EERC®
Energy & Environmental Research Center

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April 2, 2014

Ms. Karlene Fine
North Dakota Industrial Commission
ATTN: Lignite Research Program
State Capitol – 14th Floor
600 East Boulevard Avenue, Department 405
Bismarck, ND 58505-0840

Dear Ms. Fine:

Subject: EERC Proposal No. 2014-0147 Entitled "Validation of the Multielement Sorbent Trap (MEST) Method for Measurement of HCl and Metals"

The Energy & Environmental Research Center (EERC) of the University of North Dakota is pleased to submit the subject proposal. Enclosed please find an original and one copy of the proposal entitled "Validation of the Multielement Sorbent Trap (MEST) Method for Measurement of HCl and Metals." Also enclosed is the $100 application fee. The EERC is committed to completing the project as described in this proposal if the Commission makes the requested grant.

If you have any questions, please contact me by telephone at (701) 777-5268 or by e-mail at jpavlish@undeerc.org.

Sincerely,

John H. Pavlish
Senior Research Manager

Approved by:

(for)

Dr. Gerald H. Groenewold, Director
Energy & Environmental Research Center

JHP/bjr

Enclosures

c/enc: Mike Jones, North Dakota Industrial Commission

EERC
Energy & Environmental Research Center

VALIDATION OF THE MULTIELEMENT SORBENT TRAP (MEST) METHOD FOR MEASUREMENT OF HCl AND METALS

EERC Proposal No. 2014-0147

Submitted to:

Karlene Fine

North Dakota Industrial Commission
600 East Boulevard Avenue
State Capitol, 14th Floor
Bismarck, ND 58505-0840

Amount of Request: $245,000
Total Amount of Proposed Project: $860,000
Duration of Project: 18 months

Submitted by:

John H. Pavlish

Energy & Environmental Research Center
University of North Dakota
15 North 23rd Street, Stop 9018
Grand Forks, ND 58202-9018

John H. Pavlish, Project Manager

Dr. Gerald H. Groenewold, Director
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April 2, 2014

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ABSTRACT

The U.S. Environmental Protection Agency (EPA) Mercury and Air Toxics Standards (MATS) will have a significant economic impact on coal-fired power plants. The increased cost of stack emission testing to verify continuous emission monitors and/or determine emission concentrations are a significant part of the cost impact because of the expensive sampling methods needed to perform compliance testing. Industry continues to express a need for simpler, more cost-effective methods to obtain the compliance data required under MATS.

The Energy & Environmental Research Center (EERC), through the Center for Air Toxic Metals®, has developed the MEST sampling method for trace metals and/or halogen emissions; it is a much simpler sampling procedure that reduces personnel hours and eliminates the need for chemicals and solvents in the field, resulting in a method that is much easier and robust, while also offering significant cost savings over the comparable EPA Methods 29 (M29) and 26a (M26a).

A previous project (ending December 2013) funded by NDIC performed a field evaluation of MEST at three lignite-fired plants. Additional testing has also been accomplished at two Illinois coal-fired plants. The outcome of these projects showed very favorable and comparable results for the MEST method for measurement of HCl compared to M26a. The primary goal of the proposed follow-on project is to validate the MEST method for measurement of HCl by collecting specific data that can be used to support EPA determination and acceptance of MEST as an alternative method to M26 (and M26a).

The estimated cost for the 18-month project is $860,000. Of this amount, the EERC requests $245,000 from NDIC, approximately $415,000 from industry, and $200,000 from the Illinois Clean Coal Institute.

VALIDATION OF THE MULTIELEMENT SORBENT TRAP (MEST) METHOD FOR MEASUREMENT OF HCl AND METALS

PROJECT SUMMARY

Adherence to the proposed U.S. Environmental Protection Agency (EPA) Mercury and Air Toxics Standards (MATS) will lead to a significant increase in EPA Method 29 (M29) and 26a (M26a) sampling to show compliance with regulatory reductions of hazardous air pollutant (HAP) metal and halogen (HCl) emissions, respectively. M26 and M29 sampling will be required to certify and validate continuous emission monitors (CEMs) and to provide data to show plant regulatory compliance. M26 and M29 sampling may be needed as often as every 3 months, depending on the reporting criteria selected by a utility. Because of the high expense, personnel hours related to sampling, and the complicated setup and recovery involved with both M29 and M26a, a need exists for a simpler, cheaper, and more robust sampling method for measuring trace element and/or halogen emissions (U.S. Environmental Protection Agency, 1994, 1996).

