ALSTOM

Power Environment

Power Plant Laboratories

March 24, 2005

Ms. Karlene Fine
Executive Director
North Dakota Industrial Commission
600 East Boulevard Avenue
State Capitol, 10th Floor
Bismarck, ND 58505-0310

Re: ALSTOM Power Inc. – Power Plant Laboratories Proposal to North Dakota Industrial Commission Entitled "Field Demonstration of Enhanced Sorbent Injection for Mercury Control"

Dear Ms. Fine:

ALSTOM Power Inc. (ALSTOM) is pleased to submit a proposal to the North Dakota Industrial Commission (NDIC) titled "Field Demonstration of Enhanced Sorbent Injection for Mercury Control." Enclosed are the original, five copies, and a disk containing the PDF of the subject proposal and a $100 application fee. This proposal seeks NDIC funding as cost share of an existing DOE/ALSTOM program titled "Field Demonstration of Enhanced Sorbent Injection for Mercury Control" (DOE Cooperative Agreement No. DE-FC26-04NT42306).

The DOE/ALSTOM program seeks to conduct long-term demonstrations of ALSTOM's cost effective, sorbent-based mercury control technology at three host sites of which one is Basin Electric's Leland Olds Station. The program at Basin Electric will perform a seven-week long test campaign at the 220-MWe Leland Olds Unit 1 firing a North Dakota lignite coal and with an electrostatic precipitator (ESP) for air pollution control. The overall objective of the proposed work is to demonstrate a mercury control technology in coal-fired boilers that can achieve more than 70% mercury capture for various coal ranks and boiler configurations, with emphasis on lignite-fired boilers with ESPs. The potential for successful demonstration of ALSTOM's mercury control technology at a lignite-fired utility can help maintain lignite's viability as a utility fuel.

A world-class team has been assembled to conduct the field demonstrations of ALSTOM's mercury control technology. ALSTOM will lead this initiative with support from Dr. Steve Benson's group at the University of North Dakota – Energy and Environmental Research Center (EERC). PacifiCorp, Basin Electric Power Cooperative, and Reliant Energy will provide host sites for field demonstration. These host utilities and in addition Minnkota Power Cooperative, Inc. will serve on an industrial advisory board for the program.

ALSTOM is a global leader in power generation, environmental, and chemical process technology and has significant experience in studying and developing advanced combustion systems and air pollution control systems for fossil energy production. Over 40 percent of the free world's fossil generating capacity are of ALSTOM design. There are more than 500 ALSTOM designed coal-fired utility boilers in the U.S., which represent more than 40% of the total coal-fired generating capacity.

ALSTOM is committed to the successful demonstration and commercialization of this technology and is providing significant co-funding for the project. The Basin Electric demonstration is scheduled to be 13 months in duration with an expected start date of April 2005. The proposed project is budget estimated at $1,644,260. Of the amount, the Department of Energy (DOE) has committed $1,233,195 (75% cost share), and the balance of $411,065 (25% cost share) will be provided by ALSTOM and other team members (including NDIC). This proposal requests $200,000 funding from NDIC.

Please note that Appendix D – Detailed Budget Information (bound separately) in the enclosed proposal document contains ALSTOM confidential information.

We ask for your support in this technology demonstration. This proposal is valid for 120 days from the bid due date. Should there be any questions regarding this submittal, please contact Ray Chamberland, Manager, Contract R&D, Power Plant Laboratories, at (860) 285-3825.

Sincerely,

Woodrow A. Fiveland

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Ray P. Chamberland – ALSTOM Power Inc.

FIELD DEMONSTRATION OF ENHANCED SORBENT INJECTION FOR MERCURY CONTROL

Submitted to:

State of North Dakota
The Industrial Commission
State Capitol
Bismarck, ND 58505
Attn: Lignite Research Program

Amount of Request: $200,000

Submitted by:

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ABSTRACT

ALSTOM Power Inc. (ALSTOM) herein proposes a consortium-based program to demonstrate Mer-Cure™ technology – ALSTOM's cost-effective, sorbent-based mercury control technology – in Basin Electric's Leland Olds Station. The program is to perform a seven-week long test campaign in Basin Electric's 220-MW_e Leland Olds Unit 1 firing a North Dakota lignite coal and with an electrostatic precipitator (ESP) for air pollution control.

The overall objective of the work is to demonstrate a mercury control technology in coal-fired boilers that can achieve more than 70% mercury capture for various coal ranks and boiler configurations, with emphasis on *lignite-fired boilers with ESPs*. In ALSTOM's Mer-Cure™ technology, sorbents with chemical additives that promote oxidation and capture of elemental mercury are injected into an environment where the kinetics is favorable. Installation of ALSTOM mercury control technology has low-capital costs (approximately \$5/kW_e). The mercury control technology also requires a relatively small amount of enhanced sorbents, which results in low operating costs (0.5-0.75 mills/kWh) and minimal impact on balance-of-plant aspect.

In this program, ALSTOM teams up with the University of North Dakota – Energy and Environmental Research Center (EERC), Basin Electric Power Cooperative (Basin Electric), and Minnkota Power Cooperative, Inc. (Minnkota Power).

This proposal requests \$200,000 from NDIC. The total cost of the proposed project is \$1,644,260. Of the amount, the Department of Energy (DOE) has committed \$1,233,195 and the balance of \$411,065 will be provided by other team members (including NDIC.)

PROJECT SUMMARY

ALSTOM Power Inc. (ALSTOM) is applying to the North Dakota Industrial Commission (NDIC) for a grant of $200,000 for a consortium-based program to demonstrate ALSTOM's novel, sorbent-based mercury control technology in Basin Electric Power Cooperative (Basin Electric) Leland Olds Station 1, Stanton, ND. The project requires $1,644,260 of funding, of which the Department of Energy (DOE) has committed $1,233,195 and the balance of $411,065 will be provided by other team members (including NDIC).

The Leland Olds Station campaign is part of a $4,980,821 program that has been recently awarded by the U.S. Department of Energy (DOE/NETL Cooperative Agreement No. DE-FC26-04NT42306) for full-scale demonstration of ALSTOM's Mer-Cure™ technology in three host sites. The two additional host sites are: PacifiCorp's 220-MW_e Dave Johnston Unit 3 burning a Powder River Basin (PRB) coal, and Reliant Energy's 170-MW_e Portland Unit 1 burning an Eastern bituminous coal. DOE's commitment to the program is $3,735,616, and other consortium members' commitment so far is $1,045,205.

In the Leland Olds demonstration program, ALSTOM teams up with the University of North Dakota – Energy and Environmental Research Center (EERC), Basin Electric Power Cooperative (Basin Electric), and Minnkota Power Cooperative, Inc. (Minnkota Power). Basin Electric Power Cooperative has executed a host site agreement on January 7, 2005 to commit the availability of host facility and the in-kind cost share. The full-scale demonstration program is to perform a seven-week long test campaign in Basin Electric's 220-MW_e Leland Olds Unit 1 burning a North Dakota lignite coal and equipped with an electrostatic precipitator (ESP). With a very low chlorine lignite coal and relatively high flue gas temperature entering the ESP, the Leland Olds site represents one of the most challenging boiler configurations for mercury control.

The demonstration program will include installation of equipment for ALSTOM's mercury control system, its operation, and measurement of mercury species concentrations in the flue gas before and after sorbent injection and particulate control devices. The mercury control system will be operated with different enhanced sorbents and at different injection rates to determine mercury removal.

The EERC will participate in the program by providing mercury measurement expertise for the campaign. Continuous mercury monitoring (CMM) will be carried out throughout the test period by installing CMM monitors before and after the ESP to provide both elemental and oxidized mercury concentrations in the stack gas. Ontario Hydro (OH) method will also be employed for some of the key test conditions to verify CMM data and to ensure quality assurance (QA) and quality control (QC) of the measurements.

In ALSTOM's mercury control technology, a small amount of sorbent is injected into the flue gas stream for oxidation and adsorption of gaseous mercury. The sorbents are activated carbon-based and prepared with chemical additives that promote oxidation and capture of elemental mercury. The technology had been successfully demonstrated both in bench-scale and pilot-scale test programs. The pilot-scale data collected from the EERC facility showed more than 90% removal with less than 2 lb/MMacf of sorbent in contrast to only 60% removal with standard AC injection at greater than 10 lb/MMacf. This pilot-scale testing was conducted while firing the lignite coal used in Leland Olds Station 1 and with an ESP. Recent full-scale testing in a boiler with an ESP firing a PRB coal also showed similar results.

ALSTOM's mercury control technology applied to coal-fired power generation has the potential to be a cost-effective mercury control technology for the entire spectrum of coals ranging from lignite (by far the most challenging coal type) to sub-bituminous and bituminous coals. As the technology is based on oxidation and adsorption of mercury, it is also applicable to all air pollution control configurations including wet scrubber and spray dryer-ESP/baghouse units. The main focus of the project, however, is for a lignite coal-firing boiler with a cold-side ESP as the particulate control device. Cold-side ESPs represent over 70% of the coal-fired boilers in the United States. The mercury control technology has low-capital costs (approximately $5/kW$_e$). It also requires a very small amount of low-cost additives for treatment, which results in low operating costs (0.5-0.75 mills/kWh) and minimal balance-of-plant (BOP) impact.

1. PROJECT DESCRIPTION

1.1 Introduction

ALSTOM's consortium-based program has been designed to demonstrate ALSTOM's novel, sorbent-based mercury control technology in coal-fired boilers burning coals of various ranks. The grant ALSTOM is seeking for from NDIC is for one of the three test campaigns to be performed in the DOE-awarded field demonstration program. In the program, ALSTOM teams up with the EERC, Basin Electric, PacifiCorp, Reliant Energy, and Minnkota Power.

The overall objective of the work is to develop and demonstrate a mercury control technology in coal-fired boilers that can achieve more than 70% mercury capture for various coal ranks and boiler configurations, with emphasis on *lignite-fired boilers with ESPs*. In ALSTOM's Mer-Cure™ technology, sorbents with chemical additives that promote oxidation and capture of elemental mercury are injected into an environment where the kinetics is favorable. Installation of ALSTOM mercury control technology has low-capital costs (approximately $5/kW$_e$). The mercury control technology also requires a relatively small amount of enhanced sorbents, which results in low operating costs (0.5-0.75 mills/kWh) and minimal impact on BOP aspect.

The full-scale demonstration program is to perform a seven-week long test campaign in Basin Electric’s 220-MWe Leland Olds Station. Basin Electric’s Leland Olds Unit 1 in Stanton, ND, fires a ND lignite coal. The unit has a 220-MW_e boiler equipped with two ESPs with an inlet temperature of 375°F operating in parallel. The unit has one tubular air heater for primary air and two Ljungstrom air heaters for heating secondary air.

The test program includes installation of equipment for the mercury control system, its operation under various firing conditions and measurement of elemental and oxidized mercury concentrations in the flue gas. The testing will include a one-week baseline mercury measurement and two weeks of parametric testing, followed by a four-week long-term testing. During the two-week parametric testing, the ALSTOM mercury control system will be operated with sorbents of several formulations at different sorbent injection rates to determine mercury oxidation and removal efficiencies. The optimum sorbent formulation and injection rate will be selected for the four-week testing to evaluate its long-term performance.

The EERC will participate in the program by providing mercury measurement expertise. CMM will be carried out throughout the test period by installing two CMM monitors after the ESP to provide both elemental and oxidized mercury concentrations in the stack gas. Ontario Hydro method will also be employed for some of the key test conditions to verify CMM data, to obtain mercury concentration and speciation measurements at ESP inlet, and to ensure QA and QC of the measurements.

ALSTOM’s mercury control technology applied to coal-fired power generation has the potential to be a cost effective mercury control technology for the entire range of coals (lignite, sub-bituminous, and bituminous) and, in particular, the more challenging coals (for example, lignite coal). This technology is applicable to all air pollution control configurations including ESPs, which represents 70% of the installed base in the United States.

1.2 Background

Mercury Emission Control Challenges for Lignite Coals: In general, lignite coals are unique because of highly variable ash content, ash that is rich in alkali and alkaline-earth elements, high oxygen levels, high moisture levels, and low chlorine content. Lignite coals typically contain comparable levels of mercury but significantly lower levels of chlorine compared to bituminous coals. Lignite coals have chlorine concentrations well below 200 ppm in the coal, whereas Appalachian and Illinois Basin bituminous coals can have chlorine levels in excess of 1000 ppm. These differences in composition have been shown to have important effects on the form of mercury emitted from a boiler and the capabilities of different control technologies to remove mercury from flue gas.

Coals containing chlorine levels greater than 200 ppm typically produce flue gas dominated by *more easily removable* mercuric compounds (Hg^{2+}), most likely mercuric chloride ($HgCl_2$). Conversely, experimental results indicate that low-chlorine (<50-ppm) coal combustion flue gases (typical of lignite) contain predominantly Hg^0, which is *substantially more difficult to remove* than Hg^{2+}. Additionally, the generally high alkali and alkaline-earth contents of lignite coals may reduce the oxidizing effect of the already-low chlorine content by reactively scavenging chlorine species (Cl, HCl, and Cl_2) from the combustion flue gas. The level of chlorine in flue gases of recently tested lignite coals from North Dakota and Saskatchewan ranged from 2.6 to 3.4 ppmv, with chlorine contents ranging from 11 to 18 ppmw in the coal on a dry basis, respectively.

Very little published data exist demonstrating the effectiveness of oxidation technologies for plants firing lignite coal. Lignite-fired power plants have shown a limited ability to control mercury emissions in currently installed ESPs, SDAs, and wet FGD systems. This low level of control can be attributed to the high proportions of Hg^0 present in the flue gas.

In the next subsections, technical background information is presented further for mercury oxidation and capture.

***Temperature and Chlorine Content Affect Mercury Oxidation*:** Mercury oxidation with chlorine to form $HgCl_2$ can occur below about 1150°F as predicted by equilibrium calculations.[1] Above this temperature, mercury must exist in the elemental form. An increasing fraction of oxidized mercury can form as the temperature decreases below about 800°F. However, kinetics is slow, limiting this conversion.

