

## **Oxy-Combustion Boiler Development for Tangential Firing of North Dakota Lignite**

*Submitted to:*

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

Amount of Request: \$490,000

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## **ABSTRACT**

Oxy-combustion is a promising near-term technology for CO<sub>2</sub> capture and sequestration from pulverized coal (PC) power plants. The basic concept of oxy-combustion is to replace combustion air with a mixture of oxygen and recycled flue gas, thereby creating a high CO<sub>2</sub> content flue gas stream that can be more simply processed for sequestration or high purity CO<sub>2</sub> product.

Alstom Power Inc. (Alstom) herein proposes a consortium-based program to test an oxy-combustion system for tangentially-fired (T-fired) boilers while firing partially dried North Dakota lignite (dried to 25-30% moisture). This grant application to NDIC proposes to add a campaign to the existing Department of Energy (DOE) program “Oxy-Combustion Boiler Development for T-Firing” that Alstom is currently executing through September 2010 under DOE Contract DE-NT0005290. Under this grant, North Dakota lignite will be evaluated through comprehensive 15 MW<sub>th</sub> Boiler Simulation Facility (BSF) testing. This proposed work would optimize oxy-combustion boiler design and operating conditions, evaluate and improve modeling tools for T-fired oxy-combustion, and provide information needed to evaluate and demonstrate the use of North Dakota lignite for oxy-combustion firing at a larger scale. Specific objectives include:

- Comparison of furnace heat transfer for air-firing and oxy-firing,
- Comparison of emissions of major gas species for air-firing and oxy-firing,
- Comparison of mercury emissions for air-firing and oxy-firing,
- Ash deposition and material corrosion characteristics with oxyfuel, and
- Optimization of boiler operating parameters for dried lignite oxyfuel.

In this program, Alstom teams up with the University of North Dakota – Energy and Environmental Research Center (EERC), Great River Energy, Midwest Generation, Dominion Energy, Ameren, OGE Energy Corp, Luminant (TXU), LCRA/Austin Energy, Vattenfall, NB Power, ATCO, and the Illinois Clean Coal Institute (ICCI).

This proposal requests \$490,000 from NDIC. The overall project requires \$8,716,523 of funding with this additional scope. The DOE has committed \$5,000,000 and other team members (including NDIC) will provide the balance of \$3,716,523.

## 1 PROJECT SUMMARY

Alstom Power Inc. is applying to the North Dakota Industrial Commission (NDIC) for a grant of \$490,000 for a consortium-based program to test an oxy-combustion system for T-fired boiler units while firing dried North Dakota lignite. This grant application proposes to add a campaign to the existing Department of Energy (DOE) program “Oxy-Combustion Boiler Development for T-Firing” that Alstom is currently executing (DOE Contract DE-NT0005290). The project requires \$8,716,523 of funding including this additional scope, of which the DOE has committed \$5,000,000 and other team members (including NDIC) will provide the balance of \$3,716,523.

Under this grant application to NDIC, dried North Dakota lignite will be added to the fuels evaluated under the Alstom-DOE oxy-combustion program, which features comprehensive 15 MW<sub>th</sub> Boiler Simulation Facility (BSF) testing. This proposed work would optimize oxy-combustion boiler design and operating conditions and provide information needed to evaluate and demonstrate the use of dried North Dakota lignite for oxy-combustion firing at a larger scale.

A large body of scientific information and knowledge has been accumulated on oxy-combustion, but product development and technology gaps exist. In particular, oxy-combustion characteristics during T-firing are just beginning to be characterized. There are major differences in furnace aerodynamics and mixing with T-firing compared with swirl-stabilized wall-fired burners that require different design considerations to optimize oxy-combustion. Since T-fired boilers make up over 40% of the US and world’s installed base of utility boilers, a technology solution for oxy-combustion in T-fired boilers is important for both existing and new units.

Alstom, in cooperation with DOE/NETL, is conducting a 24 month test program to develop an oxy-combustion system for T-fired boiler units. The overall objectives of the project are to:

- Design and develop an innovative oxy-combustion system for existing T-fired boilers that minimizes overall capital investment and operating costs,
- Evaluate performance of oxy-combustion T-fired boiler systems in pilot scale tests at Alstom's 15 MW<sub>th</sub> T-Fired Boiler Simulation Facility, and
- Address technical gaps for design of oxy-combustion commercial utility boilers by focused testing in the BSF and improvement of engineering and CFD tools.

The program has evaluated several oxy-combustion system design concepts, including various flue gas recirculation scenarios and oxygen injection options, using engineering and 3-D computational fluid dynamics (CFD) modeling tools along with techno-economic analysis. The most promising designs are being tested in Alstom's 15 MW<sub>th</sub> Boiler Simulation Facility (BSF). These tests include a range of operating conditions and include a number of coal types. This proposal to NDIC will add a test campaign firing dried North Dakota lignite to the test campaigns already scheduled for subbituminous, low sulfur bituminous and high sulfur bituminous coals. Detailed measurements addressing changes in furnace heat absorption, ash deposition, material corrosion, combustion and pollutant formation will be obtained. Test results will be used to evaluate and improve modeling tools for T-fired oxy-combustion and provide information needed to effectively take the next step to demonstrate oxy-combustion in a commercial T-fired boiler.

## **2 PROJECT DESCRIPTION**

### **2.1 Introduction**

Oxy-combustion is a promising near-term technology for CO<sub>2</sub> capture and sequestration from pulverized coal (PC) power plants. The basic concept of oxy-combustion (“oxyfuel”) is to replace combustion air with a mixture of oxygen and recycled flue gas, thereby creating a high CO<sub>2</sub> content flue gas stream that can be more simply processed for sequestration or high purity product. On April 10, 2008, Alstom Power submitted a proposal to the U. S. Department of Energy titled “Oxy-Combustion Boiler Development for Tangential Firing.” The proposal was selected for negotiations leading to an award, and Alstom and the DOE executed a contract in September 2008.

To fit within budget constraints, no lignite is currently planned for testing in the BSF under the DOE funded effort. The DOE project includes an Industrial Advisory Group, and Great River Energy (GRE) is one of the ten members of the group. GRE operates a lignite drying system at their Coal Creek station. They have expressed interest in providing dried lignite and in-kind cofunding for an additional test campaign for the DOE oxyfuel project. It would be advantageous to leverage NDIC and GRE funding by incorporating BSF testing of dried lignite oxyfuel firing into the existing DOE project.

Oxy-firing of dried lignite in the BSF will provide realistic combustion conditions. Factors such as impurities in the coal can significantly influence performance. Impurities affect ash slagging and fouling behavior, strongly impacting heat transfer and overall boiler performance. The dried lignite will also generate a different emissions profile than as-received lignite. Tests of the lignite at Coal Creek station have shown



lower emissions with dried lignite under air firing. <sup>1</sup> Oxyfuel firing will have a strong effect on emissions as well. Testing with dried North Dakota lignite will allow evaluation and optimization of operating conditions for this fuel.

The purpose of this current proposal to NDIC is to expand the oxy-fired test program to include a full test campaign on dried North Dakota lignite. This proposed work would optimize boiler design and operating conditions and provide information needed to evaluate and demonstrate the use of dried North Dakota lignite in oxyfuel firing. Specific objectives of the proposed test campaign for dried lignite include:

- Comparison of furnace heat transfer for air-firing and oxy-firing,
- Comparison of emissions of major gas species for air-firing and oxy-firing,
- Comparison of mercury emissions for air-firing and oxy-firing,
- Ash deposition and material corrosion characteristics with oxyfuel, and
- Optimization of boiler operating parameters for dried lignite oxyfuel.

## **2.2 Background on Tangentially-Fired Oxy-Combustion**

For over a decade, Alstom Power Inc. (Alstom) and others have been actively working on various oxy-combustion based CO<sub>2</sub> control technologies. <sup>2-6</sup> Currently, Alstom is collaborating with the Swedish utility Vattenfall on a 30 MW<sub>th</sub> pilot plant demonstration of CO<sub>2</sub> capture and sequestration. <sup>7</sup> The pilot plant fires dried lignite in an oxy-combustion configuration utilizing a single, swirl-stabilized wall burner. This pilot plant has attained over 1500 hours of oxy-combustion operation and captured over 13,500 tons of CO<sub>2</sub> since start-up on air-firing in August 2008. The references cited show that boiler manufacturers including Alstom, Babcock & Wilcox, Foster Wheeler

and Hitachi are involved in oxy-combustion development, including several pilot scale demonstrations for wall firing configurations. Alstom is the only OEM demonstrating oxy-combustion at pilot scale in a tangential firing configuration.

In addition to oxy-combustion, several pre- and post-combustion technologies are currently being evaluated and developed to address greenhouse gas issues for coal-fired power plants. Pre-combustion techniques (such as IGCC) are only applicable to new units. Post-combustion techniques (such as amine or chilled ammonia scrubbing) and oxy-combustion are applicable to both new and retrofit units. Oxy-combustion builds on conventional technologies and equipment and is considered one of the most promising near-term CO<sub>2</sub> capture technologies for both existing and new boiler units.<sup>8</sup>

An oxyfuel system requires three major components:

- an air separation unit (ASU) or possibly other advanced technology to supply oxygen,
- an oxy-combustion boiler with air pollution control devices (APCD) and a flue gas condenser (FGC), and
- a flue gas processing unit (GPU) to purify the CO<sub>2</sub> for final use or sequestration.

This program supports the development of this technology while focusing on the second component, an oxy-combustion T-fired boiler.

The basic oxy-combustion concept uses oxygen to replace combustion air, producing flue gas of mainly CO<sub>2</sub> and water vapor, which can be dried, compressed, and purified for sequestration or enhanced oil or gas recovery. Burning in pure oxygen in existing boiler designs would result in excessive furnace temperatures causing ash

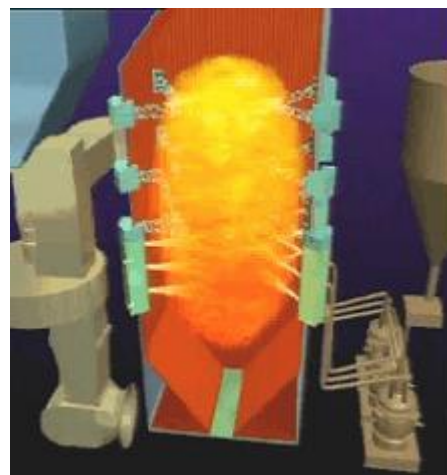
slagging issues, corrosion issues, fine ash aerosols, and possible damage to boiler waterwalls if steam-side circulation is insufficient. Most designs call for flue gas recirculation (FGR) back to the furnace to moderate the temperature. For a retrofit, it is critical to recirculate enough gas to maintain the furnace design temperatures and steam conditions. In a new unit, there is more flexibility in the design of the boiler and the amount of FGR.

Because oxyfuel flue gas has different properties than air firing, the expected quantity of FGR required to maintain performance for an existing boiler design is enough to dilute the boiler global oxygen level to about 27% oxygen. For carbon steel, the Compressed Gas Association guidelines limit the concentration of oxygen to 23.5% in a warm (>150°C) flue gas stream. Using stainless alloys for large ducts and major equipment is generally cost prohibitive. However, even in streams with low oxygen concentrations, mixing must be sufficient to avoid locally high concentration. For the primary FGR, lower oxygen content – even zero – could be advantageous for drying and pulverizing the coal at higher temperatures, which may provide other process benefits.

Alstom has investigated the advantages and disadvantages of these options, which depend on site-specific factors including plant equipment and layout, available space and fuel properties. The program will build upon this information and also evaluate other new and innovative design options.