The Energy & Environmental Research Center (EERC), through the Center for Air Toxic Metals® (CATM®), has developed a multielement sorbent trap (MEST) sampling method that can be utilized for trace metal and halogen sampling. As a potential alternative to EPA M29 and M26/26A, the EERC developed the MEST method with two separate sampling applications: one for metals (MEST-M) and one for halogens (MEST-H), in particular HCl. Although the sorbent trap materials differ, the sampling procedures used to capture HCl and trace metals are very similar. The EERC recently completed a project funded by the North Dakota Industrial Commission (NDIC) that evaluated the MEST at three lignite-fired plants (Pavlish and others, 2013a,b). Additional testing has also been performed at two Illinois coal-fired plants. The results for these tests showed very favorable and comparable results for the MEST-H method for

measurement of HCl compared to M26/M26a over the same time duration and at the same sampling location. The Background section contains more details.

As demonstrated in the field test evaluations, the MEST-H method has the potential to significantly reduce on-site sampling costs associated with personnel, eliminate solvents, and use fewer supplies while providing equivalent or better detection limits compared to M26 (or M26a). While data collected to date show very good agreement between the MEST-H and M26 (and M26a), additional test data such as ruggedness testing and HCl spiking are needed to more fully and formally evaluate the method before acceptance. Typically, a formal M301(formal procedure for evaluating whether a new method is acceptable, www.epa.gov/ttnemc01/promgate/m-301.pdf) is performed, with data provided to EPA for consideration. The primary focus of this project is to generate additional data as needed by EPA to evaluate and approve the MEST-H method as an alternative method to M26 (and M26a). This project aims to perform a more formal M301 validation of the MEST-H method and provide additional data to EPA that has been identified as lacking. Testing will be completed on the EERC's bench- and pilot-scale systems to perform additional comparative tests, spiking tests, and ruggedness tests that challenge (and define) if and under what conditions (high SO_2, high moisture, temperature limits, etc.) the MEST-H traps fail. These tests along with data requirements will be further refined as the project develops and as discussions with EPA continue. Throughout the project, the EERC will work with EPA to ensure that the data submitted for consideration are of the correct format and statistical quality and in general meet the requirements of M301.

The end result of this follow-on project is to gather data collected to date on MEST and generate additional data as needed by EPA for its determination and approval of MEST as an alternative method to M26 (and M26a). To date, discussions with EPA have been very favorable, but data gaps have been identified, as discussed earlier and as proposed to collect as part of this project. The intent of this project is to fill these data gaps and work with EPA to identify and provide data necessary to formally validate the MEST method for measurement of HCl.

As mentioned, the MEST-M method has also been tested at three lignite-fired and two Illinois coal-fired plants. Data for metals for these plants show general agreement with M29, but are more variable, primarily because of high metal variability in coal, measurement values near detection limits of both M29 and MEST-M, and relatively high background concentrations. Depending on funding availability, to minimize variability, the EERC will also further test the MEST-H under well-controlled pilot tests using an advanced synthetic trap material that will minimize (lower) background contributions.

PROJECT DESCRIPTION

Goals and Objectives

The goals of the proposed project are as follows:

1. Validate a simple, low-cost MEST-H method for measurement of HCl by collecting specific data that can be used to support determination and acceptance of MEST-H as an alternative method to M26 (and M26a).
2. Address questions and provide data to EPA as necessary to gain acceptance of the MEST method for measurement of HCl as an alternative method to M26 (and M26a). The goal is to have EPA recognize the MEST-H method as an alternative method that can be used in place of M26 (and M26a).
3. Continue to develop, test, and evaluate the MEST-M method for measurement of metals. Recently, a new trap material was identified that has background metals concentrations that are an order of magnitude lower than previously tested.