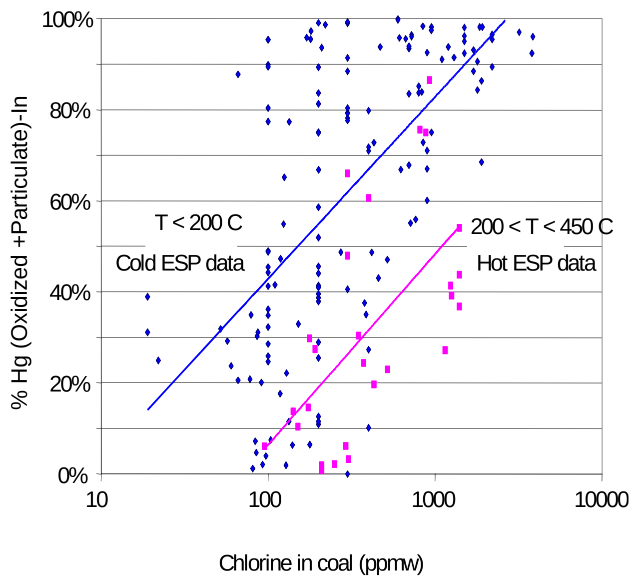


Figure 1 Mercury speciation at ESP inlet from boilers firing various coals and equipped with cold-side and hot-side ESPs as a function of coal chlorine content[5]

Data on mercury speciation from full-scale utility boilers show a varying mixture of particulate, elemental and oxidized mercury entering flue gas cleaning devices (Figure 1). Utility boiler field-test data show that the chlorine content of the coal has some impact on the speciation of mercury at the inlet to the air pollution control device[2, 3]. While there is significant scatter in data, coals with low chlorine content (less than 100 ppmw) yield predominantly Hg^0 in the flue gas, whereas flue gas from coals containing higher chlorine contents (more than 500 ppmw) have relatively little Hg^0.

The other important piece of information derived from Figure 1 is that, in the case of coal-fired boilers equipped with hot-side ESPs, mercury oxidation also occurs to a significant extent. This suggests an opportunity to employ a technology that can augment the inherent oxidation process.

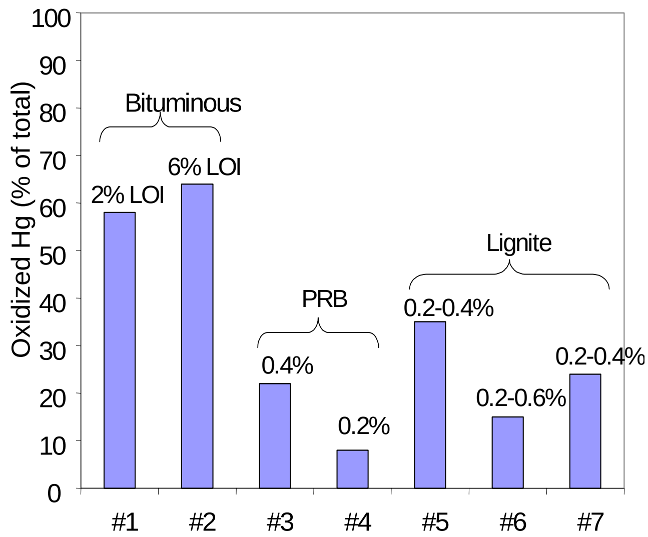


Figure 2 Mercury speciation at ESP inlet at baseline conditions for different fuels fired in a pilot-scale facility[9]. Numbers above the bars indicate LOI (%)

Unburned Carbon (LOI) in Flyash Captures Mercury:

In their detailed kinetic modeling and measurements, Niksa and Fujiwara[4] concluded that the heterogeneous mechanism (with carbon) was essential to describe mercury oxidation in utility flue gases. In the absence of carbonaceous particles, less than 10% oxidation was observed in lab-scale tests[5] even with high HCl levels in the flue gas (up to 300 ppm). The level of oxidized mercury is proportional to the level of unburnt carbon (Figure 2) at the inlet to the particulate control devices. In flue gases from the combustion of low rank fuels (lignite and PRB coals), oxidized mercury concentrations are low (~20%) compared to bituminous coals (~60%). A low unburned carbon concentration for low rank fuels results from their high reactivity. Several studies have validated this phenomenon including tests performed by us and others[2, 6, 7]. For lignite and PRB coals, unburned carbon levels remain very low (0.5-0.8%) and would not significantly enhance mercury oxidation.

Depending on the adsorption characteristics of the carbon and temperature, Hg^{2+} may be released into the gas or retained as Hg^{p}. While both carbon and chlorine contents affect the oxidation, the fraction of Hg^p is determined by the unburned carbon content in the fly ash and the amount of Hg^{2+} available to be adsorbed.

Air Pollution Control Devices Affects Mercury Capture:

The overall mercury removal across the air pollution control system is a function of the device configuration and the fuel type as shown in Figure 3[8]. Based on the above discussion, cold-side ESPs and fabric filters exhibit increased capture of mercury with bituminous coals due to increased oxidized mercury. Units that burned bituminous coals and were equipped with a cold-side ESP had an average removal of 36%. In contrast, units that burn sub-bituminous coals exhibit little capture of Hg in an ESP. Fabric filters, which constitute only about 9% of the existing units, have better Hg removal for both bituminous (90%) and sub-bituminous (72%) coals compared to ESP. This is because of the additional removal that occurs as the flue gas passes through the filter cake.

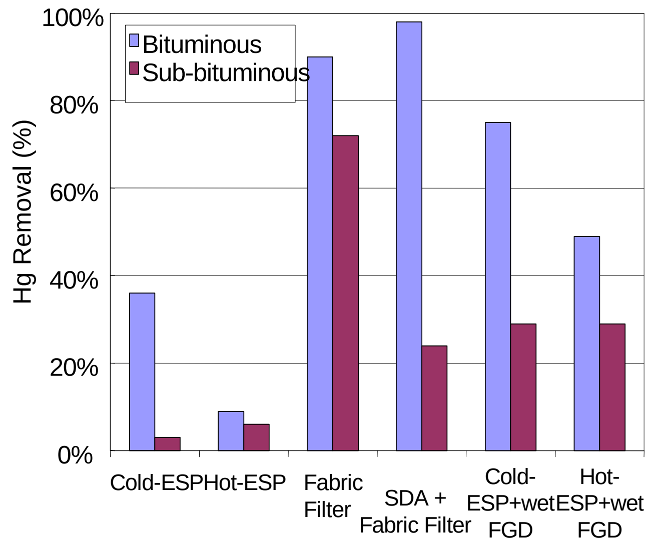


Figure 3. Average Removal across different post-combustion emission control system for pulverized coal-fired boilers[8]

The ICR data[3] show that the presence of a flue gas desulfurization system downstream of particulate control device provides additional capture of mercury as the vapor Hg^{2+} is removed to a significant extent (80-90%). The only case where the scrubber is deleterious to mercury capture is the combination of a spray dryer absorber and a sub-bituminous coal, where the alkalinity in the scrubber consumes the chlorine species and lowers mercury oxidation and subsequent capture. In all cases, therefore, it is desirable to oxidize mercury before the scrubber to the highest extent possible, so that the Hg^p fraction can be maximized and that portion removed in the ESP or fabric filter and any remaining oxidized mercury removed in the scrubber.

To summarize the current understanding, (i) the two essential species for effective oxidation and capture of mercury are carbon and oxidants such as chlorine and (ii) the oxidation kinetics is faster at a higher temperature. This is exploited in our approach.

Methods for Mercury Oxidation and Capture: Powdered AC injection is the most mature technology for mercury control. . EERC's pilot-scale ESP and TOXECON™ (injection between an ESP and fabric filter-FF) Hg removal efficiencies for Fort Union lignite coals from Saskatchewan and Poplar River and Freedom coals from North are shown in Figure 4. These are compared to DOE test data obtained at full-scale utility boilers, with carbon injection into a bituminous coal combustion flue gas upstream of a TOXECON™ (pulse-jet FF) and into bituminous and PRB sub-bituminous coal combustion flue gases upstream of an ESP. As shown, coal type, is an important parameter that affects the Hg removal efficiency of a control device. The pilot-scale results for lignite show the need for significantly higher injection rates to achieve the same performance as for tests with eastern bituminous coals using the same configuration. These higher sorbent requirements for lignite-fired units will translate into higher operating and capital costs if this issue is not resolved.

In previous demonstration projects, ADA-ES and EPRI tested injection of AC upstream existing ESPs. For a PRB coal, less than 65% removal was achieved at injection rates approaching 30 lb/MMacf (Figure 4). For a bituminous coal, 90% removal was achieved at an injection rate of 20 lb/MMacf. The injection of a large amount of AC results in high operating costs. EPRI and ADA-ES[16] are also demonstrating installation of a baghouse after an existing particulate control device and injection of carbon upstream the baghouse (TOXECON™). While this allows continued utilization of ash and high removal efficiency at low sorbent consumption, it requires initial capital investment of approximately $50/kW.

Other studies have evaluated various methods for enhancing mercury oxidation in the flue gas. Richardson, et al.[11] has investigated boiler addition of low-cost chemical reagents to increase flue gas mercury oxidation. Chloride-containing salts were added to a boiler firing lignite and PRB coals in concentrations equivalent to 70 to 100 ppm HCl in the flue gas. Fifty to 80% mercury oxidation was achieved. Only 50% were removed across a spray dryer-baghouse and 30% across a wet particulate scrubber. However, significant operational impacts were observed during testing including air heater pluggage, increased stack opacity, and indications of increased corrosion and slagging in the boiler. Mercury removal was lower than mercury oxidation.

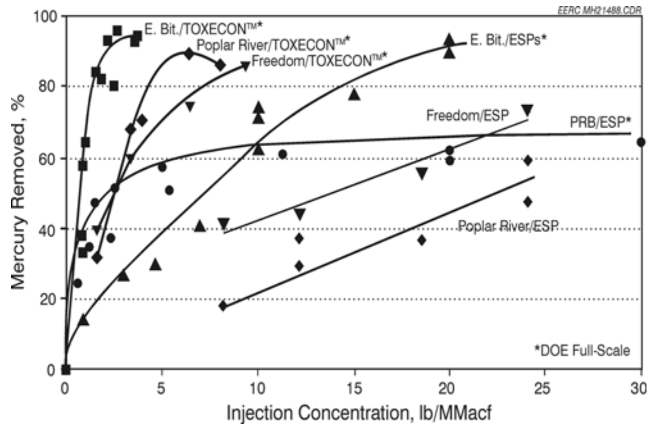


Figure 4. Mercury capture data with AC injection in full-scale and pilot-scale tests

EPRI has also been developing a mercury control technology known as MerCAP™ (gold-coated plates) wherein a mercury-absorbing sorbent coated structure is placed in the existing ductwork at the ESP outlet[10]. Tests to date have indicated 80% mercury removal with scrubbed flue gas. MerCAP did not perform well in non-scrubbed flue gas. Its performance also degraded with time due to fouling from ash leaving the particulate control device and adsorbent poisoning. Tests are underway to improve the performance, address operational issues and decrease overall costs.

1.3 ALSTOM's Mer-Cure™ Technology

In our approach, we take advantage of the research conducted so far and described in previous sections and the mechanistic understanding developed to identify the critical areas that need to be augmented to maximize mercury oxidation and capture. The approach for enhanced mercury capture is:

(1) pre-treatment of activated carbon (AC)-based sorbent with proprietary additive that enhances mercury oxidation;

(2) injection methodology that ensures dispersion and uniform distribution of sorbent in the flue gas; and

(3) injection into a flue gas environment that is favorable for accelerated mercury chemistry and retention.

1.4 Technical Feasibility and Readiness for Long-Term Field Testing

ALSTOM performed detailed and extensive laboratory-scale and pilot-scale testing to validate the performance of its mercury control technology. Laboratory-scale evaluation of the technology was performed in in-house combustion test facilities and the supporting data is presented in this section. As described below, pilot-scale evaluation of the technology was performed in conjunction with EERC at their pilot-scale pulverized coal combustion test facility under separate joint DOE and ALSTOM funding. Based on the superior performance of our methodology compared to standard carbon injection upstream a particulate control device in these tests, we are ready to take the next critical step of demonstration at full-scale.

Laboratory-Scale Test Data: ALSTOM used a unique laboratory-scale sorbent test facility to evaluate the impact of process conditions on mercury capture performance of various sorbents. The facility was designed to address several unique issues associated with mercury testing such as (a) minimizing loss of mercury to duct; (b) a relevant cooling profile for the flue gas; and (c) utilization of a mini-precipitator to separate the entrained sorbent/ash from flue gases before mercury concentration measurements, thus enabling ESP-performance simulation.

A PRB coal with an average of 0.09 ppmw Hg and 100 ppm chlorine was used in the tests. Sorbent was injected at various process conditions in these tests. With this configuration, typical residence time between injection and collection was approximately 1 sec. The sorbent is injected into the flue gas at the top of the reactor that would simulate various locations in the duct leading to the ESP in a full-scale plant.

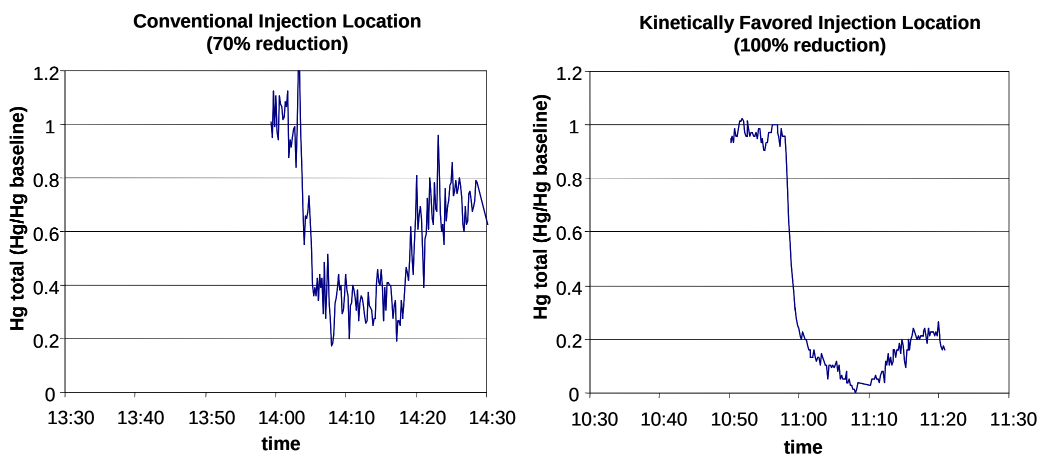
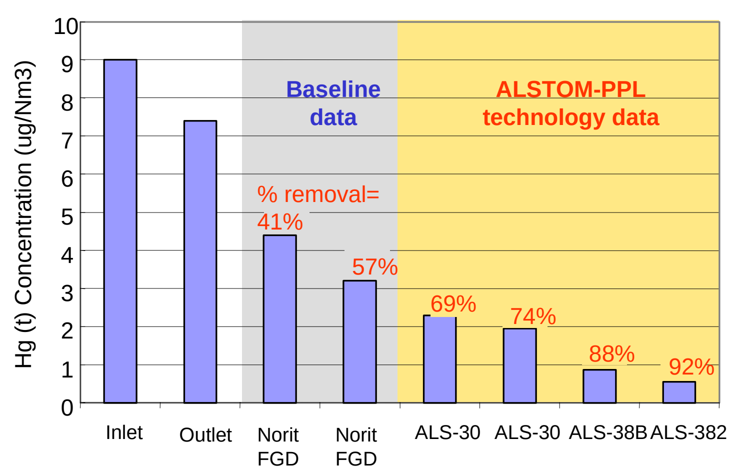


Figure 5. Mercury oxidation and capture data with sorbent injection in the laboratory-scale test facility as a function of injection temperature

As shown in Figure 5, an instantaneous drop in mercury concentration occurs upon injection of "active" sorbents and under "ideal process" conditions, followed by a slower decrease over a longer time frame. This slow decrease is due to the residual wall effects that have not completely been eliminated. When sorbent injection is stopped, there is an instantaneous recovery in the mercury concentration. The system is dismantled and cleaned between each test to achieve the same starting test condition.

