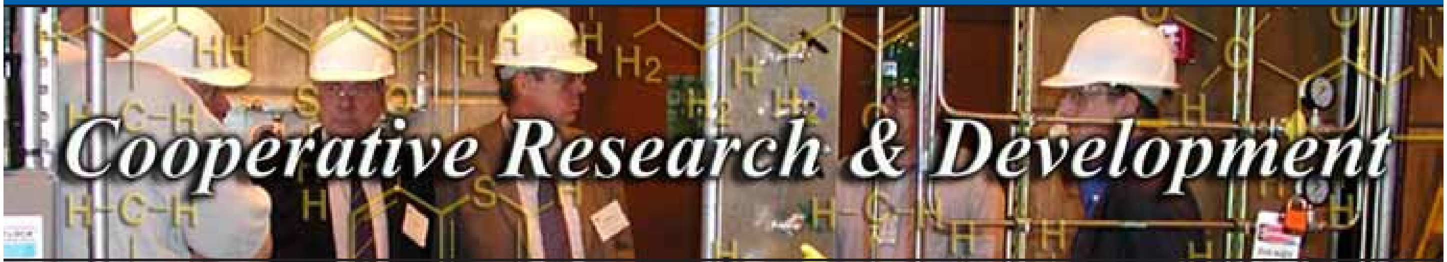
U.S. Department of Energy • Office of Fossil Energy
National Energy Technology Laboratory



Successes

Thermal Precombustion Mercury Removal Process for Low-Rank Coal-Fired Power Plants

Advanced Research

To support coal and power systems development, NETL's Advanced Research Program conducts a range of pre-competitive research focused on breakthroughs in materials and processes, coal utilization science, sensors and controls, computational energy science, and bioprocessing—opening new avenues to gains in power plant efficiency, reliability, and environmental quality. NETL also sponsors cooperative educational initiatives in University Coal Research, Historically Black Colleges and Universities, and Other Minority Institutions.

Accomplishments

- ✓ Process improvement
- ✓ Cost reduction
- ✓ Greater efficiency
- ✓ Innovative materials

Description

The University of Wyoming's Western Research Institute (WRI) is leading a multi-year, jointly sponsored research (JSR) project with Alliant Energy, Etaa Energy, Inc., and Montana-Dakota Utilities to develop a unique mercury control technology to meet increasingly stringent federal and state limits on power plant mercury emissions. The research is co-sponsored by the U.S. Department of Energy's Office of Fossil Energy (DOE-FE), and administered by the Advanced Research program and Environmental and Climate division at DOE's National Energy Technology Laboratory (NETL).

Process Development Unit at WRI Advanced Technology Center

The research is investigating two-stage thermal pretreatment of raw coal to remove both the moisture and the mercury before the fuel goes to a conventional pulverized-coal (PC) boiler. This is a novel approach in that most mercury control has been focused on removing mercury after combustion, mainly by the use of post-combustion sorbents. However, while technically feasible, most of these processes appear to be expensive, and efforts are ongoing to reduce these costs through novel concepts or process improvements.

Goals

The overall project goal is to evaluate the potential to scale up a precombustion thermal process to remove mercury from low-rank coals, both Powder River Basin (PRB) subbituminous and North Dakota lignite. The specific objectives are to determine whether this technology can successfully be deployed in PRB- and lignite-fired power plants, and provide the engineering data required to scale up the process.

Previous in-house WRI studies had confirmed the claims in a WRI patent (US 5,403,365, Process for Low Mercury Coal) that the process is able to remove between 70 and 80 percent of the mercury present in both PRB coal and lignite. Initial investigations under the JSR have explored additional factors such as processing temperature, mercury off-take gas flow-to-fuel ratio, residence time, and coal drying temperature. These factors are important to scale-up and deployment decisions.

Project Duration

Start Date

10/10/03

End Date

04/09/07

Cost

Total Project Value

$0

DOE/Non-DOE Share

$0 / $0

Industrial Partners

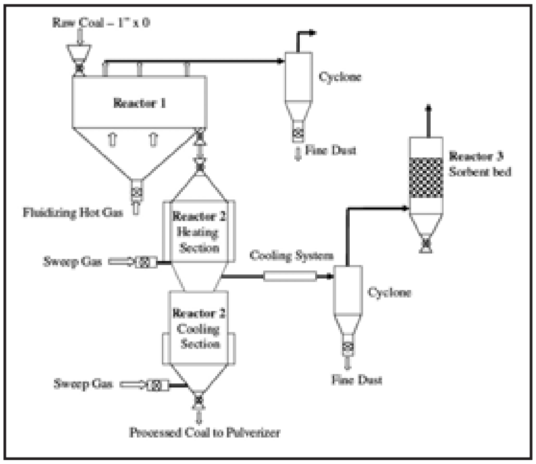
Alliant Energy
P.O. Box 351
Cedar Rapids, IA 52406-0551