In order to achieve the goals of this project, several objectives have been defined:

- Conduct ruggedness testing to define range of applicability (or limitations) of the MEST-H method.
- Conduct spiking and recovery tests.
- Perform analysis on sample storage time.
- Collect a formal data set for the MEST-H method that meets M301 criteria.
- Perform M301 statistics.
- Statistically compare the MEST-H and MEST-M data to M26 and M29 data.
- Submit a comprehensive data set to EPA for determination and approval of MEST-H as an alternative method.
- Provide a report that summarizes the test results.

These goals and objectives are consistent with NDIC Lignite Research Council (LRC) goals. By making available a simpler, lower-cost, validated method, utilities will be able to lower compliance costs, remain more competitive, help preserve existing jobs, and ensure economic stability in the industry and state.

In order to achieve the above-stated objectives, five main tasks have been identified:

- Task 1 – Perform Ruggedness Test
- Task 2 – Perform Spiking Test
- Task 3 – Perform Validation Test
- Task 4 – Data Reduction and Statistical Analysis
- Task 5 – Project Management and Reporting

Statement of Work

To further validate the MEST method, the EERC proposes to perform a number of tasks as outlined below. Most of the proposed tests are on a 550,000-Btu/hr pilot-scale test combustor (PTC) firing a relatively low chlorine coal provided by a utility project sponsor, with HCl emissions targeted near the MATS HCl limit. This test unit was used to validate the Ontario Hydro method and is already equipped with quadruplet ports to allow for quadruplet sampling, as shown in Figure 1. More details of the PTC can be found in Appendix A.

Task 1 – Perform Ruggedness Tests. The purpose of the ruggedness tests is to identify variables that strongly influence the accuracy and precision of the measurements taken by the MEST-H method. The ruggedness tests are not designed to determine optimum sampling conditions but, rather, identify sampling conditions that may limit use of the method and range of applicability. The EERC proposes to perform approximately 1 week of ruggedness testing by making systematic changes to a number of test variables while firing a relatively low chlorine coal in the PTC. For these tests, the PTC will be configured with an electrostatic precipitator

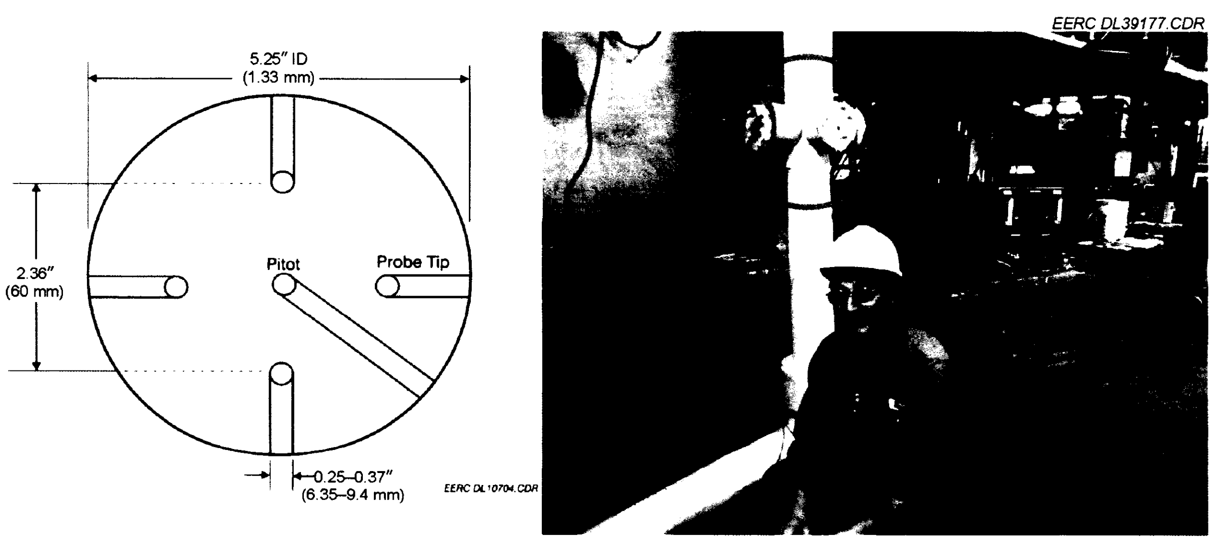

Figure 1. PTC quadruplet sampling ports.