In most tests, the elemental mercury concentration was close to that of the total mercury, indicating that any oxidized mercury was captured by the sorbent. This also indicates that mercury oxidation is the rate-limiting step in mercury capture. Several additive formulations were tested in the bench-scale facility and the best performing candidates selected for further testing in the pilot-scale tests.

Pilot-Scale Test Data: The potential for enhancement in mercury capture with ALSTOM Mer-Cure™ technology is provided by pilot-scale tests performed at EERC (Figure 6). In these tests, the mercury control technology was employed with sorbent injection at an "ideal location." This was compared to current industry standard: Norit Darco FGD™ sorbent injection with injection at 300°F upstream an ESP. The pilot facility is a 0.7 MMBtu/hr pulverized coal-fired unit. A North Dakota lignite coal from Freedom mine was fired during this test. The coal had 0.9% sulfur, 20 ppmd chlorine, and 77 ppbd Hg. The facility was equipped with a single-wire, tubular ESP operating at around 300°F. The specific collection area of the ESP was 125 ft^2/kacfm. Measurements were conducted using CMM for both elemental and total mercury and validated with selective OH measurements.



Sorbent Feed Rate (lb/MMacf)			3.75	15.0	1.1	2.5	1.9	1.5

Figure 6. Mercury oxidation and capture data with ALSTOM technology in a pilot-scale pulverized coal-fired test facility

<u>The lignite coal-ESP configuration is one of the most difficult combinations for mercury control.</u> The very low levels of unburned carbon in ash (typically 0.6% in these tests), due to the high reactivity of the fuel, and the very low chlorine content (20 ppm in coal), results in the mercury in the flue gas to be present mainly in the

elemental form. Close to 85-90% of the total mercury in the flue gas in this case was elemental. Mercury oxidation and capture results, presented in Figure 6, show that greater than 90% mercury removal is possible at sorbent injection rates around 2 lb/MMacf with ALSTOM's mercury control technology. This is in contrast to less than 55 % removal with injection rates of 15 lb/MMacf with the standard sorbent injected at 300°F upstream the ESP. During the pilot-scale tests multiple sorbent formulations were evaluated (Figure 6) and the relative performance of the sorbents in the pilot-scale tests was identical to the laboratory-scale. For the full-scale demonstration program, we selected the best performing sorbent-additive combinations in these tests for further evaluation.

Removal data as a function of sorbent feed rate in the pilot-scale tests are shown in Figure 6 and contrasts it to standard injection of pulverized AC in the pilot unit. These data show that high levels of mercury oxidation and capture are not possible with standard activated carbon injection with an ESP configuration and with lignite-derived flue gas, irrespective of the using very high feed rates. With ALSTOM technology, more than 90% removal is achieved with less than 2 lb/MMacf of sorbent injected for the same configuration.

Comparison to field data from DOE-sponsored demonstration tests for both bituminous and PRB coal for an ESP configuration is also provided in Figure 7,[11]

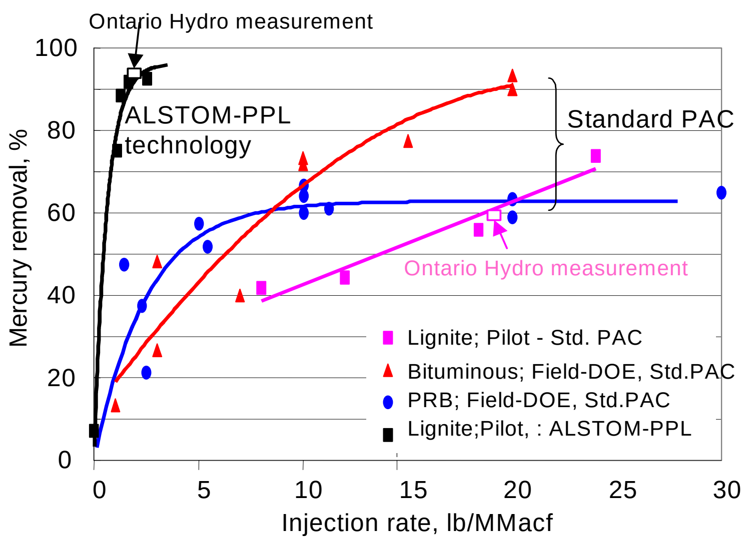


Figure 7. Mercury oxidation and capture data with ALSTOM technology in a pilot and full-scale pulverized coal-fired facilities with an ESP, as a function of sorbent feed rate

confirming the significantly lower feed rate of the sorbent and superior performance with the proposed mercury control technology. Data at the ESP outlet indicate that little difference between elemental and total mercury using the CMM, again confirming that most of the oxidized mercury is captured and predominantly all of the mercury emission from the ESP is in the elemental form.

In summary, the laboratory and pilot-scale data show sufficient justification to scale-up and demonstrate the technology at a utility boiler. With the proposed technology, very low sorbent injection rates are required to achieve very high mercury oxidation and removal even with very low chlorine coals and low unburned carbon in ash. The low sorbent injection rate also translates to minimal BOP impact including those on ESP operation.

1.5 Benefits of Proposed Technology

Carbonaceous sorbents, such as activated carbon, are typically used to remove mercury from flue gases, by injection upstream an ESP or fabric filter. Mercury removal is particularly difficult for lignite coals compared to bituminous and subbituminous coals because of the higher proportion of elemental mercury in the flue gas. A fabric filter captures mercury to a higher degree compared to an ESP due to enhanced gas-sorbent contact. However, the majority of the population of existing units in the US has an ESP.

Retrofitting existing units with a fabric filter is capital intensive (~\$50/kW$_e$); however, sorbent consumption which comprises the predominant portion of the operating costs are about 4 lb/MMacf, and at \$0.5/lb, translates to \$1.2 million/year for a 500 MW$_e$ plant. On the other hand, sorbent consumption (standard powdered activated carbon) for straight injection upstream an existing ESP is high (factor of up to 10 vis-à-vis fabric filters), with lower levels of mercury capture. At 15 lb/MMacf sorbent injection rates for this case, annual operating costs translate to

$4.5 million for a 500 MW_e unit, while capital costs are between $5-10/$kW_e$.

ALSTOM's approach herein does not require installation of a fabric filter. Capital costs with our ALSTOM approach are expected to be between $5-10/$kW_e$ similar to other sorbent injection approaches upstream the existing ESP, while sorbent consumption is expected to be comparable to a fabric filter (2-4 lb/MMacf). At $0.75/lb sorbent for an estimate for the sorbent cost, annual operating costs for ALSTOM's mercury control technology at a 500 MW_e boiler is expected to be around $0.9-1.8 million per year. The estimate for unit sorbent cost has been obtained from discussion with multiple sorbent suppliers and factoring in the cost for incorporation of the additives into the sorbent.

Our approach for mercury oxidation and capture has a broad applicability to all fuels, fuel blends and air pollution control system configurations. By the choice of a sorbent injection location where mercury chemistry is most favorable for oxidation and capture, we can achieve mercury oxidation and capture upstream existing ESPs, fabric filters or scrubbers. For one of the difficult combinations of a lignite coal (low chlorine) and dry scrubber, our methodology will be particularly applicable, as we achieve mercury oxidation upstream the scrubber, which can then be translated to a high removal of the oxidized mercury in the scrubber.

1.6 Anticipated Balance of Plant Impacts

The BOP impact of ALSTOM technology can be evaluated based on the amount and composition of materials injected into the boiler flue gas. The material we are injecting is based on powdered activated carbon. Typical composition of this material is about 60-65% carbon and remainder ash. It has a composition similar to coal char (unburned carbon), since this material is derived from gasification of bituminous or lignite coals.

The sorbent injection rate with the proposed technology is expected to be below 5 lb/MMacf. At this rate, carbon-in-ash contents will increase from a baseline value of around 0.5% for case of PRB and lignite coal firing to 1.5-2% (with sorbent injection), while it will increase from a baseline value of approximately 10% in case of bituminous coal firing to 11% (with sorbent injection). These small increases are expected to have a negligible impact on ESP performance. Much higher injection rates in earlier full-scale studies showed no impact on ESP performance and opacity.[11]

Another concern would be the impact on the air heater due to sorbent injection with our technology. We have determined from TGA analysis that our sorbent material has a similar combustibility as unburned carbon in the fly ash and that it would not be expected to burn. Even if all the sorbent were completely burnt, the estimated temperature rise in the flue gas would only be around 3^{o}F.

The impact of the additive used with the sorbent is also very small. Typical additive concentrations are below 5% of the sorbent. Testing at the operating temperatures with the sorbent-additive combination has shown that it is tightly bound to the carbon (in fact this is one of our selection criteria). Even if it were released to any significant extent, it would be too small a quantity to cause any fouling or corrosion of the air heater or downstream ducts. This is in strong contrast to other oxidation methods where halogen compounds are introduced into the boiler at significant concentrations (equivalent to 500 ppm in coal) and can cause fouling and corrosion of boiler components, particularly under low-NO_x conditions.

Previous studies have also shown that the mercury captured on activated carbon has very low leachability and we expect the same behavior with our technology.[12, 13] We do not anticipate any increase in leachability of mercury or other heavy metals in the collected ash.

At this time, we anticipate that the collected ash would be unsuitable for use in concrete applications, due to the potential for interaction of the carbonaceous sorbent and air-entraining additives. However, most of the ash (greater than 75%)[14] from coal-fired boilers in the U.S. is currently land-filled, and, in this case, would not be expected to be impacted by carbonaceous sorbent that is added in small amount to the flue gas with our technology.

1.7 Technical Approach and Work Plan

Project Objectives: The overall objective of the proposed work is to perform full-scale demonstration of ALSTOM mercury control technology in a coal-fired boiler with the most challenging configuration. In the program, ALSTOM will demonstrate that greater than 70% of gaseous mercury in the flue gas can be captured by injection of enhanced sorbent at a feed rate significantly lower than required by standard AC for all the cases. ALSTOM will also collect performance data (sorbent consumption vs. removal efficiency) that can be used to accelerate commercialization of our mercury control technology.

In previous in-house development projects, ALSTOM has demonstrated, both in bench-scale and pilot-scale testing, the technical feasibility of ALSTOM technology as a means to maximize oxidation of elemental mercury and its subsequent capture before the stack. ALSTOM believes that our mercury control technology offers a great opportunity for utility companies to control mercury in the most cost-effective manner. ALSTOM is committed to commercialize the technology and believes that the full-scale demonstration of the technology is a critical step to commercialization.

Host Site Description: The proposal requests a grant for testing in Basin Electric's Leland Olds Unit 1. Basin Electric's Leland Olds Unit 1 is a 220 MW_e unit firing North Dakota lignite coal from the Freedom mine. The unit is equipped with B&W cell burners and does not have any NOx or SOx control devices. The unit has two Ljunstrom air heaters for secondary air and a tubular air heater for primary air. Its cold-side ESP has a specific collection area of 320

ft^2/kacfm. Currently the collected flyash is not utilized. Most of the mercury in the flue gas is in the elemental form and very low removals are observed (~ 2%) in recent measurements by EERC (Table 1). Also listed in Table 1 is the information of the other two host sites where the field demonstration will take place as part of the DOE awarded program (shaded columns).

Table 1. Host site, coal and emission data for the field demonstration

	BASIN ELECTRIC	PACIFICORP	RELIANT ENERGY
Unit	Leland Olds Unit 1	Dave Johnston Unit 1	Portland Unit 1
Capacity (MW_e Gross)	220	110	172
Operation	Base-loaded	Base-loaded	Cycling 170 MW_e – peak 75 MW_e – off-peak
NO_x and SO_2 control	No low NO_x Low sulfur coal	No low-NO_x Low sulfur coal	Low-NO_x - LNCFS No sulfur control
Air Heater	Ljungstrom + Tubular	Ljungstrom	Ljungstrom
Particulate control (SCA in ft^2/kacfm)	CS-ESP (320)	CS-ESP (706)	CS-ESP (284)
Ash utilization	Disposal	Disposal	Disposal
Coal	ND lignite; ND lignite-PRB blend	PRB	Federal #2 Pittsburgh seam coal
Higher Heating Value As-received(lb/MMBtu)	Lignite 6617	8,608	12,889 14,933 (dry)
S in coal (%)	0.63	0.43	2.26%
Ash %	9.86	5.31	7.36%
Cl in coal (ppmwd)-dry		92 – 95	1,393
	Lignite coal data	PRB coal data	Bituminous coal data
Hg in coal (ppmwd)-dry	0.057-0.099	0.071-0.083	0.1-0.16
As-fired Hg level from Coal ($\mu g/Nm^3$)	6-10	7-9	10-16
Inlet Hg* (Hg^T, Hg^p,Hg^{ox},Hg^{el}) ($\mu g/Nm^3$)	T-7.9; PM-2.0; Ox-0.1; El-5.8- March ’03	T – 10.1 (April’04); 0.6% LOI T-10.7; PM-9.1; Ox-0.2; El-1.4 (Feb ’03)* 1.3% LOI	T-9.1; PM-0.9; Ox-7.4; El-0.8$^+$
Uncontrolled Hg Emission* Stack (Hg^T, Hg^p, Hg^{ox}, Hg^{el}) ($\mu g/Nm^3$)	T-7.8; PM-0.0; Ox-1.4; El-6.4- March ’03	T – 7.3 (April ’04) T-2.7; PM < 0.13; Ox-1.2; El-1.4 (Feb’03)*	T-7.5; PM-0.0003; Ox-5.2; El-2.3$^+$ after ESP, before scrubber
Removal Efficiency	2% - March’03	38.3 % - April ’04 75% - Feb.’03	17%$^+$
Removal Efficiency (ICR data)	12-25%	8.5 – 12%	36% for bituminous coals with CS-ESP
Carbon-in-ash	< 0.2%	0.5-1.6%	10-12%
Particulate Removal Efficiency/Opacity	<10% opacity	98.5% 7-10% opacity	< 5% opacity
Flue gas temperature (ESP Inlet)	375°F	276°F	277°F – full load 252°F – Min Load

*Unit 2 data. Unit 2 similar to Unit 1 & fires similar coal
$^+$Data from 150 MWe AES-Cayuga (CE-LNCFS III with an ESP/scrubber) burning similar Pittsburgh seam coal with 2.3% S, 0.09% Cl and 0.1 ppmd Hg

The four major tasks to be performed for the demonstration project are:

Task 1. Design, Engineering and Fabrication of the Mercury Control System

Task 2. Field Demonstration

Task 3. Technology Transfer

Task 4. Program Management and Reporting.

