000	MSI

Subtotal - materials	$ 194,000	
Engineering - Contingency @ 20%	$ 38,800	

Subtotal - materials / engineering	$ 232,800	
Fabrication @ 50% of materials	$ 97,000	

TOTAL MRU FABRICATED COST	**$ 329,800**	
B. COST of STCP		
Packing material w/. Silica-Gel+ TiO2 applied @ $40 / lb (density = 6.2 lb / ft3)	**$ 465,000**	

Table 3: Estimated annual mercury removed.

Assumed Mercury Removal	**Percent**	**70%**			**90%**		
Assumed power output:	MWe / hr		100			100	
Heat rate:	BTU / Kwh		10500			10500	
Coal energy content:	BTU / lb		6950			6950	
Gas flow rate:	ACFM		425000			425000	
Annual power plant capacity	hours / yr		8000			8000	
Mercury concentration	microgram / m3	**10**	**20**	**30**	**10**	**20**	**30**
ANNUAL MERCURY REMOVAL	**lbs / yr**	**18.4**	**36.8**	**55.2**	**23.6**	**47.3**	**70.9**

Table 4: Twenty-year life cycle cost analysis for 100 MWe Lignite-Fired Power Plant. (a) (this page) Total annual cost, (b) (next page) Unit cost of mercury removed.

(a)

YEAR NO.	**2005**		**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**
Operating Year No.			**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
	2005 Dollars	**Annual Escalation Factor**	**$ x 1,000**																			
ITEM																						
CAPITAL EQUIPMENT																						
Fabricated MRU	$ 329,800																					
MRU Installation @ 40% fabricated cost)	131920																					
Foundations - MRU	50000																					
Modifications to existing ID fan & ductwork	75000																					
Integrate controls w/. Existing power plant system	40000																					
SUBTOTAL - CAPITAL COST	**$ 626,720**	4.0%	$ 677.9																			
OPERATING & MAINTENANCE	**2005 Dollars**		<< ---------- **All dollars x 1,000** ---------- >>																			
STCP	$ 465,000	3.0%	$ 493.3						606.7							746.2						
Install STCP	10,000	3.5%							13.6							17.3						
Pulverize & landfill "spent" STCP (@ 5,000 per ton - landfill + $2,000 ton-pulverize)	42,000	5.0%							65.2							91.7						
Power (parasitic to plant, valued @ $0.045 / Kwh) 170 - 75 watt bulbs @ 8,000 hours / year	4,590	6.0%	$ 5.2	5.5	5.8	6.1	6.5	6.9	7.3	7.8	8.2	8.7	9.2	9.8	10.4	11.0	11.7	12.4	13.1	13.9	14.7	15.6
Additional power consumption - ID fan @ assumed delta = 175 HP	47,250	6.0%	$ 53.1	56.3	59.7	63.2	67.0	71.0	75.3	79.8	84.6	89.7	95.1	100.8	106.8	113.2	120.0	127.2	134.9	143.0	151.5	160.6
General O&M (@ 4% of installed MRU cost)	25,069	3.5%	$ 26.9	27.8	28.8	29.8	30.8	31.9	33.0	34.2	35.4	36.6	37.9	39.2	40.6	42.0	43.5	45.0	46.6	48.2	49.9	51.6
			------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------
TOTAL ANNUAL COSTS			1,934.1	89.5	94.2	99.1	104.4	109.8	801.1	121.7	128.2	135.0	142.2	149.8	157.8	1,021.4	175.2	184.6	194.5	205.0	216.1	227.9
Discounted Annual Costs	**Discount Rate =**	**3.0%**	1,819.8	81.7	83.4	85.1	86.9	88.8	627.9	92.6	94.5	96.6	98.7	100.8	103.0	646.8	107.6	110.0	112.4	114.9	117.5	120.2

(b)

Assumed Mercury Removal	70%			90%		
Summated Discounted Annual Costs Over 20 Year Period		$ 4,789,310			$ 4,789,310	
Mercury Concentration (ug/m3)	10	20	30	10	20	30
Annual mercury removal (lb / yr)	18.4	36.8	55.2	23.6	47.3	70.9
Mercury Removal - 20 Year Period (lb / 20 yr)	368	736	1,104	472	946	1,418
Unit cost of mercury removed ($ / lb)	$ 13,014	$ 6,507	$ 4,338	$ 10,147	$ 5,063	$ 3,378

As presented in Table 4 b, the cost of mercury removal per pound of mercury removed is below the average baseline cost of $60,000/lb (based on powdered activated carbon injection costs) (DOE, 2005). If the power plant industry has a chance to test the MTS technology, the industry will quickly embrace the STC technology when it witnesses the superior performance and cost benefit.

STANDARDS OF SUCCESS

We are very confident that the proposed project will be successful, for the proposal team has demonstrated success on similar projects, has worked together for at least five years, and is committed to the development of the technology. The success of the project will be judged at various stages. As expressed in the Project Summary, this project is divided into three phases. Phase I will focus on the optimization of the STCP (i.e., the core silica-titania sol coated on chemical packing) and preliminary design of a pilot reactor. Success of this Phase will be judged by the results of the characterization of the STCP, in terms of desired surface area, pore size, loading of titania, durability, and coating coverage. The “first-generation” STC material had surface areas greater than 200 m^2/g, its pore size could be controlled to the desired value (e.g., 140 angstroms), and we could achieve the desired titania loading up to 60 wt %. We expect to achieve these same values for the STCP with the addition of designing a coating protocol that allows the STCP to be transported and to experience external forces without any attrition of the coating. Success in the design of the pilot (test) reactor will be determined in Phase III.

Phase II will focus on the acquisition of preliminary data to assess the capacity of the STCP for Hg capture in an air stream containing only Hg vapor. Success of the optimization of the STCP will be further assessed in this phase by evaluating the effectiveness of the coated packing in capturing mercury from simulated mercury-laden air streams. We anticipate at least 90% Hg capture, but more likely 99%. Effluent Hg concentrations will be measured via a total Hg analyzer (Lumex Portable Mercury Vapor Analyzer Model RA-915 with MiniCEM) and via the Ontario Hydro Method (ASTM D6784-02).

Phase III will concentrate on the implementation of the STCP technology in a specifically designed pilot reactor fed by flue gas from MSI's Combustion Test Facility boiler using lignite as the feedstock. This phase will be deemed successful if the STCP achieves our goal of over 90% mercury removal at our predicted life cycle costs. This final phase is crucial to determine the overall success of the project proposed here.

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QUALIFICATIONS

The experience and qualifications of key project participants are included below in the form of biographies, résumés, or curriculum vitas.

RICHARD SHEAHAN

RICHARD SHEAHAN, P.E.; Vice President, MicroEnergy Systems, Inc. is a registered professional engineer with over 25 years experience in management, market analysis, engineering design and development of steam-cycle, gas turbine, diesel, cogeneration and waste-to-energy systems.

Sheahan spent four years with Engineering Science, Inc. concerned with areas related to environmental control and project implementation, followed by two years with Interdevelopment, Inc. involved in the market development of European energy and environmental technologies within the United States.

In 1974, he joined Henningson, Durham & Richardson, Inc. responsible for engineering design and project development of combustion and cogeneration related systems. As Assistant Vice President and Manager of Energy & Environmental Programs, he served as project manager for design and implementation of the 50-megawatt wood-fired utility plant in Burlington, Vermont and the 2,000-ton per day waste-to-energy/coal-fired facility in Norfolk, Virginia.

In 1979, Sheahan founded Energy Partners, Inc. (EPI), an energy project and financial development firm oriented toward energy and power programs. His responsibilities included market assessment, financial and engineering design, and development of power related projects throughout the United States and overseas.