Oxygen, FGR, and fuel must be fired in properly designed burners or fuel assemblies, which is as essential for oxyfuel as it is for air firing. Differences between wall-fired and tangentially-fired systems must be considered. Tangential-firing is

different from wall firing in that it utilizes fuel admission assemblies located at the corners of the boiler furnace, which generate a rotating fireball that fills most of the furnace cross section (Figure 1). The fuel and air mixing is limited until the streams join together in the boiler volume and generate a rotation. This has been described as “the entire boiler is the burner.” Whereas mixing is realized in a micro-scale for wall-fired boilers, it is realized both in a micro- and macro-scale for T-fired boiler systems.



**Figure 1 T-Fired Boiler**

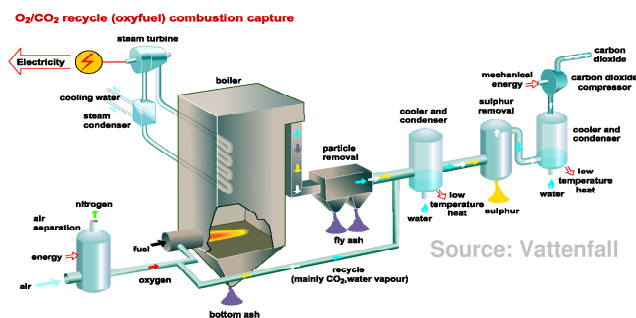
Alstom has extensive experience, calibrated engineering and CFD modeling tools, and design standards for both T-fired and wall-fired boilers with air. The combustion process, pollutant formation, ash deposition, and waterwall corrosion are all influenced by firing system design and operation, which again requires different considerations for T-firing than wall-firing.

### **2.3 Technical Feasibility and Readiness for Pilot-Scale Testing**

Alstom has been actively working on various oxyfuel technologies for more than a decade. Large pilot scale tests of an oxy-PC firing system were performed in the 1990's at 35 MW<sub>th</sub> pilot-scale at Alstom in Derby, UK. As mentioned previously, Alstom is now collaborating with the Swedish utility Vattenfall and others to demonstrate oxy-PC technology at the Schwarze Pumpe coal-fired power station in Germany. The steam generator of the 30 MW<sub>th</sub> pilot plant is equipped with a single burner in an indirect

firing system and will demonstrate oxygen firing with FGR including operation under various oxygen injection regimes for dried lignite and bituminous coal.

The demonstration of the complete required oxyfuel chain, from ASU to GPU (Figure 2), will provide information on both oxyfuel combustion characteristics and operation of the steam generator with ASU and GPU.



**Figure 2 Vattenfall Pilot Plant**

Alstom also has an on-going oxy T-fired reference plant study (850 MW<sub>e</sub>) to establish reliable economic and performance data and identify technology gaps for commercial demonstration of oxy T-fired boilers. The current DOE oxyfuel program builds upon this work, and complements Vattenfall and other efforts to address these gaps.

This current DOE oxyfuel program is designed 1) to develop a better understanding of the characteristics of oxyfuel as compared to air-fired combustion under various T-fired boiler conditions and 2) to develop and test an oxyfuel T-fired boiler concept that can be retrofitted to existing coal-fired power plants while minimizing incremental capital and operating costs. This proposal to NDIC is designed to leverage the DOE funding and to address these concerns for lignite.

## 2.4 Oxy-Combustion Project Objectives and Methodology

Alstom is currently conducting a comprehensive DOE program to develop and test oxyfuel T-fired technology for retrofit to existing boilers; in addition, the results will also be applicable to the design of new boilers. This proposal to NDIC would expand

the existing DOE program to include dried lignite oxyfuel testing. Sections 2.4 through 2.6 are taken largely from the proposal to the DOE, with updated information for tasks already completed. [The additional scope related to the North Dakota lignite testing is indicated by underlining and blue text in these sections.](#)

The overall objectives of the project are to:

- Design and develop an innovative oxyfuel system for existing T-fired boiler units that minimizes overall capital investment and operating costs,
- Evaluate performance of oxyfuel T-fired boiler systems in pilot scale tests at Alstom's 15 MW<sub>th</sub> T-Fired Boiler Simulation Facility (BSF).
- Address technical gaps for design of oxyfuel commercial utility boilers by focused testing in the BSF and improvement of engineering and CFD tools.
- Evaluate the impacts of oxy-firing with flue gas recirculation of high-sulfur Illinois coal in a dedicated test campaign and analyze and report the results as part of the overall project.
- [Evaluate the impacts of oxy-firing with flue gas recirculation of North Dakota lignite in a dedicated test campaign and analyze and report the results as part of the overall project.](#)

At the completion of this program, Alstom will have sufficient information to proceed with a commercial demonstration design, construction, and validation of oxyfuel firing in a commercial T-fired boiler. [Specific objectives of the proposed test campaign for dried lignite include:](#)

- [Comparison of furnace heat transfer for air firing and oxy-firing.](#)
- [Comparison of emissions of major gas species for air firing and oxy-firing.](#)
- [Comparison of mercury emissions for air firing and oxy-firing.](#)
- [Ash deposition and material corrosion characteristics with oxyfuel, and](#)
- [Optimization of boiler operating parameters for dried lignite oxyfuel.](#)

The technical approach proposed to develop oxyfuel T-firing is proven by Alstom's past experience. The work includes analytical screening, bench scale tests, and large oxy T-fired pilot testing in the 15 MW<sub>th</sub> BSF. BSF testing has a long successful history of supporting development and commercialization of Alstom's firing systems including the TSF2000™, CCFSTM, LNCFS™ upgrades, reburning systems, and other technologies. Today the 50 lowest NO<sub>x</sub> emitting coal-fired utility boilers in the US all incorporate technology developed in this facility. Table 1 summarizes technical issues and the proposed approach to fill gaps in Alstom's PC oxyfuel development plan.

**Table 1 Technical Issues Addressed in the Project**

<b>Issues Specific to Tangential Firing with Oxygen</b>	
<ul style="list-style-type: none"> <li>• No oxy testing has been performed on a T- fired facility at pilot scale</li> <li>• CFD and other models' reliability due to complexity and current limitations of CDF modeling</li> </ul>	
<b>Specific tangential firing issues that need to be further addressed include the following:</b>	
<b>Issues</b>	<b>Test Methodology</b>
<ul style="list-style-type: none"> <li>• Furnace Heat Absorption Patterns &amp; Distribution</li> <li>• Carbon Burnout and CO Concentration</li> <li>• Pollutants – NO<sub>x</sub>, SO<sub>2</sub>, SO<sub>3</sub>, Hg.</li> </ul>	Furnace heat flux profiles (via probes) and Q/A panels, carbon burnout, and gas emissions data for selected T-firing scenarios in the BSF. Collect detailed data for model evaluation and validation. Test range of operating conditions and coal types for broad application.
<ul style="list-style-type: none"> <li>• Slagging Characteristics</li> <li>• Waterwall Corrosion</li> </ul>	Use deposit & corrosion probes in BSF furnace for evaluation. Produce tube samples and extend exposure with bench rig. Assess the tested range of coals and conditions.
<ul style="list-style-type: none"> <li>• Fuel Assembly Design</li> <li>• Oxygen Lance Design, Location, Materials</li> </ul>	Oxygen lances, reduced gas volumetric flow versus air, and wall protection will require firing system design changes via testing, as will operation at minimal O <sub>2</sub> levels (operational cost issue).

<b>Non - Tangential Fired Specific Issues</b>	
These issues are not furnace specific and can therefore be addressed by this program and by other tests, such as the 30 MW <sub>th</sub> Vattenfall Schwarze Pumpe pilot plant. This program will emphasize the fuel specific issues to expand and enhance the database.	
<b>Issues</b>	<b>Test Methodology</b>
<ul style="list-style-type: none"> <li>• Ash Fouling Characteristics</li> <li>• Convective Tube Corrosion</li> <li>• Convective Pass Heat Transfer Rates</li> </ul>	Expose and evaluate temperature controlled corrosion specimens at selected locations in the convective pass during BSF testing and at bench scale. Assess deposit properties and deposit /tube interface. Limited convective pass testing (extensive heat transfer data from Vattenfall pilot) Assess range of coals and conditions to expand database & broaden application
Oxygen Mixing	Locally high oxygen concentrations in ducts should be avoided. Probe the gas duct to determine conditions for uniform mixing of oxygen in FGR.
Operation and Control	Evaluate feasibility of recirculated flue gas takeoff locations. Vary ramp rates transitioning air to oxygen to determine practical limits. Determine if oxygen and recirculated gas flow rates are stable with commercially available control equipment.
Air In-Leakage Control	Reducing air in-leakage will save energy required to purify the CO <sub>2</sub> in downstream GPU. Tests will vary the amount of in-leakage to investigate the effects on variables such as NO <sub>x</sub> formation and heat transfer.
Pulverizer Drying and Coal Transport	Conduct testing with high humidity gas to evaluate drying requirements and remaining PC moisture.

The impacts of oxyfuel conditions on ash behavior and fireside corrosion are areas requiring greater understanding. Near-field and global aerodynamics and mixing for T-firing regimes and the effects on combustion performance, heat transfer distribution and pollutant formation must also be understood. Focus will be given to specific oxy T-fired related impacts in order to complement and support on-going computational modeling development and data from oxyfuel test programs by Alstom and others. Central to the proposed effort is the use of Alstom’s 15 MW<sub>th</sub> BSF to generate detailed performance test data under representative T-fired conditions.

The effort utilizes a phased approach during which a number of innovative FGR scenarios and firing system options were first screened using less costly engineering and CFD tools to help select the appropriate configurations and conditions for further BSF testing. The screening also included evaluation of the option’s impact on the



overall plant. This screening allows optimization of the testing effort, reduces costs, and insures that the testing is focused on commercially relevant test conditions.

For these screening evaluations, a typical Alstom 850 MW<sub>e</sub> supercritical tangential-fired boiler design was selected for the base design and various oxy configurations were modeled using Alstom's proprietary boiler design codes. Process flow diagrams, mass and energy balances, and performance data have been generated for several different oxy options, including different FGR take-off locations, flow rates and injection locations as well as different oxygen injection schemes.

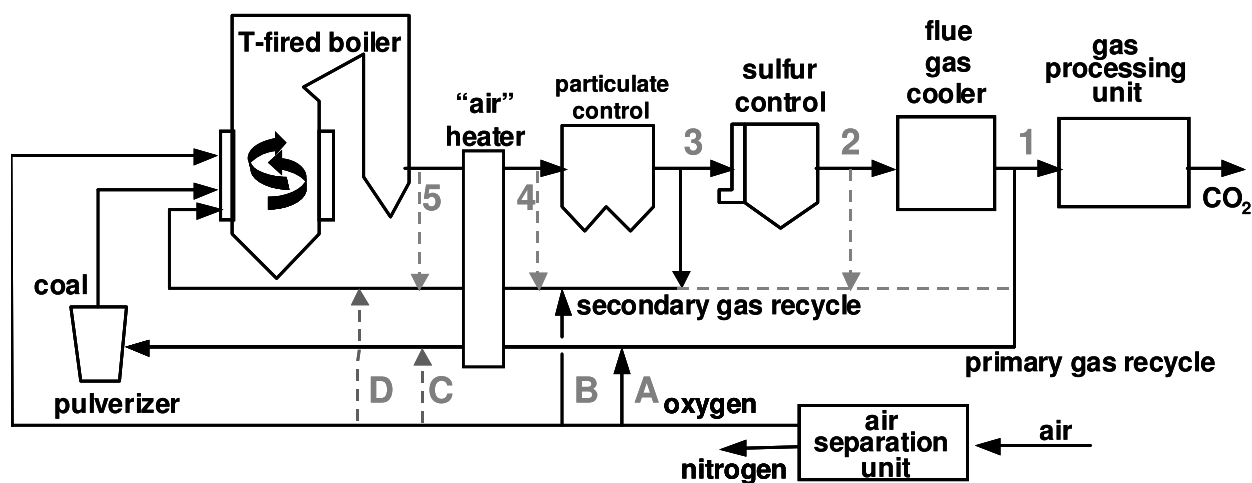


Figure 3 Simplified Oxy Combustion Process Flow Diagram

Figure 3 illustrates possible FGR take-off points (numbered 1 - 5) and oxygen injection points (lettered A – E). In general, as FGR is taken closer to the boiler, a greater portion of the downstream equipment can benefit in terms of reduced gas flow. This impacts the size and cost for equipment associated with new plants, as well as for existing plants if replacement or additional equipment is installed. However, the closer to the boiler the FGR is taken, the greater the concentration of impurities recycled back to the boiler. This could increase corrosion and ash deposition, which may need to be

addressed by boiler modifications or changes to operating conditions. Trade-offs associated with FGR recycle location are primarily dependent on fuel properties and other site-specific factors. High sulfur fuels will likely benefit if FGR is taken after some sulfur removal to limit the potential for very high sulfur concentrations in the boiler.