Detailed description of the four tasks is as follows:

Task 1. Design, Engineering and Fabrication: ALSTOM's mercury control technology requires injection of chemically enhanced sorbent into the flue gas stream where the kinetics are favorable for mercury oxidation and capture. In this task, ALSTOM's system will be sized and designed specifically for the test site.

The task will begin with an initial visit to the host site for preliminary site evaluation. At the site, ALSTOM engineers and site personnel will thoroughly review plant arrangements, site operations, baseline mercury emission levels and other plant data available since proposal submission. At this early stage, any additional mercury measurement data will be obtained as needed. This initial review of site-specific information will be aimed at optimized design of the mercury control system, the test matrix/program, and at ensuring adequacy and integrity of the planned test campaign at the specified site.

The mercury control system is composed of three components: a sorbent storage system, a sorbent delivery system, and a sorbent distribution system. The sorbent storage system is a portable system that can handle up to three 900-lb bags of sorbent. The sorbent delivery system will be operated over a range of sorbent feed rates to determine the impact on mercury capture. The sorbent distribution system consists of a flexible hose and interconnecting pipes leading up to injection lances. These will be designed to ensure uniform distribution of the sorbent in the flue gas duct. The system will be designed using Fluent, a Computational Fluid Dynamics

(CFD) software package. The system components to be fabricated and tested at ALSTOM Windsor site will be made modular and mounted on a trailer so that transport, maintenance and modification, if necessary, can be made quickly in the middle of the test campaign. As part of the testing preparation, injection ports will be installed in predetermined locations during outage prior to test period.

Task 2. Field Demonstration: The field-testing to be carried out in the test site will last seven weeks. For successful execution of the project, ALSTOM will communicate closely with the plant personnel of the test site and the EERC mercury measurement crew. Roles and scopes of each of the project team members for the demonstration program will be clearly defined and any potential operational issues of the plant and plant equipment will be thoroughly discussed. ALSTOM will also work closely with the environmental personnel of the plant to help obtain an environmental permit for the testing from the State Department of Environmental Quality. ALSTOM and the project team members will also develop quality assurance/quality control plan on the overall test program.

Most of the mercury control system will be assembled in ALSTOM site on a trailer and transported to the host site. Utilities such as electrical power will be connected to the assembled system before testing. Each of the systems will be checked out and finally commissioned by ALSTOM test crew. During the checkout, the EERC will identify appropriate locations for the two CMM monitors and OH measurements at the ESP inlet/outlet. The sampling ports will be installed by plant personnel prior to testing.

Once the systems have been set up, the project team will carry out a total of seven week testing (12 hrs/day): 1 week for baseline measurement, 2 weeks for parametric testing, and four weeks for long-term testing.

The parametric testing will begin as soon as the baseline mercury levels have been established. Injection of sorbents will take place at feed rates from 1 to 5 lb/MMacf. The feed rates will be varied during the tests in order to construct a sorbent consumption-mercury removal curve.

For a given test condition, sorbent injection will be performed over 8-12 hour period, and the mercury concentrations from the unit allowed to recover for the subsequent 12-16 hours before the next test condition. Baseline mercury concentration measurements will be obtained before each sorbent injection test in order to determine mercury capture efficiency. The two CMMs to be installed around the ESP will allow rapid measurements of mercury species concentrations for various test conditions. OH measurements will be carried out for selected test conditions in order to substantiate the mercury CMM data (Figure 8). Throughout the testing, the test crew will adhere to the procedure that will ensure tight QC and QA. For example, the CMMs will be calibrated before and after tests with zero and span drift checks.

Solid samples (coal and ESP ash) will be collected throughout the test period. Representative 5-gal bucket samples will be taken from the ESP over the course of the test campaigns. These include three buckets from baseline testing, three buckets from selected parametric test conditions and three buckets from long-term testing. These bulk ash samples will be sent out to DOE contractors for by-product characterization. Independent analysis will be also carried out by ALSTOM for selected samples. The analysis on collected samples include ultimate and

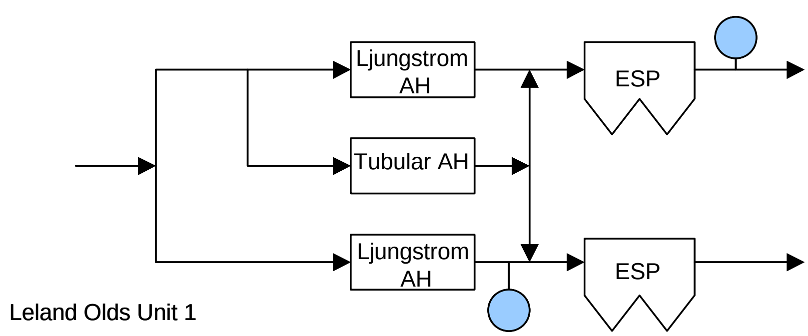


Figure 8. Sampling and measurement locations during field demonstration

proximate analysis, mercury content, LOI, TCLP (Toxic Characteristic Leaching Procedure) and foaming index tests. Plant operation data to be obtained will include flue gas temperatures around the air heater and ESP, economizer outlet and stack oxygen concentrations, stack NO_x an SO_2 concentrations, and stack opacity.

The data collected during and after the testing will be used to assess the extent of mercury removal under various conditions, obtain the technical performance data of the mercury control technology, and eventually to evaluate the process from economic, operational, and environmental points of view. Based on the data and findings, a summary report will be written and made available to the team members and project sponsors.

Task 3.0 Technology Transfer As soon as the project results and findings are made available, ALSTOM will be disseminating them to power generation industry by attending and making presentations in relevant technical conferences such as DOE/NETL sponsored meetings. Technical papers will be written and published in technical journals as well.

Task 4.0 Project Management and Reporting Throughout the project, the project manager of ALSTOM will be in close contact with the project sponsors to report progress or issues as well as to request feedback and overall directions. Any major development and findings will be immediately communicated to the project team members and sponsors.

1.8 WORK BREAKDOWN STRUCTURE

Table 2 lists the work breakdown structure for each of the main tasks of the demonstration project. ALSTOM will be leading most of the tasks with assistance by other team member organizations, i.e., the EERC, and the three utility companies. Bullet points are shown in Table 2 to designate where a particular organization has a key role.

Table 2. Work Breakdown Structure

Tasks	**Participating Organizations (● = key role)**		
	ALSTOM	EERC	Three Host Sites+
Task 1. Design, Engineering and Fabrication of ALSTOM Mercury Control System	●		
Subtask 1.1 Design and Engineering of System Architecture	●		●
Subtask 1.2 Component Fabrication and Testing	●		
Subtask 1.3 System Assembly	●		
Task 2. Field Testing and Demonstration of ALSTOM Technology	●	●	●
Subtask 2.1 Project Planning	●	●	●
Subtask 2.2 Installation, Checkout and Commissioning	●	●	●
Subtask 2.3 Parametric Testing and Measurement	●	●	●
Subtask 2.4 System Removal	●	●	●
Subtask 2.5 Data Analysis and Site Report	●	●	●
Task 3. Technology Transfer	●	●	
Task 4. Program Management and Reporting	●	●	

+The three host sites for the DOE sponsored project are PacifiCorp's Dave Johnston Unit 1, Basin Electric's Leland Olds Unit 1, and Reliant Energy's Portland Unit 1. NDIC funding will be used for Basin Electric's Leland Olds Unit 1 testing only.

1.9 Deliverables

The deliverables of the project are the site report for the Basin Electric test campaign describing the detailed analysis and conclusions of the field demonstration, and the supporting raw data. The site report will be written and submitted by the end of the performance period.

1.10 Staffing Plan

The estimated labor hours required for successful execution of each of the tasks for the Basin Electric demonstration project are listed in Table 3. As listed, Task 1 (Design, Engineering and Fabrication) will require a total of approximately 1,704 labor hours for Basin Electric Testing.

Table 3. Estimated labor hours for the Basin Electric demonstration project

	Task 1	Task 2	Task 3	Task 4
ALSTOM				
9005 Manager	180	620	90	259
9005 Consulting Eng.	498	712	89	
9023 Engineer	738	776		
9026 Technician	256	788		
Performance Proj Eng.				233
Subtotal	1,672	2,896	179	492
UND-EERC				
Manager/Senior Mgmt.		206	53	106
Principal Investigator/s		1,200		
Research Scientist/Eng		895		
Research Support		1,825		
Subtotal		4,126	53	106
BASIN ELECTRIC				
Staff Engineer		160		
Headquarter Engineer	32	160		
Instrument		16		
Operator		132		
Lab Technician		30		
Boiler Engineer		30		
Subtotal	32	528		
TOTAL	1,704	7,550	232	598

For Task 2, about 2,896 labor hours of ALSTOM personnel have been allocated. Most of these labor hours are devoted to actual testing. Host site personnel will provide technical and operational support to ensure smooth execution of field testing. They will carry out system installation and removal with the assistance by ALSTOM personnel. The total labor hours of EERC for preparation and operation of two CMM operation and OH measurement during the testing will require approximately 4,126 labor hours. ALSTOM has also allocated about 270 labor hours for sample analysis and reporting. ALSTOM has an in-house chemical laboratory in which most of the chemical analysis work will be carried out.

Task 3, Technology Transfer, is mainly for presenting the findings in relevant technical conferences and publishing technical papers. ALSTOM expects to require a total of 179 labor hours for this activity.

Throughout the project, the program manager will be in close communication with the host site personnel, DOE program manager as well as NDIC project manager in order to ensure successful execution of the demonstration project. Also at the conclusion of the program, a final report summarizing the program will be written and submitted to program sponsors. For this overall project management effort, ALSTOM expects to spend about 492 labor hours.

1.11 Travel

A total of 12 trips are planned for the demonstration project as listed in Table 4. These include 4 trips to DOE office/meeting for project management and reporting, 2 trips to technical conferences for technology transfer, 1 trip for initial site visit/survey, 1 trip to the project kickoff meeting at the host sites, and finally 4 trips to the host sites for field-testing.

Table 4. Planned trips and their purposes (Origin of all trips is from Windsor, CT)

Task No.	Purpose of trip	No. of personnel	Duration (person days)	Destination
1.1	Initial site visit to Basin Electric – Leland Olds Station by test crew	5	15	Stanton, ND
2.1	Kickoff meeting at Leland Olds Station	4	12	Stanton, ND
2.2	Equipment installation at Leland Olds Station	2	8	Stanton, ND
2.3	Field testing at Leland Olds Station	4	232	Stanton, ND
2.4	Equipment Removal	2	10	Stanton, ND
3	Present field test results in conferences (two one day trips)	1	4	To Be Determined
4	Attend project management meetings with DOE/NETL, host sites, and subcontractors	1	2	DOE/NETL – Pittsburgh, PA; Others – To Be Determined

1.12 Technology Transfer, Commercialization, and Market Penetration Potential

Upon successful completion of the demonstration of the technology, participating utility companies will consider commercial installation of ALSTOM mercury control unit in their power plants. ALSTOM is currently in discussion with a number of other utility companies that have shown similar commercial interests in the technology.

ALSTOM believes that this full-scale demonstration program is a stepping-stone to commercialization of our novel, sorbent-based mercury control technology. The technology offers a number of technical and economic advantages over those currently available in the industry. The technology does not require any significant capital investment, nor does it require high operating cost. It does not require any significant outage for installation. Also its footprint is so small compared with the baghouse installation option, for example, that virtually any power plant in the U.S. will be able to easily employ it.

2. STANDARDS OF SUCCESS

The standards of success for this project will be measured through successful field demonstration of the proposed mercury control technology. The mercury control technology needs to demonstrate technical viability and the potential for economic viability based on the design, process, sorbent consumption and balance of plant impacts. The technical objective of the technology is to effectively reduce mercury emissions over a long period of time (1 month) by at least 70%. Higher removal efficiencies are likely obtainable and will be determined during short-term parametric tests. During long-term tests, optimum conditions will be selected to meet a 70% or greater reduction while taking into consideration overall plant economics.

The performance goal of the project is low-capital cost (approximately \$5/kW$_e$), low operating costs (0.5-0.75 mills/kWh, which results from low sorbent consumption) and minimal BOP impact.

3. VALUE TO NORTH DAKOTA

In North Dakota, over 18,000 jobs, \$1.3 billion in business volume, and \$60 million in tax revenue are generated by the lignite industry each year. North Dakota produces over 30 million tons of lignite annually, and thousands of tons of lignite are fired by North Dakota power plants daily. North Dakota's economy depends on lignite production and use.

As mentioned in the previous section, control of mercury from lignite coal-fired boilers poses a significant technical challenge. Successful demonstration of ALSTOM's cost-effective mercury control technology will increase efficient and environmentally safe use of lignite coal, and ultimately will help lead to the demand for greater production. Increased lignite production and use in North Dakota will result in more jobs in all lignite-related industries in the state.

4. MANAGEMENT AND TEAM QUALIFICATIONS

The project team will consist of ALSTOM, the EERC, the three utility companies, i.e., PacifiCorp, Basin Electric, and Reliant Energy, and Minnkota Power. ALSTOM will be the principal contractor of the program, leading efforts from initial preparation, planning, and field demonstration to data analysis and project reporting. The EERC will support ALSTOM by leading the test campaign in Basin Electric site as well as providing mercury measurement services in coal-fired power plants for all three sites.

ALSTOM has an extensive background in various areas of fuel and combustion research, demonstration and commercialization. ALSTOM is the world's leader in the area of utility boilers. There are more than 500 ALSTOM-designed coal-fired utility boilers in the U.S. (40% of total coal-fired capacity). ALSTOM is also a leader in the development of clean coal technologies including fluidized bed combustion systems, low NO_x firing systems, furnace sorbent injection, and utilization of cleaned coals. ALSTOM currently has an internal project for the development and commercialization of a mercury control technology. ALSTOM has considerable experience in the management and successful completion of projects with varied scope and complexity.

The EERC, a crucial team member participating in this program as a subcontractor, brings in to the program years of experience and expertise in mercury control research and testing. The EERC is a research and development organization at the University of North Dakota recognized internationally for its expertise in cleaner, more efficient energy technologies. Over the past decade, the EERC has used a number of in-house bench- and pilot-scale systems to evaluate various mercury control technologies. Throughout the last several years, the EERC has also developed and validated a number of advanced methods for measuring mercury in coal-fired power plants, such as ASTM Method 6784-02 (Ontario Hydro method). This mercury speciation method was developed and validated by the EERC and currently serves as the worldwide standard for measuring mercury in industrial sources.