In 1988, EPI teamed with MicroEnergy Systems, Inc. (MSI) for the joint-purpose of developing power, energy and environmental power related projects utilizing the patented MSI coal and activated carbon micronization system. Sheahan has been involved in the engineering design and technical implementation of all MSI Micronized Coal and activated carbon projects, including:

- Clearfield County Pennsylvania Micronized Coal Energy Plant
- U.S. Army Activated Carbon Combustion Test Program
- USDOE Innovative Titania-Activated Carbon Air Emission Control System

- Rochelle, Illinois Municipal Utilities Micronized Coal Retrofit
- Penn State University Energy Technology Center Micronized Coal Combustion System
- USDOD & USDOE - Low-NOx Micronized Coal Burner Development
- USDOE Krakow (Poland) Clean Coal Program
- Greenbrier Combined-Cycle Diesel-Micronized Coal Combustion System (DCCC)
- Redland Quarries Fluid Coke Micronization
- Cleveland Cliffs Iron Ore Micronized Coal Energy Retrofit Program
- Reiss Viking Industrial Micronized Petroleum Coke Energy System
- Variety of other activated carbon and Micronized Coal programs
- U.S. Army Chemical Demilitarization Activated Carbon Program

Sheahan has authored two published books, including*: "Fueling the Future: An Environment and Energy Primer*" (St. Martins Press), and *"Alternative Energy Sources: A Strategy Planning Guide"* (Aspen Publications), authored over 30 articles and papers on energy and environmental matters, was contributing author to an energy handbook, chairman of eight national energy conferences, and narrated an energy series broadcast by the NBC News Network.

Education: B.S. Engineering: University of Notre Dame
M.S. Engineering: University of Notre Dame
M.B.A.: George Washington University

Books:

"Fueling the Future: An Environment and Energy Primer"; St. Martin's Press, New York, 1976.

"Alternative Energy Sources: A Strategy Planning Guide"; Aspen Publications, 1981.

"Biomass as a Nonfossil Fuel Source"; ACS Symposium, 1981 (contributing author).

"Coal Conversion Decision-Making for Industry"; Government Institutes Publications, 1982.

"Alternative Energy Sources for Universities and Colleges"; Association of Physical Plant Administrators, 1982.

"Fluidized Bed Combustion: Technical, Financial Regulatory Issues"; Government Institutes Publications, 1983.

Publications and Conferences:

"Cleveland Cliffs Using Micronized Coal", Skillings Mining Review Magazine; May 2004.

"Most Versatile Energy Source – Micronized Coal", Energy Pulse Website; energypluse.net, Jan 10, 2003.

"Micronized Coal Technology and Market Potentials"; The State of Technology in Maryland, 1st Annual Summit; Annapolis, Maryland, Jan. 15,1998.

"Micronized Coal Firing Applied to Plants in the Czech Republic and Poland"; Conference on Alternatives for Pollution Control from Coal-Fired Low Emission Sources; Plzen, Czech Republic, April 26-28, 1994.

"Micronized Coal Firing: Retrofit to an Existing Utility Plant"; ASME International Power Generation Conference; Atlanta, GA, Oct. 18-22, 1992.

"Rochelle Municipal Utilities – Nation's First Micronized Coal Fired Utility Plant"; Council of Industrial Boiler Owners Alternative Fuels III Conference, July 14, 1992.

"Micronized Coal Firing: Commercial Operating Experience"; ASME Industrial Boiler Conference, Oct. 15-18, 1989.

"Micronized Coal Firing Systems: Design, Economics and Experience"; Pittsburgh Coal Conference, Sept. 25-29, 1989.

"Micronized Coal as an Alternative Fuel"; Council of Industrial Boiler Owners Alternate Fuels Conference, May 9-10, 1989.

"Waste-to-Energy Market Potential in the General Manufacturing Sector"; Wastes-to-Energy '88: The Integrated Market Conference; <u>Power Magazine</u>, Oct. 3-4, 1988.

Sixth National Evaluating the FBC Option Conference, May 24-25, 1988, (Program Chairman).

"Fluidized Bed Combustion is a Technology for Today"; <u>Consulting Specifying Engineer Magazine</u>, July 1987.

Fifth National Evaluating the FBC Option Conference, June 3-4, 1987, (Program Chairman).

First National Industrial & Institutional Waste-to-Energy Conference"; Pollution Engineering Magazine, Nov. 13-14, 1986, Program Chairman).

Fourth National Evaluating the FBC Option Conference, June 4-5, 1986, (Program Chairman).

Third National Evaluating the FBC Option Conference, June 13-14, 1985, (Program Chairman).

Second National Evaluating the FBC Option Conference, May 1-2, 1984, (Program Chairman).

First National Evaluating the FBC Option Conference, Oct. 11-13, 1983, (Program Chairman).

"Coal Conversion Decision-making for New York Industry"; NYSERDA Industrial Coal Conversion Conference, Dec. 1982.

"Coal Conversion Orders Can Aid Industrial Facilities", Legal Times, May 10, 1982.

"Coal Conversion Engineering for Lawyers"; Regulatory Policy Institute Conference, March 1982.

"Coal Conversion Decision-making for Industry Conference"; Government Institutes Series, Feb. 1982 (Program Chairman).

"FBC & LowBtu Gasification Now More Financially Attractive"; Coal R&D, Nov. 18, 1981.

"Coal Conversion Decision-making for Industry Conference; Government Institutes Series, Nov. 1981 (Program Chairman).

"Coal Technologies Get High Ratings"; Coal News, Nov. 9, 1981.

"Users Encouraged to Invest Before Tax Credits Expire"; Energy User News, Nov. 19, 1981.

"Synthetic Fuel Energy Financing "; American Bankers Association 33rd National Credit Conference, March 1981.

"Energy From Wood Resources – Five Case Studies"; Proceedings 7th Energy Technology Conference, March 1980.

"Viewpoint – Potential of Energy Savings from Urban Mass Transportation"; Mass Transit Magazine, Feb. 1980.

"Potential of Wood Energy Resources"; Minnesota Municipal Utilities Association Conference, Oct. 1978.

"Feasibility of Electric Power Generation from Wood Wastes"; Symposium on Energy from Biomass and Wastes; Institute of Gas Technology, Aug. 1978.

"Transit, Energy and the Environment"; Transit Fact Book; American Public Transit Association, June 1977.

"Burlington Power Plant, Resource Recovery-Wood Fuel Plan"; Proceedings 68th International District Heating Association, June 1977.

"Energy Profile: Auto vs. Transit"; Mass Transit Magazine, Nov. 1976.

"Overview of New Energy Technologies"; NBC News Network, July 1976.

"A Supplementary Fuel for Power Generation"; 6th Annual Northeastern Regional Antipollution Conference, July 1975.

"The Production and Application of Synthetic Fuels from Coal"; Public Utilities Fortnightly, Aug. 1, 1974.

TIM LANAGER

<u>TIM LANAGER</u>; President, MicroEnergy Systems, Inc., is a Certified Public Accountant and member of the Pennsylvania Bar.

Prior to graduating from College, Mr. Lanager worked for the Lansberry Coal Company; Curwensville, Pennsylvania; where he was involved in all aspects of coal mining and transportation operations.

His employment background includes seven years of public accounting with Arthur Andersen & Co. where, as a Senior Manager, he specialized in areas concerning regulated industries, including electric utility regulatory reporting and rate-making proceedings. His responsibilities included design, implementation and review of cost and financial reporting systems, auditing review of quarterly and annual financial statements, including: SEC, 10Q and 10K reports.

In 1978, Mr. Lanager acquired ownership and served as President of the Chestnut Ridge Coal Corporation, an independent coal producer with operations in Pennsylvania and West Virginia. He was responsible for expanding the company's operations in areas of surface and underground mining and coal processing and preparation. He directed all negotiations related to coal sales contracts both domestically and internationally. The company was awarded State and Federal Reclamation Awards for post mining reclamation activities in Pennsylvania and West Virginia.