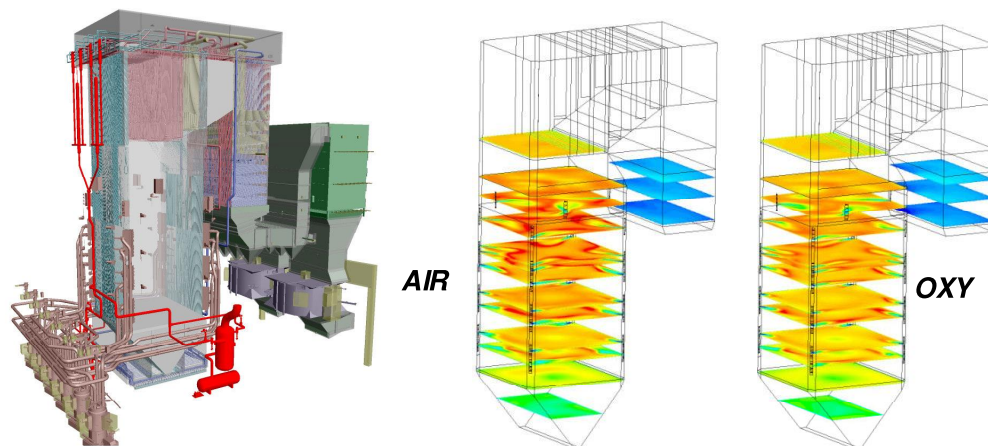
Oxygen injection location and the concentration of oxygen in the FGR also impacts equipment material requirements. Materials must be selected based on the temperature and concentration of oxygen present. For higher oxygen temperatures and concentrations, stainless steels or other alloys may be required in place of less costly carbon steel. This can limit oxygen concentrations for existing equipment such as air preheaters and may require addition or replacement of ducting and other components.

CFD modeling of the oxy firing system design variables and their impacts on boiler performance is in progress. CFD models of the BSF were developed to allow evaluation of various oxy-fired design options. Data from previous BSF testing were used for model setup and calibration of air-fired cases. The model was then used to perform simulations for oxy-fired conditions. Key variables evaluated include:

- gas recycle ratio (gas flow rates),
- gas recycle composition,
- oxygen injection method/distribution,
- windbox design, and
- separate over-fire air design.

In addition to the BSF CFD simulations, a detailed model of a large utility boiler was developed to compare and confirm similar behavior predicted for the BSF. This unit is an existing 850 MW<sub>e</sub> tangentially-fired supercritical boiler representative of a new

Alstom U.S. design. This boiler is shown in Figure 4. A number of air-fired and oxy-fired cases have been run. An example of temperature distribution predictions for an air-fired and an oxy-fired case are shown in Figure 4. For these simulations, the model was first set up and calibrated for the air-fired case. The oxy-fired case was part of a set of varying FGR flow rates and run with the same furnace geometry as the air-fired case, but varied the injection areas to provide the same gas velocity ratios for the different gas flow inputs.



**Figure 4 850 MW Study Boiler and Example of Temperature Predictions For Air and Oxy-Firing**

Results from the studied oxyfiring scenarios and CFD modeling work was used to update the BSF test plan and help establish design criteria for necessary facility modifications.

A summary of major test variables for BSF Campaign 1 is shown below:

- gas recycle flow rates and take-off locations;
- oxygen injection flow rates and locations;
- windbox and over-fire “air” compartment design.

A summary of data measurements taken for BSF Campaign 1 is provided below:

- Online Data Acquisition System – logging of all major flows rates, process temperatures, pressures, gaseous compositions, etc.;
- furnace heat transfer panels - heat absorption rates;
- fly ash loadings and samples for analyses;
- high velocity suction pyrometer, for furnace and convective pass temperature distributions;
- heat flux probe measurements at various furnace wall locations;
- detailed furnace mapping (planar temperature and gas species distributions at various furnace elevations) – for selected operating conditions:
- mercury, trace metals, and SO<sub>3</sub> measurements at selected conditions
- deposition and corrosion probes – Collection and analysis of deposits and probe metal for further evaluation

Test data from the BSF will provide direct support for commercial engineering design as well as provide a means to assess, improve and validate computational models and design tools.

## **2.5 Work Breakdown Structure**

Note that the work breakdown structure describes the test program for DOE Budget Periods 1 and 2. DOE Budget Period 1 will be completed on September 30, 2009. **This proposal is seeking NDIC funding for additional scope during DOE Budget Period 2.**

The proposed work has been divided into five major tasks in two budget periods:

Budget Period 1

Task 1A – Project Management

Task 2 – Assessment of Oxyfuel T-Fired Boiler Systems

Task 3A – Bench Scale Support Tests

Task 4A – Large Pilot Scale Testing

Test Planning

Test Preparations

BSF Oxy Shakedown

BSF Test Campaign 1 (PRB subbituminous coal)

Budget Period 2

Task 1B – Project Management

Task 3B – Bench Scale Support Tests

Task 4B – Large Pilot Scale Testing

BSF Test Campaign 2 (low-sulfur and high-sulfur bituminous coals) – This test campaign will not be supported with NDIC funding.

[BSF Test Campaign 3 \(dried North Dakota lignite\)](#)

Task 5B – Data Analysis and Documentation

The major task descriptions are provided below and are similar for both Budget Periods.

**Task 1 – Project Management** Task 1.1 addresses management of technical, budgetary and scheduling activities, including project and task planning, asset management, cost tracking and progress reporting. Quarterly and final reports will be

provided in accordance with the Federal Assistance Reporting Checklist and as defined in the Statement of Project Objectives.

Under Task 1.2, an Industrial Advisory Group has been organized, with activities coordinated to provide value to the project. The Advisory Group includes representatives from utilities as well as representatives from Alstom Business Units and DOE to provide focus and important end-user perspective for the project.

Representatives from NDIC and ICCI will be invited to participate in the Advisory Group meetings. Utility members include:

Ameren	ATCO	Dominion Energy
Great River Energy	LCRA/Austin Energy	Luminant (TXU)
Midwest Generation	NB Power	OGE Energy Corp
Vattenfall		

At least four Advisory Group meetings are planned during the course of the project, including one recently held in Windsor CT to review the overall project and one after BSF Test Campaign 1 to discuss results and provide feedback prior to Budget Period 2 work. Group members will receive progress reports and technical updates to allow feedback and comments throughout the project.

**Task 2 – Assessment of Oxy T-Fired Boiler Systems** provides screening of several different oxyfuel T-firing systems. Innovative FGR and O<sub>2</sub> scenarios will be assessed. This evaluation will utilize modeling tools that Alstom has successfully applied (and understands their strengths and limitations), including FLUENT CFD code, Chemkin, ASPEN and Alstom’s proprietary process and boiler design models. Alstom has done

substantial work improving oxyfuel modeling capabilities. Updated information available from the literature and on-going projects will be reviewed and taken into consideration.

The results of this task will be used to update the 15 MW<sub>th</sub> BSF test plan including selection of the design options and the range of test conditions.

**Task 3 – Bench Scale Support Tests** will be conducted to provide supplemental data on ash deposition and corrosion to support evaluation of candidate design options. In particular, this testing will focus on the impacts of potentially detrimental ash components such as alkalis and trace constituents under oxyfuel conditions, which would be substantially enriched for the design options where flue gas recirculation is taken prior to fly ash removal.

Supplemental corrosion tests on selected materials will be performed under oxyfuel conditions with enrichment of various ash components. This testing complements Alstom's on-going material testing under oxy combustion conditions being conducted under DOE's Advanced Materials consortium contract. The proposed work will utilize existing equipment and testing methods.

Also under this task, bench testing will be conducted on corrosion specimens with deposits that are collected during the large scale BSF testing and subjected to extended exposure in lab muffle furnaces under oxy-combustion conditions measured in the BSF. Exposed deposits will be analyzed for changes in deposit properties, particularly CO<sub>2</sub> uptake and deposit strength. [This additional exposure will include deposits collected during the lignite testing.](#)

**Task 4 – Large Pilot Scale Testing** will be conducted in Alstom’s BSF to generate key technical data to address development issues. This facility has been successfully used for several major boiler combustion systems development initiatives such as Alstom’s current TFS 2000™ system, to develop and optimize process design and equipment hardware prior to full-scale utility demonstration. The scale and design of the BSF allows replication of key combustion phenomena including aerodynamics and mixing behavior that cannot be accurately replicated at a smaller scale. Alstom has found that the 15 MW<sub>th</sub> BSF scale or larger is needed to accurately reflect the nuances of utility scale T-firing. The test facility has been configured for oxyfuel firing and required some modifications to existing equipment and installation of additional equipment and instrumentation. A simplified process flow diagram of the integrated test facility highlighting new equipment is shown in Figure 5.

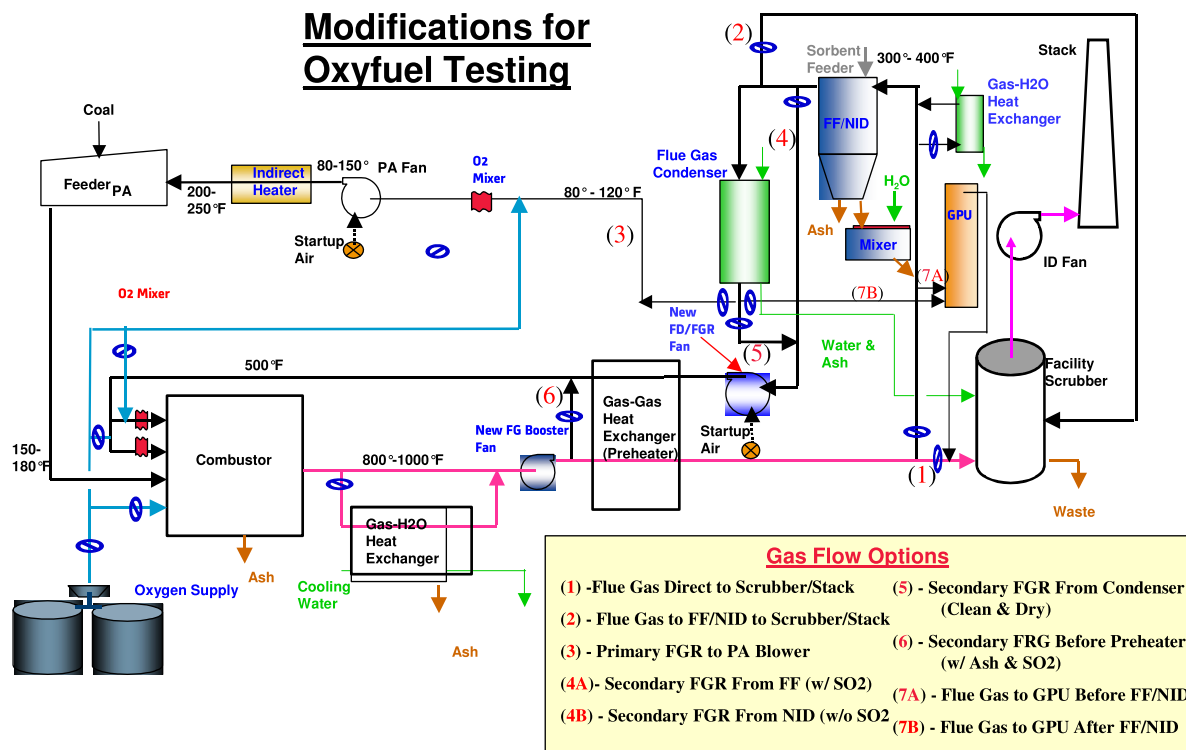


Figure 5 BSF Flow Diagram with Equipment Modifications



Modifications that have been made include:

- Addition of a common temporary oxygen supply system.
- Reconfiguration of the existing FGR system for the BSF to provide greater flexibility.
- Changes to BSF access ports and openings to minimize air in-leakage.
- Installation of a Fabric Filter to allow particulate removal from recirculated flue gas prior to the facility's existing pollution control system and removal of SO<sub>2</sub> using Alstom's NID dry scrubbing technology.
- Added instrumentation and control logic to transition to-and-from oxy firing and control conditions under oxy-firing.