The three utility host-site companies participating in this program are Basin Electric, PacifiCorp, and Reliant Energy. Basin Electric Power Cooperative is a consumer-owned, regional cooperative headquartered in Bismarck, ND. Basin Electric operates electricity-generating power plants with a total capacity of 3,373 MW_e. Basin Electric serves 124 rural electric member cooperative systems that in turn serve approximately 1.8 million consumers in the nine states of N. Dakota, S. Dakota, Montana, Wyoming, Minnesota, Nebraska, Iowa, Colorado and New Mexico. Minnkota Power has joined the team as a non-host-site utility and will perform evaluation of the technology for their plants based on results from this demonstration program.

Headquartered in Portland, OR, PacifiCorp is one of the lowest-cost electricity producers in the United States, providing more than 1.5 million customers with reliable, efficient energy. PacifiCorp has more than 8,300 MW_e of generation capacity from coal, hydro, renewable wind power, gas-fired combustion turbines and geothermal. PacifiCorp operates as Pacific Power in Oregon, Washington, Wyoming and California; and as Utah Power in Utah and Idaho.

Based in Houston, TX, Reliant Energy provides energy and energy services in North America and Western Europe. Reliant Energy provides electricity and energy services with a focus on the competitive retail and wholesale segments of the electric power industry in the United States. Reliant has approximately 1.5 million residential customers and over 200,000 small commercial accounts in Texas.

Figure 9 shows the organizational chart of the project team for the successful execution of the project. The shaded areas of the figure are the other two test campaigns to be executed as part of the DOE demonstration program. Resumes of the key personnel are provided in Appendix A.

ALSTOM, with Dr. S. Srinivasachar as the project manager, will be leading most of the activities for the project. Dr. Srinivasachar has 25 years of experience in R&D in combustion and emission control systems and project management of large R&D programs. Dr. Srinivasachar has published a number of technical papers in the area and holds several patents. Dr. Srinivasachar will be assisted by Dr. S. Kang and Mr. E. Rebula in execution of the major tasks. Dr. Kang has 23 years of experience in the development of combustion and emissions control products with a number of publications in the combustion and emissions field. Mr. Rebula, with 26 years of experience, will be in charge of the execution of the other two test

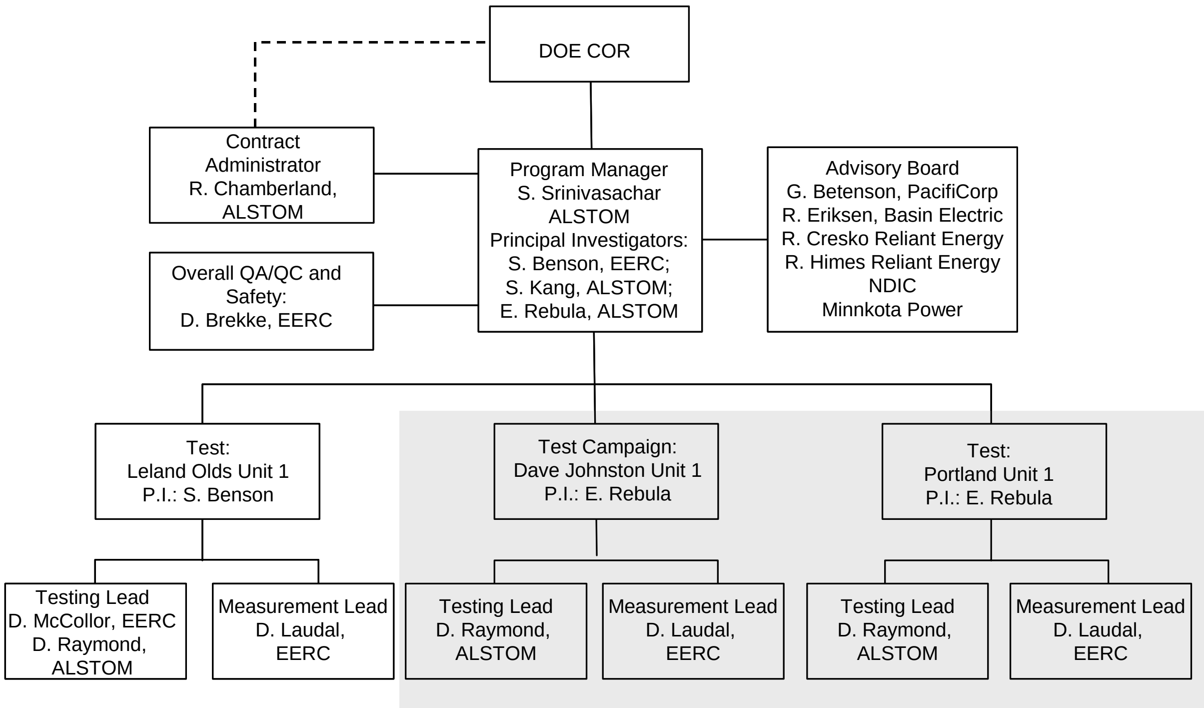


Figure 9. Project Organizational Chart

campaigns. Mr. R. Chamberland, ALSTOM, will be supporting the team on contractual issues.

Dr. Steve Benson will be the overall Project Manager for the EERC portion of the project. Dr. Benson will be in charge of coordinating all activities and integration of sampling efforts. The site lead for the Leland Olds testing will be Dr. Donald McCollor, who will have overall responsibility for all field testing at this site. Mr. Dennis Laudal will have the lead role in site measurements, and Mr. Jeff Thompson will provide direct supervision of on-site sampling activities for all three sites. Dr. McCollor and Mr. Laudal will be in charge of compilation, analysis, and reporting of test data from the sites.

The project team will also have an advisory board. Mr. G. Betenson of PacifiCorp, Mr. R. Eriksen of Basin Electric, Mr. R. Cresko of Reliant Energy, Mr. R. Himes of Reliant Energy, and Minnkota Power will serve in the advisory board providing input from utility perspective.

5. TIMETABLE

The Gantt chart in Figure 10 shows the project activities and the schedule for the entire DOE-awarded program. The test campaign requested from NDIC is for the second campaign, i.e., Leland Olds Station. The project kick off meeting has already been held at the DOE/NETL site in February 2006. As part of Task 1, Design, Engineering and Fabrication, injection and /distribution system design will begin in time for the installation of these systems during upcoming outages. Based on outage schedules of the three sites, the first test campaign has been scheduled in PacifiCorp's Dave Johnston unit in June-July 2005, followed by Basin Electric's Leland Olds unit in September-October 2005, and by Reliant Energy's Portland unit in March-April 2006.

For each of the test campaigns, Tasks 1 and 2 will be repeated according to the schedule and milestones. For example, for the Basin Electric test campaign, a system will be set up by the end of August 2005 (milestone 1), and site report will be completed by the end of May 2006 (milestone 2).

Technology transfer activities such as paper presentations and publications will take place as soon as the test results are made available. This will continue through the end of the project duration. Also, meetings with program managers of DOE and NDIC will take place as many times as needed throughout the demonstration program. The final report of the demonstration program will be submitted to the team members and program managers of DOE/NETL and NDIC by the end of March 2007 (milestone 7).

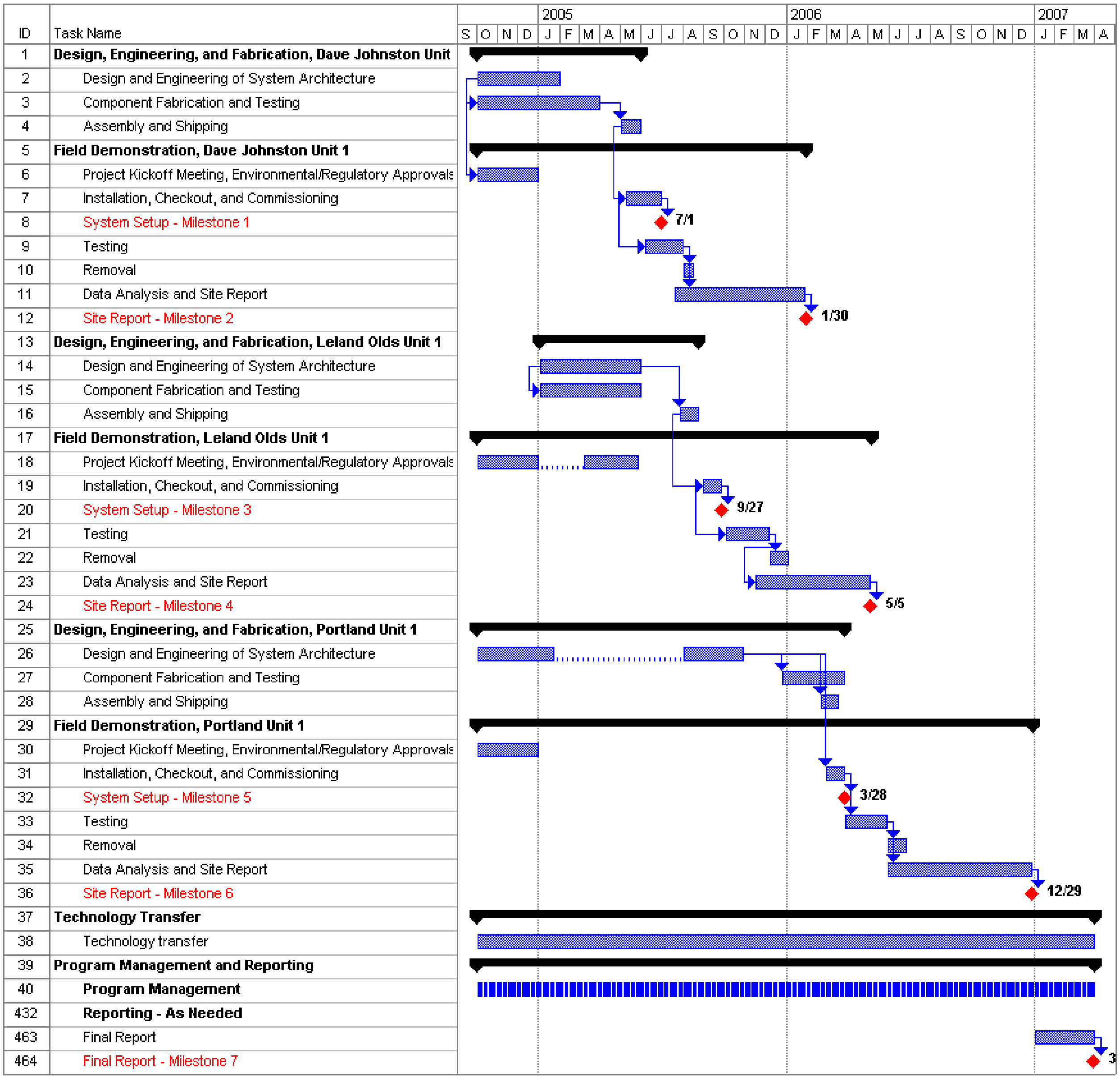


Figure 10. Project Schedule/Gantt Chart

6. BUDGET

The work of this project for Basin Electric test campaign will be performed on a cost-reimbursable basis for $1,644,260. Of that amount, DOE is providing $1,233,195 and the balance of $411,065 will be provided by consortium members. A detailed budget is attached (Appendix D), and a breakdown of cost share is provided in the following section.

7. MATCHING FUNDS

Funding requested from NDIC is $200,000. Other project partners providing cash and in-kind funding include ALSTOM Power; Basin Electric Power Cooperative; and Minnkota Power Cooperative. A detailed breakdown of cost share is provided in Table 5. Commitment has already been made by other funding sources as listed in Table 5. Letters of Support in Appendix B reflect cost share known at the time the project was proposed to DOE.

Table 5. Proposed funding sources for the project

Funding Sources	Cash Cost Share	In-kind Cost Share	Total	Cost Share percentage
NDIC	$200,000	$ -	$200,000	12.2
DOE	1,233,195			75.0
ALSTOM Power	151,065		151,065	9.2
Basin Electric		50,000	50,000	3.0
Minnkota		10,000	10,000	0.6
Total	$1,584,260	$60,000	$1,644,260	100

8. TAX LIABILITY

As of the proposal submission date, ALSTOM does not have any outstanding tax liability owed to the State of North Dakota or any of its political subdivisions. Provided in Appendix C is a letter from ALSTOM's Sales and Use Tax Department confirming this information.

9. REFERENCES

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11. Starns, T., Bustard, J., Durham, M., Martin, C., Schlager, R., Sjostrom, S., Lindsey, C., Donnelly, B., Afonso, R., Chang, R., Renninger, S., Paper 83, Mega Symposium 2003
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13. Pavlish, J., Sondreal, E.A., Mann, M.D., Olson, E.S., Galbreath, K.C., Laudal, D.L. and Benson, S. A., Fuel Processing Technology, 82 (2003) pp. 89-165

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APPENDIX A - RESUMES

The following pages are the resumes (in alphabetical order) of the project participants identified in Section 4 of the technical narrative.

DR. STEVEN A. BENSON

Senior Research Manager/Advisor, Energy & Environmental Research Center (EERC), University of North Dakota (UND), PO Box 9018, Grand Forks, ND 58202-9018 USA
Phone (701) 777-5000 Fax (701) 777-5181 E-Mail: sbenson@undeerc.org

Principal Areas of Expertise

Development and management of complex multidisciplinary programs focused on solving environmental and energy problems, including 1) technologies to improve the performance of combustion/gasification and associated air pollution control systems; 2) transformations and control of air toxic substances in combustion and gasification systems; 3) advanced analytical techniques to measure the chemical and physical transformations of inorganic species in gases; 4) computer-based models to predict the emissions and fate of pollutants from combustion and gasification systems; 5) advanced materials for power systems; 6) impacts of power system emissions on the environment; 7) national and international conferences and training programs; and 8) state and national environmental policy.

Qualifications

Ph.D., Fuel Science, Materials Science and Engineering, The Pennsylvania State University, 1987.
B.S., Chemistry, Moorhead State University (Minnesota), 1977.

Professional Experience

1999 - Senior Research Manager/Advisor, EERC, UND. Dr. Benson is responsible for leading a group of about 30 highly specialized scientists and engineers whose aim is to develop and conduct projects and programs on power plant performance, environmental control systems, the fate of pollutants, computer modeling, and health issues for clients worldwide. Efforts have focused on the development of multiclient jointly sponsored centers or consortia that are funded by a combination of government and industry sources. Current research activities include computer modeling of combustion and environmental control systems, performance of selective catalytic reduction technologies for NO_x control, carbon-based NO_x reduction technologies, mercury control technologies, particulate matter analysis and source apportionment, the fate of mercury in the environment, toxicology of particulate matter, and in vivo studies of mercuryBselenium interactions. The computer-based modeling efforts utilize various kinetic, thermodynamic, artificial neural network, statistical, computation fluid dynamics, and atmospheric dispersion models. These models are used in combination with models developed at the EERC to predict the impacts of fuel properties and system operating conditions on system efficiency and emissions. Dr. Benson is Program Area Manager for Modeling and Database Development for the U.S. Environmental Protection Agency (EPA) Center for Air Toxic Metals^{SM} (CATM^7) at the EERC. He is responsible for identifying research opportunities and preparing proposals and reports for clients.