In 1986, Mr. Lanager founded MicroEnergy Systems, Inc. as an organization dedicated to the manufacturing, marketing, and project implementation of industrial and utility energy related projects utilizing the MSI micronization system. He is responsible for all production, administration, legal and financial matters pertaining to MSI fabrication, operations and project development.

Lanager has been involved in the facilities, legal and administrative implementation of all MSI micronized coal and fuel related projects, including: U.S. Army Chemical Demilitarization Program, Clearfield County Energy Plant; Rochelle Municipal Utilities Retrofit; U.S. Army Activated Carbon Tests; Penn. State Combustion Test Program; USDOE Innovative Titania-Activated Carbon Air Emission Control System, USDOE Krakow (Poland) Clean Coal Program; Greenbrier Combined-Cycle Diesel-Micronized Coal Combustion System (DCCC); Redland Quarries Fluid Coke Micronization;

Cleveland Cliffs Iron Ore Energy Program; and Reiss Viking Industrial System -- Variety of activated carbon programs.

Education:

B.S. Finance and Accounting: Pennsylvania State University
Juris Doctorate: University of Connecticut School of Law

DAVID W. MAZYCK, Ph.D.

DAVID W. MAZYCK, Ph.D., Executive Vice President and Chief Technology Officer, Mazyck Technology Solutions, LLC. Dr. Mazyck's primary research responsibilities and objectives are to lead a nationally and internationally recognized research program dedicated to advancing the current understanding of adsorption phenomena, photocatalysis, and air/water purification through novel engineered systems. Broadly, his research focuses on the purification of air and water via adsorption, photocatalysis, and/or a combination of the two for maintaining public health. Fundamentals of adsorption are used to tailor adsorbents through the optimization of physical (e.g., pore size distribution) and chemical (e.g., electron density) properties. More specifically, the surface chemistry of carbonaceous (e.g., activated carbon) and silica adsorbents are studied to better understand the adsorbent-adsorbate interface. The robustness of these adsorbents is enhanced through the incorporation of photocatalysts (e.g., TiO_2) to either improve remediation efficiency or to accomplish in-situ regeneration. The overarching theme of my research program is to tailor sorbents for the purification of water and air (e.g., Hg capture). In other words, I rely on the fundamentals of adsorption phenomena, chemistry, photocatalysis, and engineering to custom build particles that are more efficient at their task compared to currently available technologies. Current research efforts are divided equally amongst activated carbon, silica, and photocatalytic particles. The primary objective is to tailor these materials to solve particular problems (e.g., removal of mercury from coal-fired power plant flue gas, VOCs from paper mills and potential drinking water, and taste and odor causing compounds from drinking water).

Education - Ph.D., The Pennsylvania State University, May 2000
Major: Environmental Engineering
Minor: Fuel Science

M.S., The Pennsylvania State University, December 1996
Major: Environmental Engineering

B.S., The Pennsylvania State University, May 1995
Major: Civil Engineering

- US Army, Army Corps of Engineers, 81 Bravo (Technical Drafting Specialist)

Academic Experience - Assistant Professor (July 2000-Present)

- Research

- o Tailoring of activated carbon during activation and reactivation for the separation of contaminants from water and air (e.g., Hg, taste and odor causing compounds, etc.)
- o Activated carbon surface chemistry
- o Investigation of advanced oxidation processes (e.g., TiO_2 and UV) for the destruction of organic compounds (100% water recovery for space and terrestrial applications)
- o Nanoparticles (e.g., magnetic nanoparticles, silica-titania composites)

Examples of Current Support

- DOE, An Innovative Titania-Activated Carbon System for Removal of VOCs and HAPs from Pulp, Paper, Paperboard Mills and Wood Products Facilities with *In-Situ* Regeneration Capabilities ($2.1 M), 4/03-3/06
- DOE - CPCPC, TiO_2 Coated Carbon ($50 K), 3/05-2/06
- NASA ES CSTC, Magnetically Agitated Photocatalytic Reactor for Water Recovery ($360 K), 6/02-12/05
- USDA, Photocatalytic Nanoparticles ($60 K), 8/05 – 7/06

Publications

1. Kostedt* WL, Drwiega* J, Mazyck DW, Lee SW, Sigmund W, Wu CY, Chadik. 2005. Magnetically Agitated Photocatalytic Reactor for Photocatalytic Oxidation of Aqueous Phase Organic Pollutants. ES&T. Accepted.

2. Khan* AY, Mazyck DW. The Effect of UV Irradiation on Adsorption by Activated Carbon/TiO2 Composites. Carbon 2005. Accepted.

3. Barritt* A, Drwiega* J, Carter R, Mazyck DW, Chauhan A. Multidisciplinary Design of A Potable Water Treatment Plant: A Freshman Design Experience. Chemical Engineering Education 2005. Accepted.

4. Tao* Y, Schwartz* S, Wu CY, Mazyck DW. Development of a TiO2/AC Composite Photocatalyst by Dry Impregnation for the Treatment of Methanol in Humid Airstreams. Industrial & Engineering Chemistry Research 2005. Accepted.

5. Lee* SW, Drwiega* J, Mazyck D, Wu CY, Sigmund WM. Synthesis and Characterization of Hard Magnetic Composite Photocatalyst-Barium Ferrite/Silica/Titania. Materials Chemistry & Physics 2005. Accepted.

6. Maneeratana* V, Bach* M, Mazyck DW, Wu CY, Powers K, Sigmund WM. Synthesis and Evaluation of Activated Carbon Composite Photocatalysts for Surface Enhanced Raman Scattering: Photocatalytic Layer Coating. SAE Transactions 2005. Accepted.

7. Mazyck DW, Drwiega* J, Lee* SW, Wu CY, Sigmund W, Chadik P, Park* JH, Meisel MW. Development and Characterization of a Magnetically Agitated Photocatalytic Reactor for Water Recovery. SAE Transactions 2004. Accepted.

8. MacKenzie* JA, Tennant* MF, Mazyck DW. Tailored Granular Activated Carbon for the Control of 2-Methlyisoborneol. J AWWA 2005. Vol. 97(6):76-87.

9. Mazyck DW, Cannon FS, Bach* M, Radovic LR. The Role of Calcium Content in pH Excursions for Reactivated GAC. Carbon 2005; 43(3): 511-518.

10. Pitoniak* E, Wu CY, Mazyck DW, Powers KW, Sigmund W. Adsorption Enhancement Mechanisms of Silica-Titania Nanocomposites for Elemental Mercury Vapor Removal. Environ. Sci. Technol. 39(5): 1269-1274. 2005.

11. Lee* SW, Driewga* J, Wu CY, Mazyck D, Sigmund W. Anatase TiO2 Nanoparticle Coating on Barium Ferrite Using Titanium Bis-Ammonium Lactato Dihydroxide and Its Use as a Magnetic Photocatalyst. Chemistry of Materials (American Chemical Society) 2004, 16(6): 1160-1164.

12. Nowack KO, Cannon FS, Mazyck DW. Enhancing Activated Carbon Adsorption of 2-Methylisoborneol: Methane and Steam Treatments. Environ. Sci. Technol. 2004, 38,276-284.

13. Pitoniak*E, Wu CY, Londeree* D, Mazyck D, Bonzongo JD, Powers K, Sigmund W. Nanostructured Silica-Gel Doped with TiO2 for Hg Vapor Control, Journal of Nanoparticle Research 2003;5:282-292. David W. Mazyck

14. Tennant* MF, Mazyck DW. Steam-Pyrolysis Activation of Wood Char for Superior Odorant Removal. Carbon 2003;41(12):2195-2202.

15. Mazyck DW, Cannon FS. Overcoming Calcium Catalysis During the Thermal Reactivation of GAC: Part II. Variation of Process Parameters. Carbon 2002;40(3):241-252.

16. Mazyck DW, Cannon FS. Overcoming Calcium Catalysis During the Thermal Reactivation of GAC: Part I. Steam-Curing Plus Ramped-Temperature N2 Treatment. Carbon 2000;38(13):1785-1799.