**BSF Testing** Three BSF test campaigns are planned. A summary of test objectives is shown in Table 2. BSF Campaign 1 will focus on testing the most promising FGR and oxygen injection options selected during Task 2. Baseline air-fired testing will initially be conducted to establish comparative performance and emission data for the test coal. The selected design options will each be tested in the BSF over a range of conditions with the objective of optimizing overall performance and emissions.

**Table 2 Key Objectives of the Test Campaigns**

Test Campaign	Fuel	Main Objective
BSF Shakedown	Subbituminous	Validate component and facility operation.
BSF 1	Subbituminous	Evaluate FGR options, including internal FGR. Evaluate burner design options. Characterize BSF performance.
BSF 2	Low Sulfur Bituminous High Sulfur Illinois Bituminous	With one burner design based on Campaign 1 results, optimize and characterize the BSF performance. Test to specifically look at the impact of higher sulfur concentration and ash properties of Illinois coal.
<a href="#">BSF 3</a>	<a href="#">North Dakota lignite</a>	<a href="#">Test to specifically look at the impact of mercury speciation and ash properties of North Dakota lignite.</a>

Operating variables assessed include total excess oxygen, burner zone staging, and air in-leakage. Firing system design variables included FGR take-off location, FGR stream flow rates and injection locations, oxygen concentration in different input streams, and fuel and oxidant injection nozzle velocity. A subbituminous coal was selected for this campaign due to the commercial significance in the US market. Pulverized test fuel was prepared in Alstom's Pulverizer Test Facility.

During BSF Campaign 2, firing system design will be further optimized and characterized, building upon test results from Campaign 1. A low-sulfur bituminous coal will be used for this campaign. Baseline air-fired data will be collected prior to transitioning to oxy-firing. The impact of operating and firing system design variables on performance and emissions will be assessed over a series of test points. Based upon observed results, "optimum" conditions will be selected for detailed furnace mapping measurements by multiple traverses at different elevations in the furnace and convective section. Mapping measurements will include gas temperature and gas composition. Particulate samples will also be collected at probing elevations. The mapping data will be used to better define and understand behavior as well as allow comparison to model predictions for calibration and validation.

BSF Campaign 2 will also characterize the performance of a high sulfur Illinois coal. Of particular interest are the SO<sub>2</sub> and SO<sub>3</sub> concentrations that build up due to the recycle of flue gas according to the level of sulfur capture. The test will begin with air firing for baseline comparison. Following transitioning to oxy-firing, the impact of operating and firing system design variables on performance and emissions will be assessed over a series of test points. Based upon observed results, "optimum"

conditions will be selected for detailed furnace mapping measurements by traverses at different elevations in the furnace and convective section. Mapping measurements will include gas temperature and gas composition. Particulate samples will also be collected at probing elevations.

[BSF Campaign 3 will characterize the performance of North Dakota lignite. Of particular interest are the gaseous mercury concentrations that may build up due to recycle of flue gas according to the level of mercury capture. The test will begin with air firing for baseline comparison. Following transitioning to oxy-firing, the impact of operating and firing system design variables on performance and emissions will be assessed over a series of test points. Based upon observed results, “optimum” conditions will be selected for detailed furnace mapping measurements by multiple traverses at different elevations in the furnace and convective section. Mapping measurements will include gas temperature and gas composition. Particulate samples will also be collected at probing elevations. Gaseous mercury concentrations will be measured with two Continuous Mercury Monitors \(CMMs\) at the boiler outlet and in the flue gas recycle stream to determine a mercury balance around the boiler.](#)

Typical testing parameters and measurements taken during each campaign are shown in Table 3.

**Table 3 Key Test Measurements**

- Online Data Acquisition System - flows, temperatures, pressures, emissions
- Heat transfer panels absorption rates
- Flyash samples for carbon and other analyses
- High velocity suction pyrometer, for furnace and convective pass temperature distributions
- Heat flux probe measurements in the furnace
- Furnace mapping - optimum conditions in BSF Campaigns 1, 2, [and 3](#)
- Mercury, trace metals, and SO<sub>3</sub> measurements at selected stable conditions
- Deposition and corrosion probes - analyze the probes and collect deposits for further exposure in bench-scale tests

Another objective of the testing is to evaluate flame scanner performance. Oxy flame signatures and scanner response will be characterized over a range of design and operating conditions to establish appropriate sensors and scanner location.

**Task 5 – Data Analysis and Documentation** addresses pilot scale test data reduction and evaluation. Test samples collected during testing, including test fuel, fly ash and particulate, deposits, gas sampling for mercury, trace metals and SO<sub>3</sub> will be analyzed. Probe corrosion specimens will also be analyzed with focus on the deposit- metal interface using SEM techniques.

Detailed test data including mapping measurements will be compared with BSF model predictions from Task 2. CFD models as well as engineering models will be re-run with updated boundary conditions and incorporating the new measured input test data on deposition, furnace heat flux, etc., to help evaluate model capabilities.

## **2.6 Deliverables**

The quarterly DOE technical and financial progress reports, annual topical reports, and a final report shall be submitted in accordance with the Federal Assistance Checklist. [In addition, progress reports will be provided as required by NDIC.](#) Specifically, the Budget Period 1 topical report will include a summary of results of the oxyfuel system design screening techno-economic analysis, the BSF facility modifications necessary for pilot scale oxyfuel combustion testing, a test matrix for pilot scale combustion testing in the BSF, and a summary of test results from BSF Test Campaign 1.

The Budget Period 2 topical report will include a summary of test results for BSF Test Campaign 2 [and BSF Test Campaign 3](#). The final report will be written and submitted by the end of the performance period in accordance with the Federal Assistance Reporting Checklist.

## **2.7 Tangentially-Fired Oxy-Combustion Technology**

### **Commercialization**

Oxy-combustion is one of the promising technologies being developed for carbon capture. As discussed in the proposal, there is the need for testing of tangentially fired oxy-combustion systems. T-fired boilers make up 44% of the world's and 41% of the United States' installed base of utility boilers, including 19 T-fired units with over 10 GW<sub>e</sub> capacity in the United States which fire lignite in whole or in part. <sup>9</sup>

The current test program on T-fired oxyfuel boiler development <sup>10</sup> funded by the U.S. DOE and industry cofunders is investigating and demonstrating oxy-combustion T-firing with flue gas recirculation, but only with bituminous and subbituminous fuels at this point. There will be additional questions about how to design for lignite. The benefit of adding Test Campaign 3 with lignite will be to answer these questions and demonstrate that dried North Dakota lignite can be successfully burned under oxy-combustion conditions with flue gas recirculation. Oxy-combustion conditions and performance will be optimized for dried North Dakota lignite during the proposed testing, which will allow data for better comparison with other coals during evaluations for power plant retrofit or new plants considering this technology.

Alstom intends to commercialize this technology and has been actively pursuing development. Alstom's development path for commercialization of pulverized coal oxy-combustion boilers is shown in Appendix E. At the completion of this program, Alstom will have sufficient information to proceed with a host utility on a commercial demonstration design, construction, and validation of oxyfuel firing in a commercial T-fired boiler burning lignite fuel.

### **3 STANDARDS OF SUCCESS**

The standards of success for this project will be measured through successful pilot scale demonstration of oxy-combustion while firing dried lignite. Furnace heat transfer results will show the applicability of lignite oxyfuel retrofit to existing T-fired boilers. Major gas species emissions results will show the potential impact of oxyfuel on air pollution control devices for NO<sub>x</sub> and SO<sub>2</sub> removal. Ash deposition and corrosion results will show the applicability of lignite oxyfuel to existing T-fired units and the extent of materials upgrades that may be required. Mercury test results will show the potential impact of oxyfuel on mercury capture technologies.

The performance goal of the project is to identify low-capital cost oxyfuel T-fired boiler designs for the range of fuels tested, maintaining minimal balance of plant impact.

### **4 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 almost 30 million tons of lignite annually, and tens of thousands of tons of

lignite are fired by North Dakota power plants daily. North Dakota's economy depends on lignite production and use.

Carbon capture and sequestration from lignite-fired boilers poses a significant technical challenge. Successful demonstration of Alstom's cost-effective oxy-combustion technology will allow continued use of lignite in an efficient and environmentally safe manner, and ultimately could 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.

## **5 MANAGEMENT AND TEAM QUALIFICATIONS**

The project team consists of Alstom, the US DOE, ICCI and ten utility companies who are members of the industrial advisory group, i.e., Great River Energy, Midwest Generation, Dominion Energy, Ameren, OGE Energy Corp, Luminant (TXU), LCRA/Austin Energy, Vattenfall, NB Power, and ATCO. These utilities provide valuable input from the end-user perspective. Alstom is the principal contractor of the program, leading efforts from initial preparation, planning, site modification, pilot scale field demonstration testing through data analysis and project reporting.

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<sub>x</sub> firing systems, furnace sorbent injection, and utilization of cleaned coals. Alstom currently

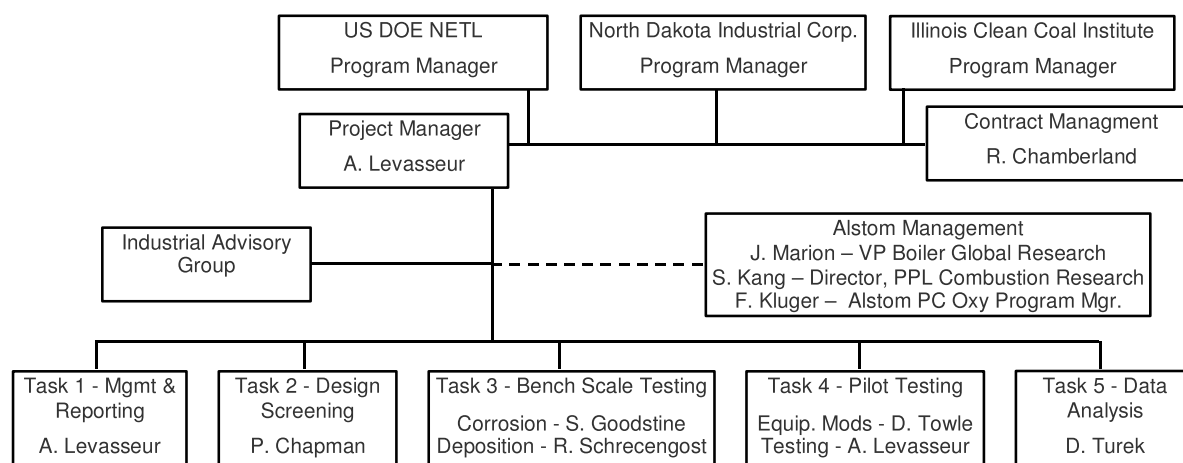
has internal projects for the development and commercialization of oxy-combustion technologies for both pulverized coal (PC) and circulating fluidized bed (CFB) boilers. Alstom has considerable experience in the management and successful completion of projects with varied scope and complexity.