1994 - 1999 Associate Director for Research, EERC, UND. Dr. Benson was responsible for the direction and management of programs related to integrated energy and environmental systems development. Dr. Benson led a team of over 45 scientists, engineers, and technicians. In addition, faculty members and graduate students from Chemical Engineering, Chemistry, Geology, and Atmospheric Sciences have been involved in conducting research projects. The research, development, and demonstration programs involve fuel quality effects on power system performance, advanced power systems development/demonstration, computational modeling, advanced materials for power systems, and analytical methods for the characterization of materials. Specific areas of focus included the development and direction of EPA CATM[7] at the EERC (CATM[7], a peer-reviewed, EPA-designated Center of Excellence, is currently in its 12th year of operation and has received funding of over $12,000,000 from government and industry sources), ash behavior in combustion and gasification systems, hot-gas cleanup, and analytical methods of analysis. He was responsible for the identification of research opportunities and the preparation of proposals and reports for clients. Dr. Benson left this position to focus efforts on Microbeam Technologies= Small Business Innovation Research (SBIR).

1986 - 1994 Senior Research Manager, Fuels and Materials Science, EERC, UND. Dr. Benson was responsible for management and supervision of research on the behavior of inorganic constituents, including air toxic metals during combustion and gasification, hot-gas cleanup (particulate gas-phase species control), fundamental combustion, and analytical methods of inorganic analysis, including SEM and microprobe analysis, Auger, XPS, SIMS, XRD, and XRF. Responsible for identification of research opportunities, preparation of proposals and reports for clients, and publication.

1989 - 1991 Assistant Professor (part-time), Department of Geology and Geological Engineering, UND. Dr. Benson was responsible for teaching courses on coal geochemistry, coal ash behavior in combustion and gasification systems, and analytical methods of materials analysis. Taught courses on SEM/microprobe analysis and mineral transformations during coal combustion.

1984 - 1986 Graduate Research Assistant, Fuel Science Program, Department of Materials Science and Engineering, The Pennsylvania State University.

1983 - 1984 Research Supervisor, Distribution of Inorganics and Geochemistry, Coal Science Division, UND Energy Research Center. Dr. Benson was responsible for management and supervision of research on the distribution of major, minor, and trace inorganic constituents and geochemistry of coals and ash chemistry related to inorganic constituents and mineral interactions and transformations during coal combustion and environmental control systems.

1980 - 1983 Research Chemist, U.S. Department of Energy (DOE) Grand Forks Energy Technology Center. Dr. Benson performed research on surface and/or chemical analysis and characterization of coal-derived materials by SEM, XRF, and thermal analysis in support of projects involving SO_x, NO_x, and particulate control; ash deposition; heavy metals in combustion systems; coal gasification; and fluidized-bed combustion.

1979 - 1980 Research Chemist, DOE Grand Forks Energy Technology Center. Dr. Benson performed research on the application of such techniques as differential thermal analysis, differential scanning calorimetry, thermogravimetric analysis, and energy-dispersive XRF analysis with application to low-rank coals and coal process-related material. In addition, research was performed on the use of x-ray analysis to measure trace elements in fuels and conversion products.

1977 - 1979 Chemist, DOE Grand Forks Energy Technology Center. Dr. Benson performed analysis on coal and coal derivatives by techniques such as wavelength-dispersive x-ray analysis, argon plasma spectrometry, atomic absorption spectrometry, thermal analysis, and elemental analysis (CHN).

1976 - 1977 Teaching Assistant, Department of Chemistry, Moorhead State University.

<u>Professional Memberships and Activities</u>

United States Senate Committee on the Environment and Public Works

- One of three technical panelists invited to provide testimony on mercury control for the coal-fired power industry.
- American Chemical Society (ACS)
  - Chair - Fuel Division 2004 - Duties comprise coordinating all aspects of the division, including publications and national conferences.
  - Fuel Division - Participates on the Executive Committee involved in the coordination and direction of division activities, including outreach, programming, finances, and publications.
  - Councilor, Fuel Division - Represents the Fuel Division at the National ACS Council meeting.
  - Chair Elect, Fuel Division - August 2002 - Elected to be Chair of the Fuel Division.
  - Member, Committee on Environmental Improvement (CEI) - The committee provides advice and direction to the ACS governance on policies and programs related to the environment. Since becoming a member of the committee, we have developed policy statements on Global Climate Change, Reformulated Gasoline and MtBE, and Energy Policy. These policy statements are used to assist legislators in developing national environmental policy. Members of CEI also provide testimony on a variety of environmental issues.
- American Society for Mechanical Engineers (ASME)
  - Advisory Member, ASME Committee on Corrosion and Deposition Resulting from Impurities in Gas Streams. Developed several conferences through the International Engineering Foundation.
- Mercury Reduction Initiative - Minnesota Pollution Control Agency (MPCA)
  - Participated in meetings for the mercury reduction initiative and provided advice regarding mercury control technologies for electric utilities and MPCA for voluntary mercury reduction strategies.

- Elsevier Science, *Fuel Processing Technology*
    - Editorial board member whose role is to provide advice and direction for the journal.

Publications and Presentations

- Has authored/coauthored over 210 publications and is the editor of six books and *Fuel Processing Technology* special issues.

GREGORY W. BETENSON

LEAD/SENIOR ENGINEER, PACIFICORP, SALT LAKE CITY, UT

PROFESSIONAL EXPERIENCE

1993 - Present, PacifiCorp/Power Supply/Technical Services, Salt Lake City, Utah

Lead/Senior Engineer

Responsibilities:

- Lead PacifiCorp generation plant emissions control specialist for Flue Gas Desulfurization, ESP/FF, SCR & Mercury Control.

1991 - 1993, Phillips Petroleum/Process Engineering Department, Woods Cross, Utah

Process Engineer

Projects:

- Lead Process Engineer for a $23 MM fuel gas desulfurization plant
- Evaluation of process technologies to reduce benzene from the refinery gasoline pool
- Evaluation of H_2S & mercaptan removal processes from the catalytic cracker

1989 - 1991, Ford Bacon & Davis/Process Engineering Department, Salt Lake City, Utah

Process Engineer

Projects:

- Lead Process Engineer for a $33 MM hazardous waste incinerator for Ciba-Geigy
- Lead Process Engineer for a $20 MM polymer plant for Dupont/Proctor & Gamble
- Fluid Bed/Shale Oil Fractionator design for a D.O.E. study
- Northwest Pipeline NGL process plant troubleshooting
- Conceptual design of a 20 MMscfd NWP/Exxon NGL/Sulfur plant
- Catalytic cracked gas plant de-bottlenecking study for Flying J Refining
    - Sulfur plant tail gas treater study for Frontier Refining
    - Process technology alternatives evaluation of coke oven desulfurization for Geneva Steel
    - Thermal waste treatment alternatives evaluation for Firestone Tire Company
- Preliminary design of an oil production waste incinerator for British Petroleum
- Preliminary design of a pharmaceutical waste incinerator for Eli Lilly

1985-1989, Utah Power & Light/Engineering Research Department, Salt Lake City, Utah

Project Engineer

Projects:

- Conversion of Hunter 3 limestone scrubber to a lime scrubber
- Scrubber mist eliminator revamp testing
- Physical flow modeling study to eliminate scrubber reheater
- Scrubber outlet duct materials of construction evaluation
- Trona mine water reagent testing at Naughton scrubber
- Blundell Geothermal Plant condensate collector retrofit
- Naughton ESP coal quality/SO_3 injection systems study
- Naughton sodium scrubber waste alternatives
- NO_X technology evaluation for fossil-fired boilers

1983-1985, UP&L Hunter Plant/Engineering Department, Castle Dale, Utah

Engineer

Projects:

- Hunter 3 scrubber start-up de-bottlenecking, testing and optimization
- Plant water treatment improvement projects

ACHIEVEMENTS/ASSOCIATIONS

1993-2004.1 Pollution Control Users Association Steering Committee

1993-2003 EPRI Gasification Users Association Board of Director

1986-2003 2 Papers and 4 Panels at Mega Symposium & Power Gen Conferences

1988 Award, EPRI - First Use Award for applying new research in FGD systems

1985-1987 Committee Member, EPRI Scrubber Advisory Program

1981-1999 Member, AIChE - Energy and Environmental Divisions

1989-2004 Member, ACS - Fuels and Environmental Divisions

EDUCATION

1983 BS Chemical Engineering, University of Utah
Graduate Courses in Fuels Engineering

RAY P. CHAMBERLAND

Manager, Contract R&D, ALSTOM Power Inc. – US Power Plant Laboratories, Windsor, CT

Summary of Qualifications

Mr. Chamberland's background has been in over sixteen years of experience contributing in project teams in R&D organizations. At US Power Plant Laboratories, he manages third party (non-ALSTOM) proposal development and contracting. Mr. Chamberland oversaw over $5 MM of third-party orders for US Power Plant Laboratories in 2003.

Professional Experience

ALSTOM Power Inc., Windsor, CT
Manager, Contract R&D (2001 to present), US Power Plant Laboratories
Responsible for proposal development and supports business development of all R&D programs with outside (non-company) funding (customers: US DOE, State Agencies, EPRI, Utilities, Oil Companies, and former ABB Divisions).

Praxair, Inc., Tarrytown, NY
Development Associate, (1991 to 2001), Applications R&D – Combustion Group
Developed and commercialized combustion technologies (process and/or equipment) to improve customer's process and overall economics of oxy/fuel combustion. Conducted feasibility studies, project proposals, and patent / technology reviews.

- Solicited and project managed over $5.5 MM federal and state funded programs on energy recovery related programs.
- Developed and globally commercialized two versions of ultra low NOx oxygen-fuel burners (1 to 10 MMBtu/hr, natural gas and oil). Transferred burner technologies to global regions via customer contracts and provided training/documentation.

Praxair, Inc., Tarrytown, NY
R&D Engineer, (1988 to 1991), Applications R&D - Atmospheres Group
Developed and commercialized gas inerting technologies (process and/or equipment) to improve processes sensitive to oxidation.

- Developed and commercialized a controlled atmosphere reflow soldering process for printed wiring board industry. Increased Praxair worldwide nitrogen sales to printed wiring board industry to more than $24 MM annually.

PERSONAL BACKGROUND

Worcester Polytechnic Institute, Worcester, MA
- Master of Science Mechanical Engineering, 1988
- Bachelor of Science Mechanical Engineering, 1986

PROFESSIONAL MEMBERSHIPS

Coal Utilization Research Council (2003 to 2004)
American Society of Mechanical Engineers (1986 to 2004)
American Flame Research Committee (1994 to 2004)

International Flame Research Foundation (1995 to 2004)
The NSF Industry-University Center for Glass Research (1995 to 2001)
Glass Manufacturing Industry Council

- Energy Efficiency Subcommittee – 1997 to 2001
- Presented results of DOE funded project at GMIC's annual project review (hosted at DOE's research labs - 1997 to 2000)

PATENTS AND PUBLICATIONS

Mr. Chamberland holds two patents in low NOx oxygen-fuel firing technology and one patent in waste heat recovery technology for glass manufacturing. Mr. Chamberland has five publications in oxygen related applications and is a co-author on two publications on comparative economic analysis of advanced power generation systems.

RICHARD A CRESKO

Technical Superintendent, Reliant Energy, Upper Mountain Bethel, PA

Work experience

2000 – Present, Reliant Energy, Portland Generating Station
Portland PA 18351
Technical Superintendent

- Prepared and maintained the Station budget for both Capital and O&M projects
- Developed and implemented a Thermal Performance Improvement Program for the Portland steam units
- Secured the technical resources to support the station's needs, utilizing in-house, corporate and contracted services

1993 – 2000, GPU/GENCO, Portland Generating Station
Portland PA 18351
Engineer Sr. I

- Project Manager of a $1.8M Underground Fuel Oil replacement Project
- Project Engineer for a $2.6M Superheater Header/Pendant replacement Project on Portland Unit #2
- Co-ordinated the Station's tuning effort for NOx emission reduction
- Assigned leader of Station's Reliability Centered Maintenance (RCM) Team

1987 – 1993, Metropolitan Edison Co., Portland Generating Station
Portland PA 18351
Engineer III

- Project Manager for a $2.8M Boiler repair project to replace Waterwall & Radiant Superheater section on Portland Unit #1
- Co-ordinated the Station's High Pressure Piping In Service Inspection Program, Boiler Inspection and Pipe Hanger Inspection Programs
- Provided Technical Support for the design, evaluation, procurement, and installation of Capital Improvement Projects at the Station

1985 – 1987, Metropolitan Edison Co., Portland Generating Station
(thru Barton Personnel) Portland PA 18351

Technical Support Engineer

- Prepared specifications for Plant Maintenance and Construction Projects

- Co-ordinated asbestos removal and reinsulation of Plant equipment

1984 – 1985, Certainteed Corporation, Mountaintop PA 18707
Project Engineer
- Prepared a complete installation package including hydraulic and electrical requirements for the installation of a Screw Press to handle process waste.

1979- 1982, Fuller Company, Bethlehem PA 18017
Product Engineer
- Directed the equipment selection and procurement for a $3M Ash Handling System for a coal fired Generating Station

1975 – 1979, Anchor/Darling Company, Williamsport PA 17701
Project Engineer
- Checked Valve designs for compliance with ASME code Standards
- Supported the qualification testing of a pneumatic/hydraulic actuator to IEEE Standards

Education

Drexel University - B.S. in Mechanical Engineering
Lehigh University - Masters in Business Administration

Professional memberships

Registered Professional Engineer - State of Pennsylvania

Member of American Society of Mechanical Engineers
New Jersey Second Grade Engineer's License (Red Seal)

ROBERT L. ERIKSEN

Environmental Compliance Administrator, Basin Electric Power Cooperative

Robert L. Eriksen is the Environmental Compliance Administrator at Basin Electric Power Cooperative. Bob received a B.S. degree in Chemical Engineering from the University of North Dakota in 1974. He has been employed with Basin Electric in the environmental field since June of 1974.

Bob's experience includes pollution control technology, environmental monitoring and reporting systems, permitting facilities, and tracking environmental legislation and regulations regarding air, water, and waste. He was instrumental in the pilot testing and development of spray dryer flue gas desulfurization in the 1970's that led to the application of spray dry FGD in the electric utility industry. He has authored or co-authored several technical publications and presentations on FGD, air dispersion modeling, and mercury controls.

He is married and has two children. His community activities include Boy Scouts, the Great American Bike Race for Cerebral Palsy, treasurer for the Magical Moments Playground project, and supporting his children's activities.