17. Cannon FS, Dusenbury J, Paulsen D, Singh J, Mazyck D, Maurer D. Advanced Oxidant Regeneration of Granular Activated Carbon for Controlling Air-phase VOCs. Ozone Sci. and Engr., 1996;18:417- 441.

Selected Recent Oral Presentations (past 5 years)

Pitoniak E, Wu CY, Londeree D, Mazyck D, Powers K. Oxidation of Vapor-Phase Mercury Using an Innovative Adsorption-Photocatalytic Oxidation System, Proc. 96th Annual Conference & Exhibition of the Air & Waste Management Association, San Diego, CA, June 22-26, 2003, Paper # 69582

Pitoniak* E, Wu CY, Mazyck D, Powers K. Development of a Novel Material for Controlling Mercury Emission, 40th Annual Conference of Florida Section of Air & Waste Management Association, Abstract No. 7, p. 11, Walt Disney World, FL, September 7-9, 2003.

Pitoniak* E, Wu CY, Londeree* D, Mazyck D, Bonzongo JC, Powers K, Sigmund W. Synergistic Adsorption and Photocatalytic Oxidation for Elemental Mercury Vapor Removal. DOE-EPRI-U.S.EPA-A&WMA Combined Power Plant Air Pollutant Control Mega Symposium, Abstract No. 73, p. 62, Washington, DC, May 19-22, 2003.

Chestnutt T, Mazyck D. The effects of dissolved oxygen during the reactivation of granular activated carbon. July, 2004 Triennial Conference on Carbon. Providence, RI.

Tennant M, Mazyck D. Role of physical and chemical characteristics of powdered activated carbon in the adsorption of 2-methylisoborneol. July, 2004 Triennial Conference on Carbon. Providence, RI.

Hobbs A, Lindner A, Mazyck D. Adsorption of substituted aromatic compounds by powdered activated carbon: A mechanistic approach to quantitative structure-activity relationships. July, 2004 Triennial Conference on Carbon. Providence, RI.

Jack Drwiega, Seung-woo Lee, David Mazyck, Chang-Yu Wu, Mark Meisel and Wolfgang M. Sigmund. Magnetically agitated photocatalysis: Development and characterization of TiO2 coated barium ferrite for magnetic agitation and photocatalysis in water treatment. Particles 2004 Particle Synthesis, Characterization, and Particle-Based Advanced Materials, Orlando, FL. March 6-9 2004.

Mazyck DW, Tennant MF. Activated carbon for controlling 2-methylisoborneol. International Activated Carbon Conference. Pittsburgh, PA. September 25-26, 2003.

Mazyck DW, Hartman N. Sorbent applications for Florida. International Activated Carbon Conference. Pittsburgh, PA. September 25-26, 2003.

Mazyck D. Activated carbon for tastes and odors: A US case study. Thames Water Global Technology Workshop on Activated Carbon Technology and Applications. Pittsburgh, PA. September 16-18, 2003.

Mazyck D. Future vision for the US carbon market. Thames Water Global Technology Workshop on Activated Carbon Technology and Applications. Pittsburgh, PA. September 2003.

Mazyck D, Chauhan A. Multidisciplinary design of a potable water treatment plant: A freshmen design experience. ASEE SE Section Annual Conference, Gainesville, FL, April 2002.

Mazyck DW, Cannon FS, Radovic LR. pH Excursions in water treatment following the installation of reactivated GAC: Causation and control. July, 2001 Triennial Conference on Carbon. Lexington, KT.

Nowack KO, Cannon FS, Mazyck DW. Enhancing activated carbon adsorption of 2-methylisoborneol (MIB). July, 2001 Triennial Conference on Carbon. Lexington, KT.

Goins, KM, Mazyck DW, Nowack KO, Cannon FS. Thermally reactivated granular activated carbons for the adsorption of 2-Methylisoborneol. Division of Fuel Chemistry for the 222nd ACS National Meeting. Chicago, Illinois - August 2001.

Mazyck DW, Cannon FS. Overcoming calcium catalysis during the thermal reactivation of granular activated carbon. 1999 Biennial Conference on Carbon. Charleston, SC.

University of Florida Patents (1 patent pending assigned to Penn State)

Wu, C. Y., "Goswami, Y., Garretson, C., Mazyck, D. and Andino, J., "Photocatalyst Coated Magnetic Composite Particle", Patent Application submitted, June 2002.

Mazyck, D. W., Londeree, D. J., Wu, C. Y., Powers, K. W., and Pitoniak, E. R., "Method for Purifying Flue Gases from Combustion Sources", Patent Application submitted, March 2004.

Andino, J. M., Wu, C. Y., Mazyck, D., Teixeira, A. A., "Chemically Assisted Photocatalytic Oxidation System", Disclosure of Invention submitted, March 2004.

ANNA I. CASASÚS, Ph.D.

ANNA I. CASASÚS, Ph.D.; Research and Development Director, Mazyck Technology Solutions, LLC, has a Ph.D. in Chemical Engineering and an Engineer in Training Certification. Dr. Casasús has over ten years of research experience in various areas, particularly for environmental applications. Since joining the team at MTS, she has worked on the "tailoring" of the STC technology for various applications. During her years of research experience she has developed QA/QC protocols and has designed and successfully completed numerous testing programs.

Education:

Doctor of Philosophy in Chemical Engineering
December 2004
University of Florida, Gainesville, Florida
Grade Point Average: 3.67/4.00

Master of Science in Chemical Engineering
August 2002
University of Florida, Gainesville, Florida
Grade Point Average: 3.50/4.00

Bachelor of Science in Chemical Engineering
June 1999
University of Puerto Rico, Mayagüez, Puerto Rico
Grade Point Average: 3.87/4.00

Engineer in Training Certification
March 2001
Puerto Rico, Certificate number: 18788

Experience:

Research and Development Director
5/2005- Present
Mazyck Technology Solutions, LLC, Gainesville, Florida
•Research and development of new technologies and tailoring patented technology for different applications in purification of water and air.

Chemical Laboratory Services Coordinator
1/2005- 5/2005
Department of Transportation, State Materials Office, Gainesville, Florida
•Research of additional services to incorporate into the State Materials Office Chemical Laboratory in order to promote service quality and take full advantage of laboratory capabilities.

PhD Candidate
2002 - 2004
University of Florida, Gainesville, Florida
Department of Chemical Engineering
Dissertation title: Effect of carbon substrate and denitrification enzymes on diauxic lag due to change in terminal electron acceptor
•Studied the effect of the oxidation state of the carbon substrate and presence or absence of denitrification enzymes on the diauxic lag of a pure culture of facultative anaerobic denitrifying bacteria growing aerobically upon switching to anoxic growth. Modified an extended previous model for biphasic growth with transient electron acceptors.

Total Quality Management Instructor
Summer 2002, 2003, 2004
University of Florida, Gainesville, Florida
Department of Chemical Engineering
Course title: Process Engineering Megacourse
•Taught approximately 40 students strategies in creative problem solving and the fundamentals of teamwork.

M.S. Candidate
1999 - 2002
University of Florida, Gainesville, Florida
Department of Chemical Engineering
Thesis title: Effect of exposure to oxygen on the diauxic lag
•Determined the effects of dissolved oxygen and aerobic growth on the ensuing diauxic lag and anoxic specific growth rate of a pure culture of facultative anaerobic denitrifying bacteria. Modified an existing model for biphasic growth with transient electron acceptors.

Summer Intern
Summer 1999
National Aeronautics and Space Administration Glenn Research Center, Cleveland, Ohio
Lewis' Educational and Research Collaborative Internship Program
Project title: Rate coefficient measurement of SO2 + O + M = SO3 + M reaction behind reflected shock waves at high temperatures
•Determined a set of experimental conditions to be used for the determination of the rate coefficient of the given reaction through a series of sensitivity analyses.