Alstom will make this project a high priority and will commit the appropriate resources and qualified people to the project. Key personnel, their roles and years of experience are summarized in Table 4. Resumes are provided in Appendix A.

**Table 4 Alstom Team Organization and Key Personnel, Roles, and Experience**

Team Member	Role
Armand Levasseur (33 years exp.)	Alstom Combustion Technology Manager, Principal Investigator
Dr. Shin Kang (17 years exp.)	Overall R&D effort planning, coordination, and execution
David Towle (27 years exp.)	Alstom Director of Combustion Research
Stephen Goodstine (35 years exp.)	Project management assistance, combustion expertise
Robert Schrecengost (24 years exp.)	Alstom PPL Facilities Manager,
Paul Chapman (27 years exp.)	Responsible for human/equipment resources for project execution
David Turek (29 years exp.)	Metallurgy and corrosion expertise
Ray Chamberland (18 years exp.)	Combustion and corrosion expertise, technical assistance
	CFD modeling, process modeling and evaluation
	Data analysis, technical assistance
	Contract management, interface with the DOE and NDIC

The key personnel will be organized as shown in Figure 6.



**Figure 6 Project Organization Chart**



The ten companies participating in the industrial advisory group include utilities from the United States, Canada and Europe. This reflects the wide interest in oxy-combustion throughout the utility industry. Two of the utilities are especially pertinent to this proposal, Vattenfall and Great River Energy. Vattenfall is testing oxy-combustion firing dried lignite at their Schwarze Pumpe 30 MW<sub>th</sub> oxy-combustion demonstration plant. In addition to their role on the industrial advisory group, Great River Energy is providing cofunding for BSF Campaign 3, including supply of the dried North Dakota lignite to be fired during the test campaign.

## 5.1 Alstom Test Facilities

The proposed work will be conducted at the engineering offices and lab facilities of Alstom's Power Plant Laboratories (PPL) in Windsor, Connecticut. PPL has one of the largest and most diverse fossil power research facilities in the world, which is well suited to addressing issues on the

development of an oxy-combustion boiler.

PPL facilities to be used for this include the Pulverizer Development Facility (PDF) and the Boiler Simulation Facility (BSF).

The BSF (Figure 7) is the only large pilot scale T- fired coal combustion test facility in the US, so it is uniquely suited to developing and analyzing boiler components for existing and new T- fired utility boilers.



**Figure 7 Boiler Simulation Facility**

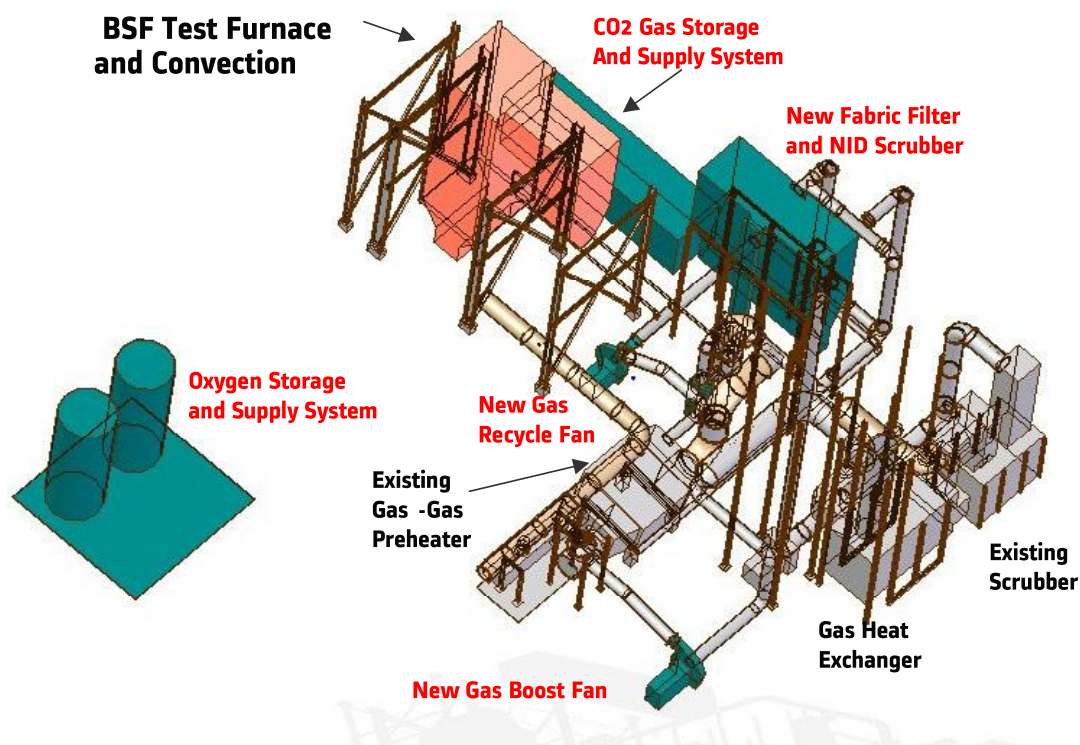
Alstom's BSF is a water-cooled, balanced draft, combustion test facility designed to replicate the time – temperature – stoichiometry history of a typical utility boiler. As configured in T-fired modes, the BSF replicates all major attributes of a utility boiler including a “V” hopper, an arch, and simulated superheater, reheater, and economizer surfaces. The BSF has a long history of successful technology development and has demonstrated results suitable for direct scale-up to the field. Commercial firing and control systems such Alstom's TFS 2000™ low NO<sub>x</sub> firing system, and Alstom Power Plant Control's NoxTrol™ stoichiometry control systems were initially developed and demonstrated on the BSF.

The BSF has been upgraded for oxyfuel capability under the on-going DOE oxy-combustion program. Figure 8 shows the BSF with modifications installed. Major facility and equipment modifications made under this program include addition of a temporary oxygen supply system, reconfiguration of the existing FGR system for the BSF to provide greater flexibility, changes to BSF access ports/openings to minimize air in-leakage, and added instrumentation and control logic to transition to-and-from oxy firing and control conditions under oxy-firing. Major equipment items purchased under the program include flue gas baghouse, NID dry sulfur scrubber, recirculated flue gas fan, sootblower, and CO<sub>2</sub> compressor/blower.



**Figure 8 BSF with Modifications Installed**

The facility has the flexibility to test under the base air-firing mode and five different oxy-fired process configurations. In order to obtain flexibility and minimize air infiltration to equipment downstream of the furnace (such as the fabric filter), a boost fan was added to the flue gas flow stream. The three fan system (FGR, gas boost, and induced draft fans) will allow both the furnace and the fabric filter / dry sulfur scrubber to operate at atmospheric or slightly positive pressure. Flexibility for oxygen injection is also incorporated in the design as oxygen flows can be independently controlled to primary FGR stream, the furnace windbox FGR stream, and separate overfire “air” upper and lower locations. Oxygen can be premixed into FGR streams or injected via lances directly into the furnace. Figure 9 provides a layout view of the BSF and its systems.



**Figure 9 Oxy Fired Boiler Simulation Facility Layout**

Alstom has the capability of pulverizing a wide variety of materials (coal, petroleum coke, etc) in its Pulverizer Development Facility (PDF). The heart of the facility is a HP 323 Bowl Mill, a 3-journal, 32 inch-bowl mill. The HP pulverizer is an air swept, medium speed vertical spindle coal pulverizer. It is equipped with a 100 Hp motor controlled by a variable speed motor controller. Its design allows for easy interchange of various mill components and milling configurations (e.g. DYNAMIC™ or static classifiers or grinding rolls). The capacity of the HP 323 mill depends on fuel properties, required product fineness and other processing requirements. At 70 to 80% passing 200 Mesh, the mill's capacity approximately 6,000 to 10,000 lb/hr.

## **6 TIMETABLE**

The Gantt chart in Figure 10 shows the project activities and the schedule for the entire DOE-awarded program. The funding requested from NDIC is for adding BSF Campaign 3, i.e., pilot-scale oxy-combustion testing with dried North Dakota lignite, to the DOE project. The DOE contract agreement was signed in September 2008.

Budget Period 1, ending September 30, 2009, included modification of the BSF for oxy-combustion operation and completion of the first test campaign. The dried lignite will be tested in the BSF under Test Campaign 3 scheduled to begin in January 2010 and be completed in March 2010. The overall project is scheduled for completion by October 2010.

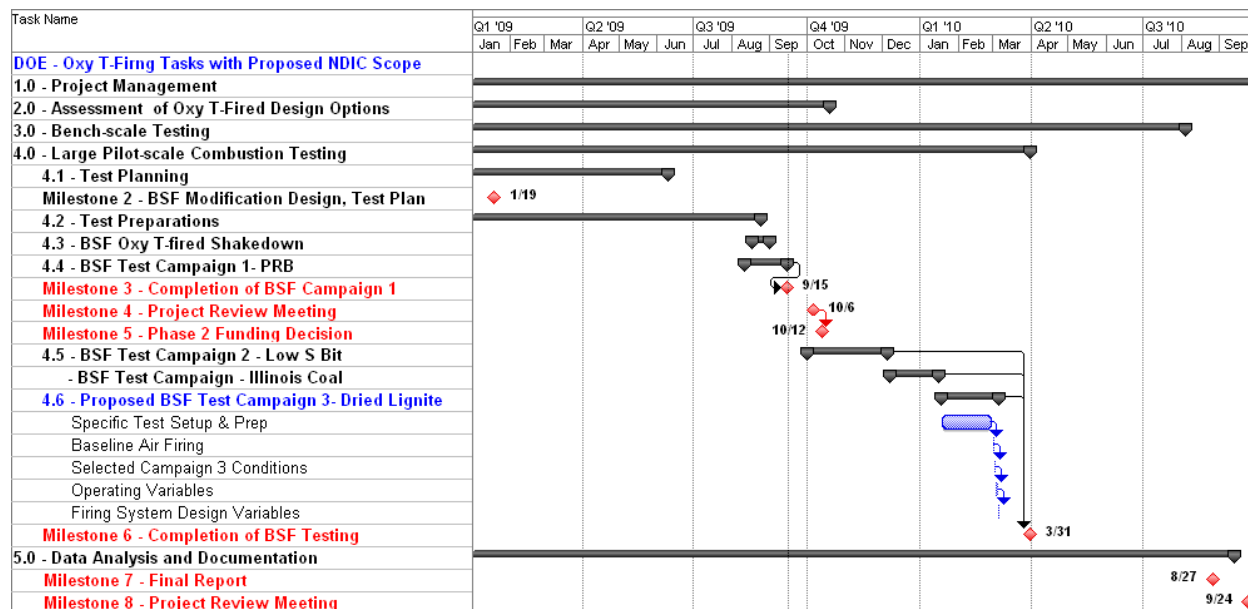


Figure 10 Project Schedule

Technology transfer activities such as paper presentations and publications consistent with Alstom’s development roadmap will take place as soon as the test results are made available. Also, meetings with program managers of DOE and NDIC will take place as many times as needed throughout the demonstration program. The final report will be submitted to the team members and program managers of DOE/NETL and NDIC by the end of September 2010 (Milestone 7).

## 7 BUDGET

The work of this BSF Test Campaign 3 will be performed on a cost-reimbursable basis for \$653,737. This does not include \$50,000 of in-kind cofunding from GRE for dried lignite fuel. DOE funding is already at its maximum, thus consortium members will provide the entire incremental budget for this test campaign. A detailed budget is included in Appendix D, and a breakdown of cost share is provided in Section 8.