Etaa Energy, Inc.
240 Longview Road
Bridgewater, NJ 08807

Montana-Dakota Utilities
400 North Fourth Street
Bismarck, ND 58501

Technical Approach and Accomplishments

To demonstrate this novel concept, a process development unit (PDU) was designed and constructed. The PDU is designed to process nominally 100 lb/hr of raw coal. It has three major subsystems: coal drying system (Reactor 1), mercury removal system (Reactor 2), and sweep gas treatment system (Reactor 3). Each system is designed in such a way that the units can be scaled up with the same results. A schematic of the PDU is shown in the figure below.



PDU schematic

The PDU encompasses two key thermal reaction steps, which remove moisture and release mercury from raw coal. In addition, the PDU is designed to study the capture of mercury from the sweep gas stream, which is high in concentrated mercury. Operation occurs in three stages.

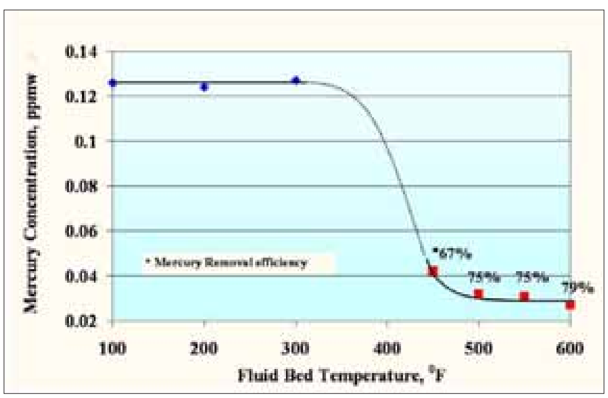
Stage 1 — Raw coal crushed to a suitable size enters the moisture removal reactor (1), where it is heated to a temperature not to exceed 302 °F. Free water and some of the more tightly bound water is vaporized and removed from the zone in a sweep gas. A vibrating fluidized-bed system was chosen for advantages including scalability and availability of design expertise in large-scale combustion and gasification applications. Dryer auxiliaries include hot gas generator, coal feeder, and valves.

Stage 2 — Coal is transferred to the mercury removal reactor (2), where it is heated to about 554 °F. A down-flow reactor is used, in which the dry coal contacts a hot inert gas, which volatizes and removes 70–80 percent of the mercury and, in the lower section of the reactor, cools the coal to about 300 °F. The coal then is ready for additional size reduction before combustion.

Stage 3 — The mercury-laden sweep gas from the mercury removal reactor (2) is transferred to a sorbent bed (3), where the mercury is removed and subsequently stabilized.

The process testing plan included performance testing using PRB and lignite coals in the PDU; evaluation of the treated coal in pilot pulverized coal combustion tests; assessment of the impact of treated coal on boiler island performance; and evaluation of the economics of the WRI precombustion process.

Precombustion Removal of Mercury: Upon successful commissioning of the PDU, PRB coal was processed. Mercury removal from these initial tests ranged from 55–87 percent, with an average of 77 percent. A typical mercury removal curve for PRB coal is shown below.



Typical mercury reduction – temperature profile for subbituminous coal

Treated Coal Combustion Tests: Coal processed in the PDU was tested in a PC-fired test combustor to evaluate combustion characteristics of the coal, measure changes in the concentration of emissions of other pollutants (SO_2 and NO_X), and assess the fate of the remaining mercury species. Analysis of the raw and treated coals based on composite samples showed a 64 percent reduction in average mercury content of the treated coal. The treated coal composite from the PDU was shipped to the University of North Dakota Energy and Environmental Research Center (EERC) for combustion tests in their 500,000 Btu/hr PC-fired pilot plant. The EERC measured the capture of mercury from pretreated coals in both electrostatic precipitator (ESP) and spray-dryer-fabric-filter equipment.

Activated carbon was injected at two different rates, representing the lowest test values. The treated PRB tests indicated that the net mercury removal (e.g., mercury removed in WRI's coal treatment process combined with mercury removed with different pollution control devices and low levels of activated carbon injection) was 90 percent and above in low-rank coals.