Undergraduate Research Assistant
1998 - 1999
University of Puerto Rico, Mayagüez, Puerto Rico
Department of Chemical Engineering
Project title: Photocatalytic Disinfection of Indoor Air Using Titanium Dioxide as Catalyst
•Designed and constructed the equipment necessary for the study of the effect of photocatalytic disinfection on fungi using titanium dioxide as catalyst.

Summer Intern
Summer 1998
University of Wisconsin, Madison, Wisconsin

Department of Environmental Engineering
Summer Undergraduate Research Experience (SURE) Program
Project title: Degradation of Trichloroethylene Using Membrane-attached Methanotrophic Biofilm Reactor
•Quantified rate of TCE degraded by methanotrophic bacteria in a biofilm reactor as well as transformation yields.

Publications and National Presentations:

Lee, D.-U., Casasús-Zambrana, A., Hamilton, R., Svoronos, S., Lee, S.-I. and Koopman, B. (2004) Significance of denitrifying enzyme dynamics in biological nitrogen removal processes: a simulation study, Water Science and Technology 49(5-6), pp. 265-274.

Hamilton, R., Casasús, A., Rasche, M., Narang, A., Svoronos, S.A. and Koopman, B. (2004) Structured model for denitrifier diauxic growth, Biotechnology and Bioengineering 90(4), pp. 501-508.

Casasús, A., Hamilton, R., Svoronos, S.A. and Koopman, B. (2004) A simple model for diauxic growth of denitrifying bacteria, Water Research 39(9), pp. 1914-1920.

Casasús, A., Lee, D.-U, Hamilton, R., Svoronos, S.A. and Koopman, B. (2004) Effect of carbon substrate and denitrification enzymes on diauxic lag due to change in terminal electron acceptor. Submitted for publication.

Hamilton, R., Casasús, A., Svoronos, S. A. and Koopman, B. (2005) An inexpensive method for the automation of biomass measurements in lab-scale bioreactors. Journal of the Association for Laboratory Automation, In Press.

Casasús, A., Hamilton, R., Svoronos, S.A. and Koopman, B. (2004) American Institute of Chemical Engineers (AIChE) Annual Meeting. A simple model for the diauxic growth of denitrifying bacteria. Austin, Texas.

JENNIFER M. STOKKE

JENNIFER STOKKE, Technology Development Director at MTS, focuses on the scale up of the technology from the lab scale to the pilot and full-scale applications. She earned her Bachelor of Science degree in Environmental Engineering from the University of Florida and has an Engineer in Training certification. Her graduate work at UF focused on the development of the silica-titania composites for the removal of VOCs and HAPs from pulp and paper mills. She focused on the synthesis and tailoring of the composite material, design and optimization of the lab-scale reactor, and design and optimization of the pilot scale unit. She was successful in engineering a system capable of removing and oxidizing methanol to inert byproducts. While at MTS, Jennifer has developed a protocol for the full-scale synthesis of the composite material, been a member of the design team for various pilot and full-scale units, and assisted with experimental design of laboratory and pilot research.

Education:

Ph.D. candidate, Environmental Engineering
expected December 2007
University of Florida, Gainesville, FL
GPA: 3.9/4.0
Advisor: Dr. David W. Mazyck

B.S., Environmental Engineering
1999–2003
University of Florida, Gainesville, FL
GPA: 3.90 summa cum laude
Highest honors paper: Gas Phase Separation of Volatile Organic Compounds Emitted from the Wood Processing Industry

Experience:

Technology Development Director
4/2005 – present
Mazyck Technology Solutions, LLC, Gainesville, FL
Technology Development Director
•Lead the scale-up of technologies developed for the purification of water and air from laboratory bench-scale systems to pilot and full-scale units.

DOE Grant ($2.1M): An Innovative Titania-Activated Carbon System for Removal of VOCs and HAPs from Pulp, Paper, Paperboard Mills and Wood Products Facilities with In-Situ Regeneration Capabilities
7/2003 – Present
University of Florida, Gainesville, FL

•Lead researcher responsible for the development of a catalytic sorbent for the control of VOCs and HAPs from the wood processing industry. Succeeded in developing a catalyst that is capable of continuously oxidizing 90+% of the methanol from an air stream to inert byproducts.

National Science Foundation SPICE (Students Partner in Inquiry-Based Collaborative Education) Fellow
6/2004 – 6/2005
University of Florida, Gainesville, FL
•Worked 15 hours/week with teachers at under-resourced middle school in Gainesville to (1) foster middle school students' desire to pursue careers in science, technology, engineering and mathematics and (2) improve science, technology, engineering, and mathematics curricula in the public schools.

Summer 2003
Baskerville-Donovan, Inc., Sarasota, FL
•Assisted with permit applications, proposals, stormwater treatment design and site planning.

University Scholar
2001-2002
University of Florida, Gainesville, FL
• Investigated the mutual solubility of organic compounds through library and laboratory research for use in environmental fate analyses.

Technical Skills:

Competent in AutoCAD, Minitab, and most Microsoft systems including Word, Excel, VBA, PowerPoint, and Publisher. Experienced with laboratory equipment including GC/FID, Hydra AA mercury analyzer, thermogravimetric analyzer and NOVA surface area analyzer.

Organizations/Activities:

Air and Waste Management Association
Golden Key National Honor Society

Awards:

Bright Futures Scholarship recipient (1999-2003)
College of Engineering Undergraduate Scholarship recipient (2002-2003)
First place team at ASCE Southeast Regional Conference competition (2002)

Publications:

Stokke JM, Mazyck DW, Wu CY. Comparison of titania-doped sorbents for VOC/HAP control. Air and Waste Management 98th Annual Conference and Exhibition. Minneapolis, MN. June 21-24, 2005.

VALUE TO NORTH DAKOTA

The economy of North Dakota relies heavily on the lignite industry, which is responsible for the employment of thousands of people in the state. Lignite-fired power plants in North Dakota generate electricity at a cost significantly below that of all coal, nuclear and natural gas power plants nationwide (www.Lignite.com). However, the possibility of environmental pollution exists unless appropriate control technologies are in place. Not meeting EPA regulatory levels may put the reputation of lignite-fired power plants in jeopardy, and may result in significant fines, ultimately having a deleterious effect on North Dakota's economy.

Because lignite is considered a "low rank coal", it is more economical than "high rank" bituminous coals. The main limitation of lignite use is the production of elemental mercury concentrations higher than those of higher ranked coals during combustion, which results in less-than-desired removal efficiency using traditional control technologies.

The technology proposed here will prove to be very advantageous to North Dakota and the lignite industry. The technology is anticipated to achieve greater than 90% mercury removal regardless of the amount of elemental mercury present, since the technology has the ability of oxidizing mercury, leading to easier removal. It will achieve this in a cost-efficient manner. Its commercialization potential is huge, since reasonable assumptions have been made in the design of this project plan, and commercialization efforts are already underway for a different application of this technology. The implementation of the technology into existing power plant configurations does not require major costs, or major reconstruction, so a commercial version of the technology should be easily accepted.

The fact that mercury emissions will no longer be an issue, coupled with the lower cost of lignite relative to bituminous coals may very well lead to an increase in use of lignite. It will not only have a positive effect on existing lignite-fired power plants, but it may inspire bituminous coal-fired power plants to switch to lignite combustion, thus generating a high demand for North Dakota Lignite and a greater income into the state of North Dakota. An increased use of lignite will help preserve existing jobs in that industry, and possibly create additional employment opportunities in order to satisfy the higher demand.

MANAGEMENT

All project participants will keep in constant communication with one another during the entire duration of the project. There are planned trips to and from Oakland, Maryland for assistance in the tasks involving MSI and MTS, or MSI and UF. Dr. David Mazyck and Mr. Richard Sheahan will serve as the key points of contact. Dr. Mazyck will oversee all activities in Gainesville, while Richard Sheahan oversees all activities in Oakland to ensure the project is on schedule and running smoothly toward the program objectives.