## 8 MATCHING FUNDS

Funding requested from NDIC is \$490,000, which is 5.6% of the total project budget of \$8,716,523. Other project partners providing cash and in-kind funding include Alstom Power; US DOE; the ten members of the industrial advisory group mentioned previously; EERC through a Joint Sponsored Research Project agreement (JSRP) with DOE; and the Illinois Clean Coal Institute (ICCI). A detailed breakdown is provided in Table 5.

**Table 5 Proposed Funding Sources for the Project**

<b>Funding Sources</b>	<b>Cash Cost Share</b>	<b>In-kind Cost Share</b>	<b>Total</b>	<b>Cost Share percentage</b>
NDIC	\$ 490,000		\$ 490,000	5.6
Great River Energy		\$ 50,000	\$ 50,000	0.6
DOE	\$5,000,000		\$5,000,000	57.4
Alstom Power	\$2,169,117		\$2,169,117	24.9
ICCI	\$ 480,767		\$ 480,767	5.5
Industrial Advisory Group	\$ 500,000		\$ 500,000	5.7
EERC (through JSRP)	\$ 26,639		\$ 26,639	0.3
<b>Total</b>	<b>\$8,666,523</b>	<b>\$ 50,000</b>	<b>\$8,716,523</b>	<b>100.0</b>

Contracts have already been executed with Alstom for the existing project by the funding sources listed, except for NDIC and EERC. The only other funding sources for this test campaign are Alstom, Great River Energy, and the DOE through a JSRP with EERC. A Letter of Support from Great River Energy is included in Appendix B. The EERC proposal to DOE for a JSRP is also included in Appendix B.

Cofunding contributions from Alstom, Great River Energy and EERC's JSRP with DOE are subject to a definitive contract agreement with NDIC should this grant proposal be awarded.

## 9 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.

## 10 REFERENCES

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3. "Development of Oxy-Fuel Firing to Enable CO<sub>2</sub> Capture," Nsakala, N.y, Liljedahl, G.N., Chamberland, R.P., Kluger, F., Suranti, S., 32<sup>nd</sup> International Technical Conference on Coal Utilization & Fuel Systems, June 2007, Clearwater, Florida.
4. "30 MW<sub>th</sub> Clean Environment Development Oxy-Coal Combustion Test Program," McDonald, D.K., Flynn, T.J., DeVault, D.J., Varagani, R., Levesque, S., Castor, W., 33<sup>rd</sup> International Technical Conference on Coal Utilization & Fuel Systems, June 2008, Clearwater, Florida.
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7. "Schwarze Pumpe CCS Pilot: Putting Oxycoal Theory into Practice," Power Engineering International Vol. 17 Issue 1, January 2009.

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9. US Energy Information Agency,  
<http://www.eia.doe.gov/cneaf/electricity/page/capacity/capacity.html>
10. "Alstom's 15 MW Oxyfuel Test Program for Tangential Firing," Marion, J.L., Levasseur, A.A., 1<sup>st</sup> International Oxy-Combustion Conference, September 2009, Cottbus, Germany



## **APPENDIX A – RESUMES**

The following pages are the resumes (in alphabetical order) of the project participants identified in Section 5 of the proposal narrative.

**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 2008.

**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 review (DOE's research labs 1997-2000)

**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.

**Paul J. Chapman**

Technology Manager, Combustion and Environmental Research Dept., Alstom Power Inc. US Power Plant Laboratories, Windsor, CT

**SUMMARY OF QUALIFICATIONS**

Paul Chapman has extensive experience in the application of CFD modeling tools to analyze and develop improved products for many different Alstom boiler products. He is capable of managing the range of activities associated with testing, modeling, and development for important company projects. With 28 years of experience at Power Plant Labs, Mr. Chapman has managed and completed a large number of CFD studies within the Combustion Research Department. As a technology manager, he is responsible for guiding the development and infrastructure essential to the efficient completion of detailed FLUENT modeling projects for a range of internal customers. He is responsible for generating CFD proposal studies, managing their execution, and reviewing reports, while also maintaining a competence and proven track record in solving difficult CFD problems. To balance this CFD expertise, Mr. Chapman has extensive for physical flow modeling experience developed prior to the modern CFD-era. This experimental background includes cold flow modeling techniques, velocity mapping, LDV, and combustion measurements in the field at both industrial and utility locations.

**EDUCATION**

1985: MSME University of Connecticut, Storrs, CT

1980: BSME University of Massachusetts at Amherst, Amherst MA

**PROFESSIONAL EXPERIENCE**

2004 - Present: Technology Manager – Fluid Flow and Reaction Chemistry - Power Plant Labs  
Responsible for the coordination of CFD modeling activities at PPL associated with combustion modeling applications with the Combustion Research Department. This includes both execution of a range of studies for contracted CFD modeling, as well as the development of technical proposals for both PPL and external Alstom company modeling projects. Coordinates the budgeting control for software licensing, hardware upgrades, and technical developments associated with a core group of 5 CFD modeling engineers, while maintaining competence in the area of coal combustion modeling, overfire air systems, mixing devices, and environmental products that include SCR's, Dry FGD, WFGD, Fabric Filters, Ductwork, and ESP's.

1998 - 2004: Consulting Engineer – Power Plant Labs

Performed extensive CFD modeling for ABB Lummus Global to support their development of Ethylene Cracking Furnace CFD modeling competence. Applied CFD to the development and validation of FLUENT to pilot-scale process burners for ethylene furnaces in coordination with Lummus. Developed integrated fireside and process coil models with multi-million cell 3D pyrolysis furnaces. Validated the model components and applied CFD to screen the performance of Ultra-Low NOx burner retrofits to existing Ethylene furnaces with modelers at Lummus.

1980- 1998: Combustion Engineering – ABB Power Plant Labs

Performed a range of engineering tasks with emphasis of cold flow modeling studies performed to evaluate a range of components and systems. Special focus on the development of advance Overfire Air designs such as HMZ™ for industrial boilers and chemical recovery furnaces.

**PUBLICATIONS**

Authored at least 16 technical conference papers and in the area of combustion, industrial boilers, biomass combustors and chemical recovery boilers.

**PATENTS**

Mr. Chapman is named on 3 US patents that are associated with control of furnace gas balance, and ethylene cracking furnace burners.

**Stephen L. Goodstine**

Technology Manager, Mechanical Systems, Alstom Power Inc. US Power Plant Laboratories, Windsor, CT

**SUMMARY OF QUALIFICATIONS:**

Mr. Goodstine has 35+ years of experience in laboratory research, field testing, and customer consulting in the areas of steam generator water technology and corrosion control, fluidized bed combustion, flue gas desulfurization systems, fluid thermodynamic properties, heat transfer, high temperature oxidation /nitriding and surface modification coatings.

**EDUCATION:**

Chemical Engineering, Bachelor of Science, Tufts University, 1970

Master of Science - Management/Management of Technology, Rennselaer Polytechnic Institute, 1997

**PROFESSIONAL EXPERIENCE:**

Mr. Goodstine is responsible for technical project execution and management of laboratory research programs and customer consulting in the process technology area. His varied assignments have included:

- Power plant water treatment / corrosion control
- fluidized bed combustion (pilot plant operation)
- heat transfer (boiling and conduction)
- new product development
- instructor (boiler tube failure analysis course)
- high temperature degradation of materials (oxidation, nitriding, fireside corrosion)
- fluid thermodynamic properties measurement

His responsibilities for these programs include technical direction and contribution, budget control, scheduling, and interfacing with groups outside of PPL. He has project managed and technically directed large scale laboratory research projects with internal funding and with program funding from DOE and EPRI.

**SELECTED TECHNICAL PUBLICATIONS:**

Author of twelve publications in various technical journals dealing with water technology, fluidized bed combustion and reports of laboratory pilot-scale research.

**PATENTS:**

Co-inventor of nine U.S. patents on topics relevant to the power generation industry.

**DR. SHIN G. KANG**

Director, Combustion and Environmental Research Dept., US Power Plant Laboratories, Alstom Power Inc., Windsor, CT

**SUMMARY OF QUALIFICATIONS**

Dr. Shin Kang has over 17 years experience in researching combustion and thermal sciences. Dr. Kang has applied his management skills and technical experience in multi-faceted product development projects. He has successfully conducted technology/product development in power generation industries based on his analytical skills, broad experience and knowledge in combustion chemistry, and mechanical design.

**EDUCATION**

Masters in Business Administration, Rensselaer Polytechnic Institute, Hartford, CT, 2005  
Chemical Engineering, PhD (minor in Materials Science and Engineering), Massachusetts Institute of Technology, Cambridge MA, 1991  
Chemical Engineering, MS, University of Cincinnati, Cincinnati OH, 1986  
Chemical Engineering, BS Cum Laude, Seoul National University, Seoul Korea, 1984

**PROFESSIONAL EXPERIENCE**

Jan 2008 – Present Alstom Power, Windsor, CT

- Director, Combustion Research: Manages a variety of product development activities on PC and CFB boilers as well as post-combustion equipment, that include analytical, computational fluid dynamics and experimental work.

Feb 1998 – Jan 2008 Alstom Power, Windsor, CT

- Technical Fellow, Product Development and Technology; Senior Consulting Engineer, Combustion Technology:  
Developed and commercialized combustion/environmental control products for coal-fired power industries. Recent accomplishment is the design, development, and commercialization of a cost-effective mercury control technology for coal-fired boilers – Alstom’s patented Mer-Cure™ system. Development steps included conceptual design, feasibility tests at various scales, economic and market analysis, business plan development, securing external funding for full-scale demonstration, and protection of related intellectual property. Managed multi-million dollar grants including those from the US Department of Energy for Mer-Cure™ field demonstration.

Other previous experiences include development of a cement-and-power cogeneration process, a novel coal gasification-based power generation process in a cross-disciplinary, multi-national focus team, and an ultra low-NOx firing system for ethylene cracking furnaces.

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.

**PUBLICATIONS**

Authored more than 25 technical papers in peer-reviewed technical publications and presented papers in technical conferences in the areas of combustion, environmental control and atmospheric chemistry. Holder of 5 patents and 3 patents pending.

**Armand A. Levasseur**

Manager, Combustion Technology, US Power Plant Laboratories, Alstom Power Inc., Windsor, CT

**SUMMARY OF QUALIFICATIONS**

Over 30 years of experience in research and development involving fuels and combustion technologies for the Power Industry. Proven technical leader and administrator with strong analytical and communication skills. Extensive background in project management as well as technical expertise in fuel characterization, ash deposition, fluidized bed combustion, fireside corrosion, particulate and gaseous emission prediction and control. Authored more than 75 technical papers in associated areas presented domestically and internationally.

**EDUCATION**

Chemical Engineering, Lowell Technological Institute, Bachelor of Science, 1974  
Chemical Technology, Thames Valley Technical College, Associate, 1972

**PROFESSIONAL EXPERIENCE**

**Manager, Combustion Systems Technology**, Alstom Power Plant Laboratories (2004 - Present)  
Responsible for building and maintaining core competencies in the areas of combustion, firing systems development and fuels technologies. Responsible for development, management and execution of major R&D projects as well as providing technical expertise supporting performance, operating and design issues related to Alstom's global boiler businesses.

**Manager, Facility Operations and Services**, Alstom Power Plant Laboratories (2001 - 2006)  
Responsible for PPL test facility operations including management of operating budget, scheduling, and technical and administrative management of facility staff. Responsible for environmental compliance including ISO 14001 Environment Management certification of Alstom's Windsor, CT site. Responsible for management and execution of major research and development projects as well as providing technical expertise supporting business unit service and design issues related to ABB's global boiler.

**Principal Consulting Engineer**, Combustion Technology, Alstom Power Plant Laboratories (1997 - 2001)  
Responsible for management and execution of major research and development projects as well as providing technical expertise supporting business unit service and design issues related to Alstom's global boiler business. Responsible for leading experimental efforts involving CFB process improvements as well as project manager for various company and third party contract efforts.