RAYMOND C. HIMES

Manager, Project Engineering, Reliant Energy, Reading, PA

Raymond C. Himes, P.E., is a Project Engineering Manager for Reliant Energy, Reading, Pa. He has over 30 years' experience in power generation and supply and is responsible for managing technical support for a portion of the Reliant generating station fleet, including the engineering and construction of plant modifications. He has held several engineering management and consultant positions, participating in major station modifications and new generating unit development. Mr. Himes received a bachelor's degree in electrical engineering from the University of Pittsburgh and is a senior member of the IEEE. He is a registered Professional Engineer in the state of Pennsylvania.

DR. SHIN G. KANG

Technical Fellow, Product Development and Technology, US Power Plant Laboratories, ALSTOM Power Inc., Windsor, CT

SUMMARY OF QUALIFICATIONS

Managerial skills and experience in multi-faceted product development projects. Technology/ product development in power generation industries based on analytical skills, broad experience and knowledge in combustion chemistry, mechanical design, etc.

PROFESSIONAL EXPERIENCE

Feb 1998 – present ALSTOM Power, Windsor, CT

- Technical Fellow, Product Development and Technology; Senior Consulting Engineer, Combustion Technology: Led projects for development of new combustion products for new business areas including petrochemical industries. Currently working on a high-visibility, high- impact project in a cross-disciplinary focus team on development of new power generation processes. Activities ranged from conceptual design, bench-scale and pilot-scale feasibility tests, economic and market analysis, identification of potential customers, securing funding, to full-scale demonstration.

Oct 1995 – Jan 1998 John Zink Company, a Koch Industries Company, Tulsa, OK

- Manager, Combustion Product Development Group; Senior Principal Engineer: Supervised a number of projects for development and improvement of combustion products and technology for petrochemical industries. Supervised warranty projects for troubleshooting products for customers. Initiated product standardization efforts. Provided business groups with technical/consulting support through technical review, and risk evaluation on commercial projects. Developed training courses and programs for engineers. Evaluated technologies of candidate M&A companies and various product concepts from external sources.

Dec 1991 – Sep 1995 Physical Sciences Inc., Andover, MA

- Principal Research Scientist; Principal Scientist: Secured research funding from various federal agencies (DOE, DOD, NASA, NSF, etc.); performed various projects on combustion, emission control, and high-temperature materials processing as Principal Investigator; worked on consulting and contract R&D projects for utility industry.

EDUCATION

1991 Ph.D. in Chem. E., (minor in Materials Sci. and E.) Massachusetts Institute of Technology, Cambridge MA
1986 M.S. in Chem. E., University of Cincinnati, Cincinnati OH
1984 B.S. in Chem. E., Cum Laude, Seoul National University, Seoul, Korea

TECHNICAL PUBLICATIONS AND PATENTS

Authored more than 25 technical papers and 5 patents including 3 patents pending

DENNIS L. LAUDAL
Senior Research Advisor
Energy & Environmental Research Center (EERC)
University of North Dakota (UND) PO Box 9018, Grand Forks, North Dakota 58202-9018 USA
Phone (701) 777-5000 Fax (701) 777-5181 E-Mail: dlaudal@undeerc.org

Principal Areas of Expertise
Mr. Laudal's principal areas of expertise include mercury measurement and control. Mr. Laudal is considered a leading expert on continuous emission monitors for mercury. Other areas of expertise include particulate characterization and control, control measurements of SO_x/NO_x and air toxics, fluidized-bed combustion, and preparation and analysis of combustion fuels.

Qualifications
M.S., Chemical Engineering, University of North Dakota, 1984.
B.A., Chemistry and Biology, Concordia College, 1974.

Professional Experience
2001 - Senior Research Advisor, EERC, UND. Mr. Laudal's primary responsibility is program development and management at the EERC, primarily related to mercury control and measurement. For the past 9 years, he has been directly responsible for large, multipartner projects at the bench-, pilot-, and field-scale level, including development of project quality plans, project oversight, research analysis, and reporting, as well as developing work plans and budgets for future projects.

1994 - 2001 Research Manager, Gas Cleanup Technologies, EERC, UND. Mr. Laudal's responsibilities include the direct supervision of personnel involved in flue gas cleanup research programs at the EERC as well as planning, implementation, supervision, and reporting of research projects involving field- and pilot-scale studies. For the past 8 years, Mr. Laudal has directed mercury research programs at the EERC.

1984 - 1994 Research Engineer, Gas Stream Cleanup Systems, EERC, UND. Mr. Laudal's responsibilities included planning, implementation, and supervision of tests conducted on a pilot-scale pc-fired combustor and catalytic fabric filtration research. He performed particle sampling and sizing, including EPA-5 dust loading, impactors, SASS train, multicyclone, and laser particle-size analysis and performed EPA wet tests for flue gas analysis. Other work included computer-aided data analysis and equipment design.

1982 - 1984 Graduate Studies, Chemical Engineering (under Domestic Mining, Minerals, and Mineral Fuels Conversion Fellowship), UND Graduate School.

1977 - 1982 U.S. Department of Energy, Grand Forks Energy Technology Center. Mr. Laudal served as the Technical Project Officer for the coal preparation and analysis laboratory. Analyses included ultimate, proximate, ash fusion, surface area, and Btu value. Research work on various environmental projects included leaching characterization of fly ashes and sludges, 6-inch AFBC, 18-inch AFBC, pilot-scale ash alkali wet scrubber, and peat analysis and utilization studies. The work included operation and maintenance of pilot plant equipment, data analysis, project planning, and reporting.

Publications and Presentations
Has authored or coauthored over 80 publications

ED REBULA

Senior Project Manager, Performance Projects, ALSTOM Power Inc., Windsor, CT

SUMMARY OF QUALIFICATIONS

Twenty-six years experience in technical, commercial, project management and general management in the power industry.

PROFESSIONAL EXPERIENCE

Senior Project Manager ***December 1995 to Present***

Responsible for managing domestic and international service and rehabilitation projects, ensuring that all work is completed on time, within budget and with acceptable quality, while at the same time meeting contractual requirements and customer needs. Support large proposals, as needed. Projects have been located in Asia, South America and Europe, as well as the U.S., including Consumers Energy Cobb Station.

Director, Project Management & ***July 1992 to December 1995***
Controller ***July 1992 to November 1993***

On expatriate assignment to ABB Energy Systems Indonesia, a start-up Joint Venture. This position entailed a broad base of responsibilities, in addition to those specifically assigned, as the company grew from 150 in 1992 to over 800 by the end of 1995. Also heavily involved in proposal development and contract negotiations, as well as general management, filling in for the General Manager when necessary. In Controller function, managed accounting department of ten, implemented a new PC based accounting system, responsible for financial reporting, budgeting, analysis and development of procedures.

Controller ***April 1991 to July 1992***

Financial Controller for two different business units during this time period. Responsible for all financial functions of the business: accounting, financial reporting, budgeting, analysis.

Lead Contract Administrator ***September 1990 to April 1991***

As Lead Contract Administrator, managed a department of three while concurrently administering several major contracts. Provided impetus to redefine role of Administrator to include more emphasis on pre-award issues and financial control. Special projects included chairing business unit team on both Cycle Time and Cost Reduction and working with other departments to define business unit workflow and procedures.

Supervisor, Contract Administration ***August 1989 to September 1990***

On expatriate assignment in Canada, supervised a staff of four while concurrently administering several major domestic and international contracts. Reviewed contract requirements to evaluate obligations, risks, and claims and either advised staff on approach or made recommendations to management. Maintained liaison with other internal departments to co-ordinate activities an all contracts, developing new procedures as required.

Senior Contract Administrator ***September 1985 to August 1989***

Managed commercial aspects of short term and long term industrial and government contracts up to $ 100 million. Interfacing with customer included negotiating terms and conditions, ensuring customer requirements were met, resolving claims and commercial disputes, and developing and providing quotations. Within the organization served as commercial focal point of contract, disseminating information throughout the company, interfacing and resolving issues with various departments such as projects, legal, sales, accounting, treasury, etc. Also served as the department focal point for mainframe and personnel computer applications.

Senior Development Engineer ***December 1980 to September 1985***

Responsible for a number of engineering functions related to advanced energy processes such as coal gasification, fluidized bed combustion, and solar power: developed conceptual and detailed system designs; developed computer models and analysis programs to analyse/correlate data from two gasification test facilities; performed applied research into chemical and thermal aspects of these processes. Prepared technical and cost proposals and written reports, as well as presentations to customers. Extensive use of both mainframe and personal computers.

Babcock and Wilcox, Diamond Power Subsidiary -

Project Engineer ***June 1978 to December 1980***

Responsible for both management and technical aspects of new product/process projects related to boiler cleaning: developed goals, funding requirements, and schedules; coordinated and directed other personnel in the design, fabrication, installation and testing of new equipment both in-house and at customer sites; computer modeling, design, experimentation, and data analysis. Also developed computer codes for the contract engineering department.

EDUCATION

Master of Business Administration
Rensselaer Polytechnic Institute, 1985

B.S. Mechanical Engineering
Rensselaer Polytechnic Institute, 1978

Several graduate level engineering courses taken at Rensselaer and The Ohio State University

PATENTS

Holder of two United States Patents

DR. SRIVATS SRINIVASACHAR

Principal Consulting Engineer, US Power Plant Laboratories, ALSTOM Power Inc., Windsor, CT

SUMMARY OF QUALIFICATIONS

Experience in energy and environmental engineering, power plant systems and cross-industry product development. Developed and implemented strategies for new products and processes. Worked in cross-disciplinary international project teams. Presented evaluations/project summaries to senior management. Led product and process development groups. Generated contract research business with industry and government. Managed multi-contractor projects. Obtained multiple patents and published over 50 technical papers. Upgraded skills with executive management and leadership development courses.

PROFESSIONAL EXPERIENCE

1999- Present ALSTOM Power Inc.
1993-1999 ABB Combustion Engineering Inc.,Windsor, CT

- New Business Development (Sept. 1999 to Present)
  Alstom Boiler Segment, Combined Cement and Power Plant Development: project to develop a new business. Defined new plant concept. Filed 7 patent applications. Developed business concept with outside management consulting firm. Established technical feasibility in pilot tests. Developing first demonstration projects: customer contacts, partnerships, industry financing and government funding, detailed technical design, economic and environmental assessment.
- Environmental Group Leader, (Oct. 1998 – Sept. 1999)
  ABB Power Segment - Special project on new plant design on coal gasification and syngas generation. Defined and developed cost-effective technologies to minimize nitrogen, sulfur and particulate-based pollutants. Detailed overall process design and application.
- Principal Consulting Engineer, US Power Plant Laboratories (Oct. 1997-)
  Member, cross-functional team for ABB Power Segment to define leapfrog plant design. Applied for 3 patents on different concepts.
- Senior Consulting Engineer, US Power Plant Laboratories (USPPL)
- Project Leader on Electrostatic Precipitator (ESP) projects. Worked intimately with worldwide Product Technology Manager (PTM) and Business Unit personnel to improve ESP performance and reduce cost. Secured $ 2.3 million for a US Department of Energy project on Ultra-High Efficiency ESP Development. Led a cross-functional team of researchers from USPPL, ABB Flakt, Sweden, CHCRC, Switzerland and VTT Technology, Finland to construct, operate and test an integrated combustor-ESP pilot test facility.
- Conducted advanced testing to link particulate properties (size, composition) to collection efficiency. Developed criteria for plant sizing and design standards. Provided technical support on sizing for various plant quotations.
- Presented technical papers at international conferences and symposia. Patent applied -Linked control system for improved ESP performance based on fuel properties and (process) boiler operating conditions.

- Project Leader on Air Preheater project. Linked two business area products to develop an integrated lower cost concept => low-temperature air heater – air pollution control system. Performed field testing to identify most suitable locations for dump air withdrawal. Patent granted: 6,089,023 – method and means for improving performance of particulate control device by controlling gas temperature from an upstream air heater.
- Task Leader and Technical Consultant on Low-NO_x firing systems. Developed high-performance fuel nozzles for boilers to reduce nitric oxide emissions and minimize tip deposition. Replaced standard tips in product portfolio. Developed fuel injection system design for improved heat flux distribution and combustion efficiency and reduced NO_x emission. Patent applied – Variable Fuel Admission System Design.

1986-1993 Physical Sciences Inc., Andover, MA

- Manager, Environmental Remediation and Resource Utilization (1992-93)
  Directing R&D for an emerging business area. Negotiated with strategic partner for $250,000 funding to develop an on-site peroxide generator. Secured and managed a $750,000 Superfund project to remediate heavy metal-contaminated soils. Patented method to minimize metal emissions from a high temperature treatment process.
- Principal Research Scientist (1986-92)
  Principal Investigator on a $4.3 million university-industry effort - elucidated chemical and physical transformations of ash during coal combustion. Determined role of chlorine on alkali deposition in turbines. Created a PC-based software for electric utilities to predict coal quality impacts on power plant performance and to evaluate savings with various fuel switching options.

1981-1986 Massachusetts Institute of Technology, Cambridge, MA

- Research Assistant at a 3 MW combustion research facility. Studied atomization and combustion behavior of coal-liquid mixtures in turbulent diffusion flames. Evaluated strategies to minimize nitrogen and sulfur oxide and soot emissions.

EDUCATION

1981-1986 - Massachusetts Institute of Technology, Cambridge, MA
Sc.D. Degree in Chemical Engineering

1976-1981 - Indian Institute of Technology, Madras, India
Bachelor of Technology, Chemical Engineering

PATENTS

U.S. Patent 5,556,447 and 5,245,120 “Process for treating metal-contaminated materials”
U.S. Patent 6,089,171,”Minimum Recirculation Flame Control Pulverized Solid Fuel Nozzle Tip”
U.S. Patent 6,089,023, “Steam Generator System Operation”

AWARDS AND RECOGNITION

- Selected for "International Management Development Program" and "Leadership in ABB" programs
- ABB Combustion Engineering, Inventor of the Year, 1995
- Key Contributor, Management Performance Incentive Plan, 1996-2000
- Richard A. Glenn Award, most outstanding paper at the American Chemical Society, 197th National Meeting, 1989
- Physical Sciences Inc. Achievement Award – 1988, 1989, 1990, 1991

APPENDIX B - LETTERS OF SUPPORT

The letters of support for Basin Electric – Leland Olds Station Unit 1, Industrial Commission of North Dakota, and Minnkota Power Cooperative, Inc. are provided in the following pages, respectively.

BASIN ELECTRIC POWER COOPERATIVE

1717 EAST INTERSTATE AVENUE
BISMARCK, NORTH DAKOTA 58503-0564
PHONE 701-223-0441
FAX: 701/224-5336

April 28, 2004

U.S. Department of Energy
National Energy Technology Laboratory
P.O. Box 10940
Pittsburgh, PA 15236-0940

Reference: Letter of Interest and Financial Commitment for Field-Testing Activities Proposed by ALSTOM Power Inc. – U.S. Power Plant Laboratories to the U.S. Department of Energy – National Energy Technology Laboratories (DOE/NETL) Solicitation No. DE-PS26-03NT41718 Titled "Large Scale Mercury Control Technology Field Testing Program – Round 2"

Basin Electric is pleased to submit this letter of support and interest to participate in the field-testing activities that are described in the attached proposal by ALSTOM Power Inc. – U.S. Power Plant Laboratories' (ALSTOM) for evaluating long-term impacts of mercury control with enhanced sorbents to the subject DOE/NETL Solicitation No. DE-PS26-03NT41718. Our Leland Olds Station Unit 1 in Stanton, North Dakota will be an excellent facility to evaluate ALSTOM's Mer-Cure™ technology with enhanced sorbents to control mercury.