During the course of the project, Table 5 (presented in the Timeline section below) will be constantly referenced to ensure that the project is running on schedule. Weekly teleconferences will be scheduled to evaluate the progress made in each task, and to make any changes or decisions necessary if unexpected results or conflicts were to arise. At the stipulated completion date of each task, thorough evaluations will be made to determine the success level of the task.

TIMETABLE

Table 5 includes each of the tasks required for completion of the project, and the months during which each task will be carried out. It includes starting points of each task, as well as deadlines for each task. Proposed dates during which interim reports required by section 43-03-05-8 of the “Contracts for Land Reclamation Research and Research, Development, and Marketing of Lignite Products Derived from Lignite” are also included. Quarterly reports are recommended, as well as a final report. Any additional reports will be added to the schedule as requested. Tasks will be completed in an amount of time equal to or lower than what is stipulated in Table 5.

Table 5: Expected duration of each task.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1.0 PROGRAM MANAGEMENT	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX
2.0 STCP DESIGN	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX														
3.0 ACQUIRE TEST COALS			XXXXXXX															
4.0 MANUFACTURE STCP		XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX													
5.0 MODIFY EXISTING REACTOR			XXXXXXX	XXXXXXX	XXXXXXX													
6.0 Hg RECOVERY TESTS- REACTOR					XXXXXXX	XXXXXXX	XXXXXXX											
7.0 DESIGN / FAB NEW TEST-MRU								XXXXXXX	XXXXXXX	XXXXXXX								
8.0 EQUIPMENT INSTALLATION										XXXXXXX	XXXXXXX							
9.0 Hg RECOVERY - TEST-MRU												XXXXXXX	XXXXXXX	XXXXXXX				
10.0 TEST SAMPLE ANALYSES							XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX
11.0 COMPILATION ALL DATA							XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX
12.0 VERIFY PERFORMANCE							XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX
13.0 COMMERCIALIZATION															XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX
14.0 REPORTS				XXXXXXX				XXXXXXX				XXXXXXX				XXXXXXX		XXXXXXX

BUDGET

Table 6 summarizes the budget requirements for the completion of this project. Separate budgets are presented below for MSI (Table 7), MTS (Table 8), and UF (Table 9). A justification for the required budgets is also given.

Table 6: Total Project Budget Costs.

	Total Project Costs	Cost Share (50%)	Net Due
Mazyck Technology Solutions, LLC (MTS)	$342,704	$171,352	$171,352
MicroEnergy Systems, Inc (MSI)	$1,100,688	$550,344	$550,344
University of Florida (UF)	$60,668	$30,334	$30,334
TOTAL	**$1,504,060**	**$752,030**	**$752,030**

Table 7: MSI Project Budget Costs.

Month Number		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	TOTALS
LABOR SUMMARY	HOURLY RATE																			
Senior Manager	$ 76.13	40	40	120	120	120	120	120	120	120	80	80	120	120	120	80	120	140	80	1,860
Senior Engineer	$ 76.13	40	40	80	80	80	80	80	80	80	40	40	60	60	60	80	80	80	80	1,220
Senior Technician	$ 31.76			140	140	140	140	140	140	80	140	140	120	140	140	40	20	20	140	1,820
Technician	$ 13.23			140	140	140	140	140	140	80	140	140	120	140	140	40	20	20	140	1,820
LABOR	RATES	$ 6,090	$ 6,090	$ 21,525	$ 21,525	$ 21,525	$ 21,525	$ 21,525	$ 21,525	$ 18,825	$ 15,434	$ 15,434	$ 19,102	$ 20,002	$ 20,002	$ 13,980	$ 16,126	$ 17,648	$ 18,479	$ 316,362
FRINGE	33.23%	2,024	2,024	7,153	7,153	7,153	7,153	7,153	7,153	6,256	5,129	5,129	6,348	6,647	6,647	4,646	5,359	5,865	6,141	$ 105,127
SUBTOTAL - LABOR		8,114	8,114	28,677	28,677	28,677	28,677	28,677	28,677	25,081	20,563	20,563	25,450	26,649	26,649	18,626	21,484	23,513	24,620	$ 421,489
OVERHEAD	67.23%	5,455	5,455	19,280	19,280	19,280	19,280	19,280	19,280	16,862	13,824	13,824	17,110	17,916	17,916	12,522	14,444	15,808	16,552	$ 283,367
DIRECT COSTS																				
Equipment, Materials, Fabrication				3,000	5,000	5,000	3,000	3,000		15,000	15,000	4,000	5,000	5,000	5,000					$ 68,000
Coal, energy, power													11,918	15,890	11,918					$ 39,725
Travel		1,000	1,000	1,000	1,000	500	2,400	500	500	500	500	500	2,400	500	500	500	1,000	1,000	1,000	$ 16,300
SUBTOTAL-DIRECT COSTS		1,000	1,000	4,000	6,000	5,500	5,400	3,500	500	15,500	15,500	4,500	19,318	21,390	17,418	500	1,000	1,000	1,000	$ 124,025
G&A	10.66%	1,553	1,553	5,539	5,752	5,699	5,688	5,485	5,166	6,123	5,318	4,145	6,596	7,031	6,607	3,374	3,937	4,298	4,496	$ 88,359
SUBTOTAL - LABOR & DIRECT COSTS		16,123	16,123	57,496	59,709	59,155	59,045	56,942	53,622	63,566	55,205	43,033	68,473	72,985	68,589	35,022	40,865	44,619	46,668	$ 917,240
MARGIN	20%	3,225	3,225	11,499	11,942	11,831	11,809	11,388	10,724	12,713	11,041	8,607	13,695	14,597	13,718	7,004	8,173	8,924	9,334	$ 183,448
TOTAL PROJECT COSTS		$ 19,347	$ 19,347	$ 68,995	$ 71,650	$ 70,987	$ 70,854	$ 68,331	$ 64,347	$ 76,279	$ 66,247	$ 51,639	$ 82,168	$ 87,582	$ 82,307	$ 42,027	$ 49,038	$ 53,543	$ 56,001	$ 1,100,689
CONTRIBUTION BY MSI																				
Labor & Direct Costs		$ 6,449	$ 6,449	$ 22,998	$ 23,883	$ 23,662	$ 23,618	$ 22,777	$ 21,449	$ 25,426	$ 22,082	$ 17,213	$ 27,389	$ 29,194	$ 27,436	$ 14,009	$ 16,346	$ 17,848	$ 18,667	$ 366,896
Profit @ 100 %		3,225	3,225	11,499	11,942	11,831	11,809	11,388	10,724	12,713	11,041	8,607	13,695	14,597	13,718	7,004	8,173	8,924	9,334	$ 183,448
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Total Contribution by MSI		9,674	9,674	34,497	35,825	35,493	35,427	34,165	32,173	38,140	33,123	25,820	41,084	43,791	41,154	21,013	24,519	26,771	28,001	$ 550,344
CONTRIBUTION BY LIGNITE COUNCIL		9,674	9,674	34,497	35,825	35,493	35,427	34,165	32,173	38,140	33,123	25,820	41,084	43,791	41,154	21,013	24,519	26,771	28,001	$ 550,344
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TOTAL PROJECT COST		$ 19,347	$ 19,347	$ 68,995	$ 71,650	$ 70,987	$ 70,854	$ 68,331	$ 64,347	$ 76,279	$ 66,247	$ 51,639	$ 82,168	$ 87,582	$ 82,307	$ 42,027	$ 49,038	$ 53,543	$ 56,001	$ 1,100,689

Table 8: MTS Project Budget Costs.