**Senior Project Coordinator**, Combustion Research, ABB Power Plant Laboratories (1994 - 1997)  
Responsible for management and coordination of research efforts addressing combustion and fuel performance impacts. Oversaw work in areas involving fuel-switching impacts, coal beneficiation, fluidized bed combustion, biomass, air toxics, gasification and pressurized combustion. Project manager of DOE Beneficated Coal-Based Fuel contract as well as for major company research initiatives including fuel switching and performance impacts associated with Low NOx Firing Systems.

**Manager**, Fuels Technology, ABB Power Plant Laboratories (1987 - 1994)  
Responsible for technical and administrative management of a staff of over 15 engineers and scientists. Responsible an annual R&D budget of approximately 3 MUSD, to deliver improved combustion and fuel related predictive tools as well as process and product improvements in support of ABB/CE's international boiler and environmental businesses. Managed 2 MUSD department operating budget. Responsible for development and operation of six major combustion research facilities and execution a broad range of programs.

**Principal Engineer, Senior Engineer, Engineer**, CE Kreisinger Development Laboratory (1974 - 1987)  
Responsible for numerous research and development initiatives beginning as an engineer and culminating as a department manager. Project manager and/or principal investigator of EPRI Clean Coal Characterization program, DOE Coal-Water Mixture Combustion program, and ETSA Salty Australian

Brown Utilization program as well as company programs on fuel characterization, boiler performance predictions and boiler design improvements.

**PUBLICATIONS**

Mr. Levasseur has authored more than 100 technical papers in the areas of fuel characterization, ash deposition, fluidized bed combustion, fireside corrosion, particulate and gaseous emission prediction and control.

**PATENTS**

Mr. Levasseur holds two patents on deposition control and sulfur control.

**Robert A. Schrecengost**

Principal Consulting Engineer, Combustion and Environmental Research Dept., US Power Plant Laboratories, Alstom Power Inc., Windsor, CT

**SUMMARY OF QUALIFICATIONS**

Over 23 years of experience in combustion and emissions consulting involving fuels and combustion technologies for the Power Industry. Proven project manager with strong analytical and communication skills. Extensive background and technical expertise in mercury, particulate and gaseous emission prediction and control. Authored more than 25 technical papers in associated areas.

**EDUCATION**

Chemical Engineering, Carnegie-Mellon University, Bachelor of Science, 1985

**PROFESSIONAL EXPERIENCE**

Principal Consulting Engineer, Combustion Research, Alstom Power Plant Laboratories (2007 - Present)

Responsible for project management in the areas of mercury control and predictive capability, SO<sub>3</sub> measurement and predictive capability, and firing systems development. Responsible for development, management and execution of research and development projects as well as providing technical expertise supporting performance, operating and design issues related to Alstom's mercury control technologies.

Vice President, Breen Energy Solutions, Pittsburgh PA (2002 - 2007)

Responsible for technology development in the areas of mercury, NO<sub>x</sub> and SO<sub>3</sub> control, on-line fireside corrosion measurement, combustion optimization utilizing model predictive control software, and on-line SO<sub>3</sub>/ammonium bisulfate fouling measurement. Project manager for DOE/NETL funded "Waste Coal Fines Reburn for NO<sub>x</sub> and Mercury Emission Reduction" at a pulverized coal-fired electric utility boiler (DE-FC26-06NT42807) and Pennsylvania Energy Development Authority funded "In-situ Gasification and NO<sub>x</sub> Reburn Using Waste Coal Slurry" at an institutional stoker-fired boiler (Document #4100034124).

Vice President, Market Development, ESA Environmental Solutions. Lawrence PA (2000 - 2002)

Responsible for sales efforts and project coordination of fuel lean gas reburn retrofits for NO<sub>x</sub> control on coal-fired utility boilers. Resulted in commercial installations of fuel lean gas reburn on thirteen utility boilers.

Engineering Director, Consulting Engineer, Senior Engineer, Energy Systems Associates, Carnegie PA (1985 - 2000)

As engineering director, responsible for technical direction of overall consulting business. Managed projects involving fuel switching and characterization, low NO<sub>x</sub> burner retrofits, particulate and opacity reduction, furnace slagging and fireside corrosion, and acid smut fallout characterization and abatement.

**PUBLICATIONS**

Mr. Schrecengost has authored more than 25 technical papers in the areas of combustion optimization using model predictive control software, fuel lean gas reburn, on-line measurement and mitigation of fireside corrosion, and particulate and gaseous emission control.

**PATENTS**

Mr. Schrecengost holds six patents on mercury control and fireside corrosion monitoring, and has coauthored three additional patent applications on mercury capture, NO<sub>x</sub> control and SO<sub>3</sub>/ammonium bisulfate fouling measurement and control.



**David P. Towle**

Facilities Manager, US Power Plant Laboratories, Alstom Power Inc., Windsor, CT

**SUMMARY OF QUALIFICATIONS**

Mr. Towle has over 27 years of experience in the field of combustion science, in both research and management roles. Presently, he is the manager of Alstom Power Plant Laboratories' test facilities and staff. He has managed product development programs and the Combustion Research department, led several major test programs, and led construction of one of Alstom's large test facilities. Mr. Towle is the project manager on the Alstom – DOE/NETL program to develop low NO<sub>x</sub> pulverized coal burner technology (DOE/NETL Cooperative Agreement No. DE-FC26-04NT42300).

**EDUCATION**

Mechanical Engineering, Bachelor of Science, Rensselaer, May 1979, with minor in Economics.

**PROFESSIONAL EXPERIENCE**

**Alstom Power/ ABB/ Combustion Engineering**

**PPL Facilities Manager (2006 – Present)**

Added managerial responsibility for the PPL Facilities department and staff to the Technology Manager – Facilities Operations position. The new department includes 12 permanent technicians, 3 permanent engineers, and temporary help as required to support the facilities operations.

**Technology Manager – Facilities Operations (2004 – 2006)**

Responsible for managing the operation and maintenance of the PPL experimental test facilities and assigned resources, including planning, capital additions, test program execution, and reporting of results. Also plans and executes R&D projects, including recently DOE Enhanced Low NO<sub>x</sub> and New Brunswick Power Low NO<sub>x</sub> Petcoke. In addition, manages the facilities to provide R&D/Lab services to support existing products in the field and third party contracts.

**Senior Project Manager (1998 - 2004)**

Responsible for the organization and management of the product development programs for two Alstom Power business units. Included cultivating new ideas, proposing new programs utilizing the new ideas, getting organizational support for new programs, marketing studies, organizing project teams, planning the work, efficiently executing the work, making course corrections as needed, appropriately reporting the results, and launching and supporting commercialization activities. Also continued to administer and improve the Lotus Notes project management and reporting system.

**Manager of PD&T (Product Development & Technology) Administration (1997)**

Responsible for the organization and operation of a new group managing 80 R&D projects. Led the creation and global implementation of a Lotus Notes project management and reporting database. Jointly developed a system for simplified retrieval of project expenditures.

**Administrative Manager of Combustion Research (1993-1996)**

Responsible for management of the people, facilities, and environmental permitting of the Combustion Research department at Power Plant Laboratories. Developed objectives for and gave performance reviews and ongoing feedback to approximately 30 engineers, technicians, and secretaries. Managed the dept. workload among staff members and the combustion test facilities. Accountable for developing and implementing the \$4 million department budget for manpower, facility maintenance, and capital.

**Combustion Research Staff Engineer (Engineer II, Senior Engineer, Principal Engineer 1981-1993)**

Performed engineering and project management tasks of a continually ascending responsibility level, including test program leader of the Low NO<sub>x</sub> Tangential Firing System development program which led to the TFS 2000 Firing System. Other major programs led included OFA/reburn test programs for ENEL (Italian utility), sorbent injection studies for the US EPA, and Boiler Simulation Facility construction.

**Pratt & Whitney Aircraft, Experimental Test Engineer (1979-1981)**

Responsible for the fabrication and test of experimental hardware and materials for improving aircraft gas turbine engines. Wrote failure analysis reports on damaged hardware returned by customers.

**PUBLICATIONS**

*"Development of a High Turndown 'T'-Fired Pulverized Coal Nozzle,"* J. L. Marion and D.P. Towle. Presented at the Joint ASME/IEEE Power Generation Conference, Oct. 20-24, 1985.

*"Testing and Optimization of Furnace Sorbent Injection for SO<sub>2</sub> Control on a Tangentially Coal-Fired Utility Boiler,"* D.P. Towle, J.L. Marion, D.K. Anderson, J.P. Clark, D.G. LaChapelle. Presented at the EPRI 1990 SO<sub>2</sub> Control Symposium, May 8-11 1990.

*"An Update on NO<sub>x</sub> Emissions Control Technologies for Utility Coal, Oil and Gas Fired Tangential Boilers,"* D. Towle, C. Maney, J. Marion, and R. LaFlesh. Presented at the American Flame Research Committee Spring 1991 Meeting on NO<sub>x</sub> Control, Developments and Commercial Applications, March 18-19, 1991.

*"Cost-Effective NO<sub>x</sub> Reduction for Tangentially Fired Boilers,"* M. Hagar, G. Camody, R.D. Lewis, C.Q. Maney, & D.P. Towle. Presented at the ASME International Joint Power Generation Conference, August 24-26, 1998.

*"Development of an Enhanced Combustion Low NO<sub>x</sub> Pulverized Coal Burner,"* D. Towle, R. Donais, R. Lewis, T. Hellewell. Presented at the 32<sup>nd</sup> International Technical Conference on Coal Utilization & Fuel Systems, June 10-15, 2007

**PATENTS**

*"Minimum Recirculation Flame Control (MRFC) Pulverized Solid Fuel Nozzle Tip,"* M.A. Fong, T.D. Hellewell, R.D. Lewis, C.Q. Maney, S. Srinivasachar, M.A. Toqan, D.P. Towle, U.S. Patent No. 6,089,171, August 15, 1997.

*"Integrated Low NO<sub>x</sub> Tangential Firing System,"* M.J. Rini, T.D. Hellewell, D.P. Towle, P.L. Jennings, R.C. LaFlesh, D.K. Anderson, U.S. Patent No. 5,315,939, May 13, 1993.

*"Pulverized Coal Fuel Injector,"* M.J. Rini, D.P. Towle, U.S. Patent 5,113,771, August 14, 1991.

**David G. Turek**

Senior Consulting Engineer, Combustion and Environmental Research Dept., US Power Plant Laboratories, Alstom Power Inc., Windsor, CT

**Summary of Qualifications**

Twenty seven years of experience at Alstom Power primarily in the areas of fluidized bed combustion and advanced coal conversion technologies. Experience in fossil technologies includes test planning and facility design, data analysis and correlation, mathematical modeling and computer simulation, technical and economic analyses, cycle analyses, and project management.

**Education**

B. S. Chemical Engineering, University of Maryland, 1977  
M. S. Chemical Engineering, University of Maryland, 1979

**Professional Experience**

Senior Consulting R&D Engineer (1994 - present)  
Consulting R&D Engineer (1990 - 1994)  
Principal R&D Engineer (1985 - 1990)  
Senior R&D Engineer (1980 - 1985)

Technical assignments have included:

2000 - 2008 Analyze CFB field data and develop or improve Engineering Performance Standards  
1998 - 2007 Test Planning, Test Engineer, and Data Analysis for over 30 test campaigns in PPL's MTF, including 3 DOE-sponsored tests of oxycombustion.  
1996 - 1997 Process Engineering and Design for PPL's 9.9 MMBtu/hr Multiuse Test Facility.  
1990 - 1996 Process Engineering for ABB's Black Liquor Gasification development program. Process modelling, system design and evaluation, and test analysis.  
1991 - 1993 Responsible for developing improved cycle analysis tools and capabilities for Power Plant Labs.  
1983 - 1991 Project Manager for DOE-sponsored Generic Studies of Advanced Fluidized Bed Air Heater Technology Project. Designed and evaluated and industrial cogeneration system using indirect-fired gas turbines and the follow-on AFB Cogeneration Air Heater Experiment: testing of tube materials for high temperature air heating in fluidized bed combustors  
1981 - 1996 Modeling fluidized bed combustion, black liquor gasification, and other systems using ASPEN and ASPEN Plus process simulators

Publications include co-authoring six recent papers on oxycombustion technologies.