Process Integration Impacts on Boiler Island: Its intended deployment at power plants facilitates integration of the WRI process as a heat source, as a means to avoid dustiness and spontaneous combustion, and as a source of clean water for cooling tower or plant use. Two options were considered as heat sources for drying and heat treatment of coal: an independent coal combustion and hot gas generation system, and one using boiler flue gas heat. The latter option was used to prepare a preliminary concept for an integrated boiler.

Results of this analysis suggest that improvements in plant performance are possible in the following areas:

1) reduction in the volume fraction of moisture in the flue gas by about a third, decreasing flue gas velocity in the convection zone and improving convective heat transfer efficiency and reduction in the flue gas;
2) improvement of coal quality resulting in higher flame temperature, increased heat radiation, and improved furnace heat absorption;
3) reduction in coal moisture content due to reduction in sensible and latent heat in flue gas, resulting in boiler thermal efficiency improvements; and
4) significant reductions in auxiliary power consumption, due to the increased boiler thermal efficiency and reduction in the flue gas, air, and fuel flow rates.

Technical and Economic Evaluation: Cost estimates were developed by Washington Group International (WGI) for the WRI coal processing technology based on installation of the processing equipment on site for a 500 MW boiler. The WRI cost estimates were then compared to base case costs for PRB and lignite coals employing the TOXECON™ process. The results of this comparison indicate that the WRI process is 16–25 percent less costly in terms of cost of electricity (COE) for PRB and lignite coals, respectively. The comparison indicates that the WRI coal treatment could be a viable alternative for boilers firing PRB and lignite coals. The process does not require extensive integration with existing utility equipment, thereby providing a lower retrofit factor for the processing equipment. The cost estimates do not take into account the boiler efficiency increases and other cost benefits.

"WRI has demonstrated that precombustion thermal treatment of coal is very promising for the control of mercury emissions when firing subbituminous and lignite coals."

States and Localities Impacted

Laramie, WY
Cedar Rapids, IA
Bridgewater, NJ
Bismarck, ND

Next Steps

Initial results showed this technology to be promising for mercury removal from subbituminous PRB coal. As a result, the process was selected by DOE for further development through the DOE Mercury Control Phase III solicitation. WRI will conduct bench- and pilot-scale testing on a set of representative coals, with the objective of achieving a mercury removal efficiency improvement of at least 50 percent in the incoming coal at a cost of less than $30,000/lb of mercury removed. Testing and evaluation of alternative non-carbon high-temperature (550 °F) sorbents will be done. This follow-on also will include modeling by Foster Wheeler Development Corporation (FWDC) of the integrated performance of the PDU with a PC-fired utility unit. WGI will perform an economic study of the commercial-scale application of the WRI process. Successful demonstration of the process will lead to an accelerated deployment of commercial systems using subbituminous coals such as PRB and lignites such as Fort Union. Co-benefits are also expected through significant reductions of NO_x emissions. Based on testing to date, the WRI technology has proved to have strong commercial potential.

In summary, the process offers the following advantages:

1) the technology appears viable to remove mercury from the coal before combustion, through a simple thermal evolution that separates out the mercury;
2) the technology not only removes mercury, but also dries the coal; and it is expected to have lower operating costs than post combustion processes;
3) the technology is suitable for integration into the large number of existing PC-fired power plants;
4) the technology is applicable to both PRB coal and lignite, which are abundant U.S. fossil fuel resources; and
5) WRI's technology is expected to remove 80–90 percent of the mercury through the combination of pretreatment reduction and the downstream particulate control equipment.

National Energy Technology Laboratory

1450 Queen Avenue SW
Albany, OR 97321-2198
541-967-5892

2175 University Avenue South, Suite 201
Fairbanks, AK 99709
907-452-2559

3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507-0880
304-285-4764

626 Cochrans Mill Road
P.O. Box 10940
Pittsburgh, PA 15236-0940
412-386-4687

One West Third Street, Suite 1400
Tulsa, OK 74103-3519
918-699-2000

Visit the NETL website at:
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Customer Service:
1-800-553-7681

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Contacts

Robert R. Romanosky
Technology Manager,
Advanced Research
National Energy Technology Laboratory
3610 Collins Ferry Road
P.O. Box 880
Morgantown, WV 26507-0880
304-285-4721
robert.romanosky@netl.doe.gov

Edgar B. Klunder
Project Manager
National Energy Technology Laboratory
626 Cochrans Mill Road
P.O. Box 10940
Pittsburgh, PA 15236-0940
412-386-4678
edgar.klunder@netl.doe.gov

Alan E. Bland
Principal Investigator
Western Research Institute
365 North 9th Street
P.O. Box 3395
Laramie, WY 82072-3380
307-721-2386
abland@uwyo.edu