Mon th Number	HOURLY RATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	TOTALS
LABOR SUMMARY																				
Senior Manager	$71.84	40	40	40	40	40	20	20	20	20	20	20	40	40	40	40	40	40	20	580
Senior Engineer	$31.13	80	80	80	80	60	40	40	40	40	40	20	60	40	80	80	80	60	40	1,040
Junior Engineer	$30.00	60	60	60	60	20	20	20	20	20	20	20	30	20	40	40	40	20	20	590
Laboratory Assistant	$15.00	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	540
Laboratory Assistant	$15.00	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	540
LABOR	RATES	$ 8,064	$ 8,064	$ 8,064	$ 8,064	$ 6,241	$ 4,182	$ 4,182	$ 4,182	$ 4,182	$ 4,182	$ 3,559	$ 6,541	$ 5,619	$ 7,464	$ 7,464	$ 7,464	$ 6,241	$ 4,182	$ 107,942
FRINGE	30.00%	2,419	2,419	2,419	2,419	1,872	1,255	1,255	1,255	1,255	1,255	1,068	1,962	1,686	2,239	2,239	2,239	1,872	1,255	$ 32,383
SUBTOTAL - LABOR		10,483	10,483	10,483	10,483	8,114	5,437	5,437	5,437	5,437	5,437	4,627	8,504	7,304	9,703	9,703	9,703	8,114	5,437	$ 140,325
OVERHEAD	50.00%	5,242	5,242	5,242	5,242	4,057	2,718	2,718	2,718	2,718	2,718	2,314	4,252	3,652	4,852	4,852	4,852	4,057	2,718	$ 70,163
DIRECT COSTS																				
Equipment, Materials, Fabrication		2,000	2,000	2,000	2,000	500	500	500	500	500	500	500	500	500	500	1,000	1,000	-	-	$ 15,000
Consultant - ACS		4,000	4,000	4,000	4,000											1,000	500			$ 17,500
Travel		-	-	500	500	1,000	1,000	1,000	500	500	500	500	1,000	1,000	1,000	500	1,000	1,000	500	$ 12,000
SUBTOTAL-DIRECT COSTS		6,000	6,000	6,500	6,500	1,500	1,500	1,500	1,000	1,000	1,000	1,000	1,500	1,500	1,500	2,500	2,500	1,000	500	$ 44,500
G&A	12.00%	2,607	2,607	2,667	2,667	1,640	1,159	1,159	1,099	1,099	1,099	953	1,711	1,495	1,927	2,047	2,047	1,580	1,039	$ 30,599
SUBTOTAL - LABOR & DIRECT COSTS		24,332	24,332	24,892	24,892	15,311	10,813	10,813	10,253	10,253	10,253	8,894	15,966	13,951	17,981	19,101	19,101	14,751	9,693	$ 285,586
MARGIN	20%	4,866	4,866	4,978	4,978	3,062	2,163	2,163	2,051	2,051	2,051	1,779	3,193	2,790	3,596	3,820	3,820	2,950	1,939	$ 57,117
TOTAL PROJECT COSTS		$ 29,198	$ 29,198	$ 29,870	$ 29,870	$ 18,373	$ 12,976	$ 12,976	$ 12,304	$ 12,304	$ 12,304	$ 10,672	$ 19,160	$ 16,742	$ 21,578	$ 22,922	$ 22,922	$ 17,701	$ 11,632	$ 342,703
CONTRIBUTION BY MTS																				
Labor & Direct Costs		$ 9,733	$ 9,733	$ 9,957	$ 9,957	$ 6,124	$ 4,325	$ 4,325	$ 4,101	$ 4,101	$ 4,101	$ 3,557	$ 6,387	$ 5,581	$ 7,193	$ 7,641	$ 7,641	$ 5,900	$ 3,877	$ 114,234
Profit @ 100 %		4,866	4,866	4,978	4,978	3,062	2,163	2,163	2,051	2,051	2,051	1,779	3,193	2,790	3,596	3,820	3,820	2,950	1,939	57,117
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Total Contribution by MTS		14,599	14,599	14,935	14,935	9,187	6,488	6,488	6,152	6,152	6,152	5,336	9,580	8,371	10,789	11,461	11,461	8,851	5,816	$ 171,352
CONTRIBUTION BY LIGNITE COUNCIL		14,599	14,599	14,935	14,935	9,187	6,488	6,488	6,152	6,152	6,152	5,336	9,580	8,371	10,789	11,461	11,461	8,851	5,816	$ 171,352
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TOTAL PROJECT COST		$ 29,198	$ 29,198	$ 29,870	$ 29,870	$ 18,373	$ 12,976	$ 12,976	$ 12,304	$ 12,304	$ 12,304	$ 10,672	$ 19,160	$ 16,742	$ 21,578	$ 22,922	$ 22,922	$ 17,701	$ 11,632	$ 342,703

Table 9: UF Project Budget Costs.

	HOURLY RATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	TOTALS
LABOR SUMMARY																				
Senior Personnel - D. Mazyck	$ 51.73	10	10	10	5	10	5	5	10	10	10	5	10	10	10	10	10	10	10	160
Graduate Student	$ 15.00	60	60	50	60	50	50	60	60	60	50	60	60	50	60	50	40	60	60	1,000
LABOR	RATES	$ 1,417	$ 1,417	$ 1,267	$ 1,159	$ 1,267	$ 1,009	$ 1,159	$ 1,417	$ 1,417	$ 1,267	$ 1,159	$ 1,417	$ 1,267	$ 1,417	$ 1,267	$ 1,117	$ 1,417	$ 1,417	$ 23,277
FRINGE - Senior Personnel	36.92%	191	191	191	95	191	95	95	191	191	191	95	191	191	191	191	191	191	191	$ 3,056
FRINGE - Gradaute Student	7.49%	67.38	67.38	56.15	67.38	56.15	56.15	67.38	67.38	67.38	56.15	67.38	67.38	56.15	67.38	56.15	44.92	67.38	67.38	$ 1,123
SUBTOTAL - LABOR		1,676	1,676	1,514	1,322	1,514	1,160	1,322	1,676	1,676	1,514	1,322	1,676	1,514	1,676	1,514	1,353	1,676	1,676	$ 27,456
DIRECT COSTS																				
Supplies		250	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250	250	$ 4,500
Sample Analysis		250	250	250	250			250	250	250	250	250	250	250	250	250	250	250	250	$ 4,000
Graduate Student Tuition (no OH)		464	464	464	464	464	464	464	464	464	464	464	464	464	464	464	464	464	464	$ 8,352
Travel		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	$ -
SUBTOTAL-DIRECT COSTS		964	964	964	964	714	714	964	964	964	964	964	964	964	964	964	964	964	964	$ 16,852
OVERHEAD	45.50%	990	990	917	829	803	642	829	990	990	917	829	990	917	990	917	843	990	990	$ 16,360
SUBTOAL - LABOR & DIRECT COSTS		3,630	3,630	3,395	3,114	3,031	2,516	3,114	3,630	3,630	3,395	3,114	3,630	3,395	3,630	3,395	3,160	3,630	3,630	$ 60,667
MARGIN		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL PROJECT COSTS		$ 3,630	$ 3,630	$ 3,395	$ 3,114	$ 3,031	$ 2,516	$ 3,114	$ 3,630	$ 3,630	$ 3,395	$ 3,114	$ 3,630	$ 3,395	$ 3,630	$ 3,395	$ 3,160	$ 3,630	$ 3,630	$ 60,667
CONTRIBUTION BY UF																				
Labor & Direct Costs		$ 1,815	$ 1,815	$ 1,698	$ 1,557	$ 1,516	$ 1,258	$ 1,557	$ 1,815	$ 1,815	$ 1,698	$ 1,557	$ 1,815	$ 1,698	$ 1,815	$ 1,698	$ 1,580	$ 1,815	$ 1,815	$ 30,334
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Total Contribution by UF		1,815	1,815	1,698	1,557	1,516	1,258	1,557	1,815	1,815	1,698	1,557	1,815	1,698	1,815	1,698	1,580	1,815	1,815	$ 30,334
CONTRIBUTION BY LIGNITE COUNCIL		1,815	1,815	1,698	1,557	1,516	1,258	1,557	1,815	1,815	1,698	1,557	1,815	1,698	1,815	1,698	1,580	1,815	1,815	$ 30,334
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TOTAL PROJECT COST		$ 3,630	$ 3,630	$ 3,395	$ 3,114	$ 3,031	$ 2,516	$ 3,114	$ 3,630	$ 3,630	$ 3,395	$ 3,114	$ 3,630	$ 3,395	$ 3,630	$ 3,395	$ 3,160	$ 3,630	$ 3,630	$ 60,667

Table 10 summarizes the budget explanation for MSI.