## **APPENDIX B – LETTERS OF SUPPORT**

A Letter of support from Great River Energy and the proposal from EERC to Alstom that includes an estimate of DOE cofunding through a Joint Sponsored Research Project are provided on the following pages.



GREAT RIVER  
E N E R G Y

12500 Elm Street, Redwood Falls, Minnesota 55369-1718 • 753-445-3300 • Fax 753-445-1050 • www.GreatRiverEnergy.com

September 18, 2009

Ms. Karlene Fine, Executive Director  
North Dakota Industrial Commission  
Lignite Research, Development and Marketing Program  
State Capitol, 14th Floor  
800 E. Boulevard Avenue, Dept. 405  
Bismarck ND 58505-0840

Dear Ms. Fine:


Subject: Letter of Interest and Financial Commitment for Lignite Fuel Testing in Alstom Power Inc. Program Titled "Oxyfuel Firing System Development for Tangentially Fired Boilers" (U.S. Department of Energy / NETL Cooperative Agreement No. DE-NT0005290)


Great River Energy (GRE) is pleased to submit this letter of support and interest to participate in the addition of a lignite fuel test campaign in Alstom Power's oxy boiler development program titled "Oxyfuel Firing System Development for Tangentially Fired Boilers" (U.S. Department of Energy/NETL Cooperative Agreement No. DE-NT0005290). This proposed work will optimize tangentially-fired boiler design and operating conditions with oxy-combustion firing for North Dakota lignite and provide information needed to evaluate and demonstrate the use of North Dakota lignite for oxy-combustion firing at larger scale.

GRE is currently participating in a 10-member utility advisory group on the existing Alstom program. The advisory group provides focus and important end-user/utility perspective for the project. The Alstom project has made good progress with initial coal testing starting in September 2009.

Great River Energy is the wholesale electric supplier for 28 member cooperatives in Minnesota and Wisconsin. Great River Energy is concerned about future regulation of greenhouse gas emissions. With approximately 50 percent of electric generation coming from coal-fired power plants, GRE recognizes the need to develop and demonstrate CO<sub>2</sub> mitigation options for the existing coal-fired power generation fleet. GRE endorses the subject proposed program as an important step to develop and demonstrate lower cost CO<sub>2</sub> mitigation options such as oxy-fired coal boilers.

Great River Energy has been pleased to support the original test program with cash cost share of \$50,000 and an in-kind cost share for the Falkirk lignite test being proposed valued at

A Touchstone Energy<sup>®</sup> Cooperative 

 100% post-consumer waste

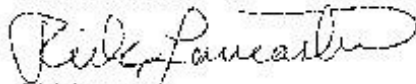
North Dakota Industrial Commission  
September 18, 2009  
Page 2

\$50,000 for a total project cost share of \$100,000. Our contributions will be subject to a definitive contract agreement with NDIC.

We look forward to NDIC's review of the Alstom proposal and partnering on this interesting and needed project.

Sincerely,

GREAT RIVER ENERGY



Rick Lancaster  
Vice President, Generation

6:\Generation\Executive Assistant Files\Rick Lancaster\091809 Letter Of Support - GRE CE Docx



September 10, 2009

Mr. Shin G. Kang  
Technology Quality Manager  
ALSTOM Power, Inc.  
2000 Day Hill Road  
Windsor, CT 06095-0500

Dear Mr. Kang:

Subject: EERC Proposal No. 2010-0054 Entitled "Determination of the Impact of a CO<sub>2</sub> Mitigation Technology on Mercury Emissions"

This letter proposal summarizes work to be conducted by the Energy & Environmental Research Center (EERC) at ALSTOM Power, Inc.'s pilot combustor located in Windsor, Connecticut. The EERC will conduct mercury sampling using two continuous mercury monitors (CMMs) in determining the effect of a CO<sub>2</sub> mitigation technology on mercury emissions when firing a North Dakota lignite coal.

The overall objective of the proposed work is to perform 5 days of mercury measurements at two locations, the inlet and outlet of a particulate control device (PCD). A CMM will be set up at each location and operated and staffed around the clock. The CMMs are designed to provide both total and elemental mercury concentrations.

#### **Project Planning**

The EERC will participate in planning meetings with ALSTOM Power as required and will provide two CMMs and personnel to provide 24-hr operation of these instruments.

#### **Installation of the CMMs**

Because the CMM requires a clean, temperature-controlled environment, the EERC will set up a modular shed at each location (depending on the location of the two sampling ports, the EERC may only need one shelter). The EERC is planning on having two people on-site. It is expected that 2–3 days will be necessary to set up the two instruments and to make sure they are operating properly. One person can operate the two instruments, but two people (each working a 12-hr shift) are necessary to staff the instruments around the clock.

#### **The EERC's Logistical Requirements for This Test Program**

The EERC's requirements at each CMM location include a minimum of four 110-V circuits nearby (within 100 feet), a source of compressed air nearby, a space large enough (6 feet by 8 feet minimum) to set up a temporary CMM shelter within 50 feet of each test location, and reasonable access to a sample port that is clean and at least 4-inches i.d. In addition to the CMM requirements, the EERC will require a designated parking site for our on-site sample trailer. The electrical power requirement for the trailer is one 50-A circuit at 110/208 V. Although the EERC has a well-developed workplace safety program in place, we must be made aware of any issues that may be site-specific.

Mr. Kang/2  
September 10, 2009

The EERC is currently not planning a site visit; therefore, ALSTOM must provide pictures of each of the sampling locations and duct dimensions at each of the sampling locations.

**Test Plan and Project Schedule**

Assuming a start date of January 2, 2010, a tentative schedule would have the EERC arriving on-site on February 11, 2010. Following setup, planned sampling would begin February 15, 2010, and continue through February, 19, 2010. A tentative project schedule is shown in Table 1.

**Deliverables**

Each day of the project, the CMM data collected will be downloaded and provided to ALSTOM Power. Also included will be a description of the performance of the monitors (sampling log book). The data will also be e-mailed to the EERC each night and will be reviewed. The final results will be reported to ALSTOM Power as a draft report within ~2 weeks of completing the test. Once ALSTOM Power has reviewed and commented on the report, the EERC will complete the final project report.

As this project is being proposed under the EERC–U.S. Department of Energy (DOE) Jointly Sponsored Research Program (JSRP), after the final report is reviewed by ALSTOM Power, a final report will also be provided to DOE at the completion of the project.

**Cost**

The total cost for the project, on a cost-reimbursable basis, is \$79,473. Of this cost, the EERC requests \$52,834 from ALSTOM Power. This includes all travel and setup costs. Sampling activities include continuous operation of the CMM at the baghouse inlet and outlet for 2 weeks. Also included are the compilation of quality control checks of all of the data and a final report.

As mentioned, it is planned for this project to also be proposed under the EERC–DOE JSRP. Although it cannot be guaranteed that DOE funding will be made available for this project under the JSRP, I do not think obtaining the DOE funding for this project would be a problem. If JSRP funding is to be used, the amount to be funded by ALSTOM Power would be \$52,834 with \$26,639 contributed by DOE.

**Table 1. Sampling Schedule**

Item	Date (2010)	Days
Travel to Site	Feb 8–10	3
Setup	Feb 11–13	3
Sampling Activities	Feb 15–19	5
Teardown	Feb 20	1
Travel Home	Feb 21–23	3
Complete All Analysis	Mar 15	–
Complete Draft Final Report	March 31	–
Complete Final Report	May 1	–

\* Although the schedule has the project ending May 1, 2010, because of the tentative nature of this schedule, a project end date of June 31, 2010, is shown in the proposal.



Mr. Kang/3  
September 10, 2009

Once a letter of commitment has been received from ALSTOM Power for this amount, an application will be made to DOE for the remainder.

Three items are required from ALSTOM Power for inclusion in our proposal to DOE:

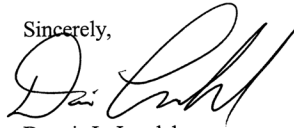
- A formal commitment to the project. This can be a letter of commitment, a purchase order, or a signed contract.
- A biographical sketch or resume for ALSTOM Power's project manager or key technical contributor.
- A short overview of ALSTOM Power.

The EERC will submit a proposal to DOE for its approval upon receipt of ALSTOM Power's commitment and the information above. Typically, it takes between 30–45 days to receive funding from DOE under this program.

A detailed budget and accompanying budget notes are enclosed.

If you have any questions or comments, please feel free to contact me by phone at (701) 777-5138 or by e-mail at [dlaudal@undeerc.org](mailto:dlaudal@undeerc.org). We look forward to this additional opportunity to team with ALSTOM Power.

Sincerely,



Dennis L. Laudal  
Senior Research Advisor

Approved by:



Dr. Barry I. Milavetz  
Associate VP for Research & Economic Development  
Research Development & Compliance

DLL/kmd

Enclosures

DETERMINATION OF THE IMPACT OF A CO2 MITIGATION TECHNOLOGY ON MERCURY EMISSIONS  
 ALSTOM POWER, INC. (API)  
 PROPOSED PROJECT START DATE: 1/2/2010  
 EERC PROPOSAL #2010-0054

**BUDGET**

CATEGORY	TOTAL	API SHARE	EERC DOE SHARE
<b>TOTAL DIRECT HRS/SALARIES</b>	580 \$ 21,239	446 \$ 14,416	134 \$ 6,823
<b>TOTAL FRINGE BENEFITS</b>	\$ 11,405	\$ 7,741	\$ 3,664
<b>TOTAL LABOR</b>	\$ 32,644	\$ 22,157	\$ 10,487
<b>OTHER DIRECT COSTS</b>			
TRAVEL	\$ 9,845	\$ 9,845	\$ -
SUPPLIES	\$ 1,300	\$ 275	\$ 1,025
COMMUNICATION - PHONES & POSTAGE	\$ 297	\$ 80	\$ 217
PRINTING & DUPLICATING	\$ 250	\$ 80	\$ 170
OPERATING FEES & SYCS			
Particulate Analysis	\$ 5,230	\$ -	\$ 5,230
Graphics Support	\$ 366	\$ -	\$ 366
Shop & Operations Support	\$ 584	\$ 584	\$ -
Remote Sampling Trailer	\$ 264	\$ -	\$ 264
<b>TOTAL DIRECT COST</b>	\$ 50,780	\$ 33,021	\$ 17,759
<b>FACILITIES &amp; ADMIN. RATE - % OF MTDC</b>	VAR	60% \$ 19,813	50% \$ 8,880
<b>TOTAL PROJECT COST - US DOLLARS</b>	\$ 79,473	\$ 52,834	\$ 26,639

Due to limitations within the University's accounting system, bolded budget line items represent how the University proposes, reports and accounts for expenses. Supplementary budget information, if provided, is for proposal evaluation.

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9/10/2009 2:11 PM

## **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.



**Power**

Services

September 15, 2009

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 "Oxy-Combustion Boiler Development for Tangential Firing of Dried Lignite," 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, MST, CPA  
Sr Tax Manager, Sales and Use  
Phone: (860) 285-5237  
Fax: (860) 285-9507  
email: ronald.r.papke@power.alstom.com

cc: Shiru Kang – Alstom Power Inc.  
Ray F. Chamberland – Alstom Power Inc.  
Robert A. Schreckengost – Alstom Power Inc.

ALSTOM Power Inc.  
7200 Day Hill Road  
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