Basin Electric recognizes the need to develop business practices that also foster innovative ways to protect and enhance the environment. We are very interested in the technologies and economics of controlling emissions from our facilities. We feel that the Leland Olds facility will provide an excellent and cost-effective location for the proposed project. With the combined capabilities and experience of the proposed project execution team of ALSTOM and Energy and Environmental Research Center (EERC), we expect a successful project.

Basin Electric is prepared to participate in the project by providing Leland Olds Unit 1, a 220 MW_e coal-fired electrical generating unit, as the host facility, as well as experienced and qualified personnel in the manner outlined in the proposal. This unit is uniquely suited for the proposed project as the pollution control system features a cold-side electrostatic precipitator (ESP). The unit mainly fires a lignite coal, and periodically a blend of sub-bituminous and lignite coal. This combination represents a particularly challenging case for mercury control because of the high proportion of elemental mercury in the flue gas. The site will be accessible to the project team for the term of the project, subject to reasonable and customary arrangements regarding site security and safety, and confidentiality.

Basin Electric is pleased to offer support to the proposed program of in-kind support, engineering, and management valued up to $50,000. Our contributions will be subject to a definitive Cooperative Agreement with the DOE/NETL and a "Host Site Agreement." It is understood that Basin Electric's funding and/or in-kind contribution for this project will provide cost sharing for federal funding from the U.S. Department of Energy (DOE); therefore, Basin Electric hereby certifies that our contribution will be comprised of nonfederal dollars.

We look forward to DOE's review of the proposal and partnering with DOE on this interesting and needed project. Bob Eriksen, Environmental Compliance Administrator is serving as project manager for this large-scale mercury test program. Please coordinate the test program with Bob at (701) 355-5654 or beriksen@bepc.com.

Sincerely,

David P Schmitz

for Wayne W. Backman
Senior Vice President
Generation

rle:mev

cc: Srivats Srinivasachar, ALSTOM Power
John Hendrikson, EERC
Steve Benson, EERC
Curt Melland, Leland Olds Station
Bob Eriksen, Project Manager

INDUSTRIAL COMMISSION OF NORTH DAKOTA

LIGNITE RESEARCH, DEVELOPMENT AND MARKETING PROGRAM

Governor,
John Hoeven
Attorney General,
Wayne Stenehjem
Agriculture Commissioner,
Roger Johnson

April 26, 2004

Dr. Steven A. Benson
Senior Research Manager
Energy & Environmental Research Center
P.O. Box 9018
Grand Forks, ND 58202-9018

Subject: Support for Field-Testing Activities Proposed by ALSTOM Power Inc. – U.S. Power Plant Laboratories to the U.S. Department of Energy – National Energy Technology Laboratory's (DOE/NETL) Solicitation No. DE-PS26-03NT41718 Titled "Large Scale Mercury Control Technology Field Testing Program – Round 2"

Dear Steve:

This letter is in response to your request for participation in the field-testing activity described in the proposal by ALSTOM Power Inc. – U.S. Power Plant Laboratories' (ALSTOM) for evaluating long-term impacts of mercury control with enhanced sorbents to the subject DOE/NETL Solicitation No. DE-PS26-03NT41718.

The North Dakota Lignite Research, Development and Marketing Program (Program) recognizes the need to develop advanced environmental control technologies for control of pollutants from our lignite-fired facilities. The Leland Olds facility would provide an excellent and cost-effective location for the proposed project.

This letter of support and potential funding of up to $200,000 is subject to DOE approval of the proposed activity and submission of a proposal to the North Dakota Program by ALSTOM and the Energy & Environmental Research Center. North Dakota funding is subject to submission of a proposal that meets Program guidelines, a funding recommendation by the Lignite Research Council and approval by the North Dakota Industrial Commission.

It is understood that North Dakota Program funding for this project will provide cost share to federal funding from the U.S. Department of Energy. The North Dakota Program funding guidelines require matching industry funds and activities that preserve and enhance the use of North Dakota lignite.

Sincerely,

Harvey Ness

Harvey M. Ness
Director and Technical Advisor
Lignite Research, Development and Marketing Program

cc: Karlene Fine, Executive Director and Secretary, North Dakota Industrial Commission
John W. Dwyer, Chairman, Lignite Research Council

LIGNITE RESEARCH COUNCIL

John Dwyer
Chairman
jdwyer@lignite.com

Harvey Ness
Director & Technical Advisor
hness@lignite.com

P.O. Box 2277
Bismarck, N.D. 58502
(701) 258-7117 (701) 258-2755 FAX

INDUSTRIAL COMMISSION OF NORTH DAKOTA

Karlene Fine
Executive Director & Secretary
kfine@state.nd.us
600 E. Blvd., State Capitol
Bismarck, N.D. 58505
(701) 328-3722 (701) 328-2820 FAX

Minnkota Power
MPC COOPERATIVE, INC.
Your Touchstone Energy® Partner

1822 Mill Road • P.O. Box 13200 • Grand Forks, ND 58208-3200 • Phone (701) 795-4000

April 28, 2004

Dr. Steven A. Benson
Senior Research Manager
Energy & Environmental Research Center
PO Box 9018
Grand Forks, ND 58202-9018

Subject: Letter of Interest and Financial Commitment for Field-Testing Activities Proposed by ALSTOM Power Inc. – U.S. Power Plant Laboratories to the U.S. Department of Energy – National Energy Technology Laboratory's (DOE/NETL) Solicitation No. DE-PS26-03NT41718 Titled "Large Scale Mercury Control Technology Field Testing Program – Round 2"

Dear Steve:

Minnkota Power Cooperative, Inc. is pleased to submit this letter of support and interest to participate in the field-testing activities that are described in the attached proposal by ALSTOM Power Inc. – U.S. Power Plant Laboratories' (ALSTOM) for evaluating long-term impacts of mercury control with enhanced sorbents to the subject DOE/NETL Solicitation No. DE-PS26-03NT41718. The testing will be conducted at Basin Electric's Leland Olds Station Unit #1 in Stanton, North Dakota. This plant will be an excellent facility to evaluate ALSTOM's Mer-Cure™ technology with enhanced sorbents to control mercury.

Minnkota Power Cooperative, Inc. recognizes the need to develop cost effective business practices that also foster innovative ways to protect and enhance the environment. We are very interested in the technologies and economics of controlling mercury from our own facilities. We feel that Basin Electric's Leland Olds facility will provide an excellent and cost-effective location for the proposed project. Based on what is learned at Leland Olds, we believe it will have a direct impact on our own Milton R. Young station. With the combined capabilities and experience of the proposed project execution team of ALSTOM and Energy and Environmental Research Center (EERC), we expect a successful project.

Minnkota Power Cooperative, Inc. is pleased to offer support to the proposed program of $10,000 In-Kind dollars. Our contributions will be subject to a definitive Cooperative Agreement with the DOE/NETL. It is understood that Minnkota Power Cooperative, Inc. In-Kind funding for this project will provide cost share to federal funding from the U.S. Department of Energy; therefore, Minnkota Power Cooperative, Inc. hereby certifies that our contribution will be comprised of nonfederal sources.

We look forward to DOE's review of the proposal and partnering with DOE on this interesting and needed project. Any questions regarding Minnkota Power Cooperative, Inc. involvement in the project may be directed to me, Luther Kvernen, VP – Generation.

Sincerely,

MINNKOTA POWER COOPERATIVE, INC.

Luther Kvernen
Vice President – Generation

gae

APPENDIX C – STATEMENT OF ALSTOM TAX LIABILITY IN NORTH DAKOTA

The following is a letter from ALSTOM's Sales and Use Tax Department providing a statement of ALSTOM's tax liability to the State of North Dakota or any of its political subdivisions.

ALSTOM

Power

Tax Services

March 23, 2005

Ms. Karlene Fine
Executive Director
North Dakota Industrial Commission
600 East Boulevard Avenue
State Capitol, 10th Floor
Bismarck, ND 58505-0310

Re: ALSTOM Power Inc. – Power Plant Laboratories Proposal to North Dakota Industrial Commission – Statement on ALSTOM Tax Liabilities in North Dakota

Dear Ms. Fine:

In reference to the ALSTOM Power Inc. – Power Plant Laboratories proposal to the North Dakota Industrial Commission titled "Field Demonstration of Enhanced Sorbent Injection for Mercury Control," this letter confirms that as of this date ALSTOM Power Inc. (ALSTOM) has no outstanding tax liability owed to the State of North Dakota or any of its political subdivisions.

Should there be any questions, please contact Ray Chamberland, Manager, Contract R&D, Power Plant Laboratories, at (860) 285-3825.

Sincerely,

Ronald R. Papke

Ronald R. Papke
Sr. Manager, Sales and Use Tax
Phone: (860) 285-5237
Fax: (860) 285-9587
email: ronald.r.papke@power.alstom.com

cc: Srivats Srinivasachar – ALSTOM Power Inc.
Shin Kang – ALSTOM Power Inc.
Ray P. Chamberland – ALSTOM Power Inc.

ALSTOM Power Inc.
2000 Day Hill Road
Windsor, CT 06095
Tel: (860) 285-5237
Fax: (860) 285-9587

APPENDIX D - DETAILED BUDGET INFORMATION

NOTICE OF RESTRICTION ON DISCLOSURE AND USE OF DATA

The data contained in pages [71 - 86] of this Appendix D – Detailed Budget Information have been submitted in confidence and contain trade secrets or proprietary information, and such data shall be used by North Dakota Industrial Commission only for the purpose of evaluating the suitability of an award to the applicant. This restriction does not limit North Dakota Industrial Commission's right to use or disclose data that does not constitute trade secret or proprietary information of the applicant.

1. PROJECT BUDGET

As mentioned in the previous sections, a successful demonstration of ALSTOM's technology in Basin Electric requires $1,644,260. The overall project budget is summarized in Table 1. Through the DOE/ALSTOM Cooperative Agreement (DE-FC26-04NT42306), DOE has made a commitment of $1,233,195, i.e., 75% of the required amount. The balance of the project cost has to be provided by the consortium members as costshare. Other project partners providing cash and in-kind funding include ALSTOM Power; Basin Electric Power Cooperative; and Minnkota Power Cooperative. In this proposal, the project team requests $200,000 from NDIC as cash costshare. If less funding is available than that requested, the project objective would be unattainable.

Table 1. Project Budget

Category	**Total**
Personnel	$521,775
Travel	67,440
Equipment/Supplies	284,708
Contractual	533,544
Total Direct	**$1,407,467**
Total Indirect	176,793
In-Kind Cost Share	60,000
Total	**$1,644,260**

A detailed breakdown of cost share is provided in Table 2. Commitment has already been made by other funding sources as listed in Table 2. Letters of Support in Appendix B reflect cost share known at the time the project was proposed to DOE.

Table 2. Proposed funding sources for the project

Funding Sources	Cash Cost Share	In-kind Cost Share	Total	Cost Share Percentage
NDIC	$200,000	$ -	$200,000	12.2
DOE	1,233,195			75.0
ALSTOM Power	151,065		151,065	9.2
Basin Electric		50,000	50,000	3.0
Minnkota		10,000	10,000	0.6
Total	$1,584,260	$60,000	$1,644,260	100

2. Additional Cost Detail

Additional cost detail is included in this section.

	Task	Cost
Planned Travel		
Basin Electric – Leland Olds Station – Stanton, ND 5 people x $770 per person airfare, $50 per day x 3 days car rental, 15 person-days x $140 per diem	1.1	6,100
Basin Electric – Leland Olds Station – Stanton, ND 4 people x $770 per person airfare, $50 per day x 3 days car rental, 12 person-days x $140 per diem	2.1	4,910
Basin Electric – Leland Olds Station – Stanton, ND 2 people x $770 per person airfare, $50 per day x 4 days car rental, 8 person-days x $140 per diem	2.2	2,860
Basin Electric – Leland Olds Station – Stanton, ND 4 trips x 4 people per trip x $770 per person airfare, $50 per day x 60 days car rental, 4 trips x 58 person-days per trip x $140 per diem	2.3	47,800
Basin Electric – Leland Olds Station – Stanton, ND 10 person-days x $140 per diem	2.4	1,400
Technical Conferences 2 trips x 1 person per trip x $750 per person airfare, $50 per day x 2 days car rental, 2 trips x 2 person-days per trip x $180 per diem	3	2,320
Project Management Meetings with DOE/NETL, host sites and subcontractors 2 trips x 1 person per trip x $750 per person airfare, $50 per day x 4 days car rental, 2 trips x 1 person-days per trip x $175 per diem	4	2,050
Planned Travel Total		$67,440

	Task	Cost
Planned Subcontractors		
EERC CMM and Ontario Hydro services	2.3	$505,528
EERC – Technical Conferences	3	13,660
EERC – Project Management	4	14,360
Planned Subcontractors Total		**$533,544**
Planned Materials and Supplies		
Lab tests of coal samples	1.1	$1,000
Injection lance fabrication (16 lances x $500 per lance)	1.2	8,000
SpiroFlo Rental (4 units x $8,400 per unit)	1.2	33,600
SpiroFlo spare parts	1.2	3,000
Sorbent for checkout of SpiroFlo equipment	1.2	100
Sorbent treatment device rental (1 unit x $23,000 per unit)	1.2	23,000
Miscellaneous equipment fabrication/modification	1.2	1,000
Control system fabrication	1.2	10,000
Air Compressor rental	1.2	20,000
Air Compressor wiring cost	1.2	10,000
Manifold fabrication	1.2	10,000
Sorbent – (First Batch – 500 pounds, $0.75 per pound)	1.2	375
Sorbent – full production (70 tons, $0.75 per pound)	1.2	105,000
Sorbent testing	1.2	2,000
Shipping – injection lances to site	1.3	500
Shipping – SpiroFlo to site	1.3	3,600
Shipping – Sorbent treatment device	1.3	1,000
Shipping – Manifold	1.3	500
Shipping – Sorbent	1.3	4,000
Task 1 Subtotal		**$236,675**
Trailer rental	2.2	$4,700
Sample analysis service	2.5	20,000
Task 2 Subtotal		**$24,700**
Project Management service – ALSTOM Performance Projects engineer	4	$20,000
Project Scheduler service – ALSTOM Performance Projects engineer	4	3,333
Task 4 Subtotal		**$23,333**
Planned Materials and Supplies Total		**$284,708**