Table 10: MSI budget justification.

ITEM	COST ESTIMATE	SOURCE
MODIFICATIONS TO EXISTING REACTOR & TESTING		
New duct between FD fan & Reactor (enhance air tight integrity due to toxicity of Hg	$ 300	Beitzel
New exhaust duct between reactor outlet and building exterior	$ 500	Beitzel
Modifications to existing UV bulb matrix holder & other Reactor parts	1,500	Beitzel
Misc. seals, gaskets, sealants, metal parts, fasteners, etc.	250	
NEW MRU & TESTING		
Reactor housing for MRU, inlet & outlet plenums, UV Bulb matrix holder, rotatable floor assembly, air flow dampers, support legs, UV bulb quartz seal system	27,500	Beitzel
Exterior (outside) foundation for MRU	750	MSI
MRU insulation & lagging	500	MSI
Reorient existing ID fan, modify existing ducting plus new ducting between existing ID fan and baghouse	4,000	Beitzel
New dampers on ducting	500	Beitzel
Temporary cover over MRU for weather protection	1,500	MSI
Electrical interconnections, ballasts to UV bulbs, transformer, control modifications to MRU	1,000	Beitzel
New UV bulbs, ballasts & quartz tubes & housing seals for quartz tubes	1,200	bulbs.com
Misc. seals, gaskets, sealants, metal parts, fasteners, etc.	500	
TEST EQUIPMENT & SYSTEM REQUIREMENTS		
Lumex Hg monitor - rental @ $2,000 / mo for 6 months	12,000	Pine Environ.
New positive displacement pump for Hg injection	400	MSI
New Hg electric vaporizer	1,800	MSI
Change-out baghouse with all new bags (96 bags @ $45 / bag)	4,320	MSI
Computer program mod, setup, interconnect to Allen Bradley data acquisition system	4,000	Beitzel + MSI
Calibrate LAND Combustion Analyzer - before & after test program	2,500	LAND
Misc. calibration & span gases + priority FedEx shipping	3,000	MSI
SUBTOTAL - EQUIPMENT, MATERIALS, FABRICATION	**$ 68,020**	
COMBUSTION TEST MATERIALS & ENERGY		
Assume: Ten-8 hour tests in boiler		
10 Startups (boiler warm-up) on gas : 8 hrs x 12 MMBtu/hr (ave) x 10 x $9.00//MMBtu-natural gas	8,640	MSI
10 test runs on Lignite: 8 hrs ea @ 15 MMBtu/hr net heat input @ 85% boiler efficiency @ 7,000 BTU/lb-lignite @ $100 / ton delivered to MSI	11,765	MSI
10 shutdowns x 6 hrs x 8 MMBtu (ave) x $9.00 /MMBtu-natural gas	4,320	MSI
Power for boiler, micronization mill, all mechanical systems (based on experience) - $2,500 / test month - covers monthly demand + consumption) x 4 months overall combustion test period	10,000	MSI
Misc. consumption: water, boiler blowdown maintenance, chemicals	5,000	MSI
SUBTOTAL - COMBUSTION TEST MATERIALS & ENERGY	**$ 39,725**	
TRAVEL		
Annapolis, MD- Oakland - Per diem @$100 / day + rent-car @ $60/day + gas $80 per R/T trip. Assume 10 R/T @ 3 day per trip	$ 5,600	MSI
Curwensville, Pa - Oakland - Per diem @$100 / day + rent-car @ $60/day + gas $40 per trip. Assume 10 R/T @ 3 day per trip	$ 5,200	MSI
Two trips - BWI-North Dakota @ $1200 /RT + 3 per diems $200/day+ rental car + airport/home @ $45 /cab	$ 5,000	United AL
Misc. travel MSI -to Beitzel	$ 500	MSI
SUBTOTAL - TRAVEL	**$ 16,300**	

The budget explanation for MTS is described below:

Labor

Labor rates are based on the actual rates for the individuals that will be performing the work. The labor hours are based on the amount of time required with respect to the scheduled tasks.

Fringe Benefits

Fringe is calculated based on retirement, FICA, vacation, sick leave, holidays, workman's compensation, insurance, training, and miscellaneous fringes.

Overhead and G&A

Overhead and G&A include safety facilities, administration, courier and communications.

Equipment, Materials, and Fabrication

$15,000 is requested for research supplies, which is based on experience for projects of similar scope.

Consultant – Advanced Catalyst Systems, LLC (ACS)

Advanced Catalyst Systems (ACS) will provide technical support for the synthesis of the silica titania coated packing (STCP) for the amount of approximately **$17,500** over the project duration. ACS is the manufacturer of STC for MTS mercury recovery units in chlor-alkali plants. We have chosen to use their services for this project due to their technical competence, fair and reasonable pricing, and experience with the catalyst material. The rate of **$100/hour** that will be charged by ACS represents their most favored customer rate.

Travel

In order to disseminate the research and visit Oakland, MD, several trips are planned at roughly **$1,000/person** to defray travel, lodging and other cost.

The estimates are based on the following:

Airfare: $300 airfare/ person	$300
Rental Car	$100
Hotel: $150 for 1 room for 3 nights	$450
Per Diem: $50/day for 3 days	$150
Total	$**1,000**

These rates are based on our previous travel experience.

The budget explanation of UF is described below:

Senior Personnel

Dr. Mazyck will cost share his entire labor for tasks taking place at UF. The total amount is calculated based on his normal base salary.

Graduate Student Salary

The cost for one graduate student in the Department of Environmental Engineering Sciences to conduct the experiments has been included. The PhD student is paid at the existing UF rate.

Fringe Benefits

Fringe benefits for Dr. Mazyck are calculated based on the rate of 36.92 % of his salary. Fringe benefits for a graduate student are based on a rate of 7.49 %.

Supplies

The amount requested (**$4500**) is for the purchase of materials and supplies for use in the studies. This figure is estimated based on previous projects similar in scope. Examples of supplies include chemicals, laboratory glassware, sample vials, containers, and storage devices, and routine maintenance parts for equipment.

Sample Analysis

The analytical tests required will cost **$4,000** dollars. Each sample will be at least run in duplicate and if replicate measurements do not meet QA/QC standards, a third measurement will be performed.

Tuition

This tuition for the graduate student is based on the rate of **$8,352** per student for the duration of the project. This is the standard rate for the University of Florida for 2005-2006.

Indirect Costs

This item is calculated based on the standard rate of the University of Florida of 45.5% of the total of direct costs less tuition less capital equipment.

MATCHING FUNDS

MTS, MSI, and UF will all contribute to the cost-sharing requirement of this solicitation. MTS and MSI will donate all their profit to the project. They will also donate 40% of their total labor and direct costs. Dr. Mazyck will donate 100% of his UF labor costs for this project, as well as 42% of UF's other costs. This will result in a total cost share that is 50% of the entire project costs.

TAX LIABILITY

By these means I, Steven E. Edwards, state that neither I nor Mazyck Technology Solutions, LLC have any outstanding tax liabilities owed to the State of North Dakota or any of its political subdivisions.

Signed on the 29th day of the month of September of the year 2005.

Steven Edwards

Steven E. Edwards, President and CEO
Mazyck Technology Solutions, LLC