(ESP, or possibly baghouse), with sampling to be performed downstream of the ESP (or baghouse). Test parameters to be varied include:

- Sampling temperature. Tests will be conducted at 250°, 325°, and 400°F.
- HCl concentration. Additional HCl will be injected into the system equivalent to approximately 10, 30, and 50 ppmv in the flue gas.
- SO_2 concentration. Additional SO_2 will be injected into the system at equivalent to approximately 500, 1500, and 3000 ppmv in the flue gas.
- Moisture. Additional moisture will be added to the flue gas to approach near-saturation. Three tests are planned.
- Sampling time. Sampling time will be varied at 15 minutes, 30 minutes, and 1 hour. The minimum sampling time will be calculated based on chlorine concentration in the coal, with sampling times adjusted accordingly.

These and/or other parameters identified in discussions with EPA may also be added/changed. Quadruplet sampling is planned for each test condition; that is, two sets of MEST-H and two M26 samples will be collect concurrently at each test condition.

Task 2 – Perform Spiking Tests. The purpose of this testing is to determine the best mode of spiking the MEST-H traps and determine the stability of the spiked traps under sampling conditions. To date, the EERC along with Ohio Lumex has spiked a limited number of traps, and the preliminary results are promising, as shown in Table 1.

Additional tests are needed to further evaluate the spiking method and stability of the spike under real flue gas sampling conditions. A week of PTC testing is planned for evaluation of

Table 1. Preliminary Spiked Trap Analysis

Sample No.	Spike, µg	Read, µg	Recovery, %
1	350	371	106
2	350	383	109
3	700	751	107
4	700	736	105
5	1200	1257	105
6	1200	1262	105
		Average	106.2

spiked MEST-H traps. Traps will be spiked at three different levels based on discussions with EPA and within the range typical of utility plant stacks compliant with MATS. Initial tests will be completed while natural gas is fired in the PTC to evaluate the stability of the spikes in combustion flue gas over two sampling durations: 2 and 4 hr. The flue gas temperature will be controlled to approximately 325°F. To evaluate HCl capture and recovery, one test will include the addition of a known quantity of HCl to the flue gas. Following the natural gas tests, the PTC will be run with a low-chlorine coal. The stability of a set of spiked traps will be evaluated for sampling durations of 2 and 4 hr. For these tests, one spiked and one unspiked trap will be used. Additionally, M26 samples will also be collected for comparative analyses.

Task 3 – Perform Validation Tests. The EERC will collect ten quadruplet sets of M26 and MEST-H samples that will serve as the formal data set on which M301 statistics will be performed to determine accuracy, bias, and precision. These samples will be collected over the course of 1 week at the outlet of the ESP PTC while a low-chlorine coal is fired. The coal chosen for the test will be based on coal chlorine content and input from EPA and project sponsors.

M301 specifies that an analysis be done to identify the effect of storage times on MEST-H samples. As part of this analysis, half of the samples must be analyzed within 72 hours, and the other half of the samples should be stored and analyzed near the end of 2 weeks, the maximum storage time allowed for emission samples. The EERC will collect and perform analyses according to M301. The effect of storage time will be quantified by comparing the results at the minimum and maximum storage times using statistical procedures outlined in M301.

Should budget allow, the EERC will also collect a number of M29 and MEST-M samples. As mentioned, the EERC has identified a synthetic trap material that shows promise of significantly lowering background contributions of all metals of interest, as shown in Figure 2.

Samples collected on the PTC are thought to be much less variable, providing an excellent opportunity to evaluate the benefits of using the synthetic trap materials, as well as an excellent opportunity to compare M29 and MEST-M results. The number of MEST-H and M29 samples to be collected will be determined based on project sponsorship and budget availability.

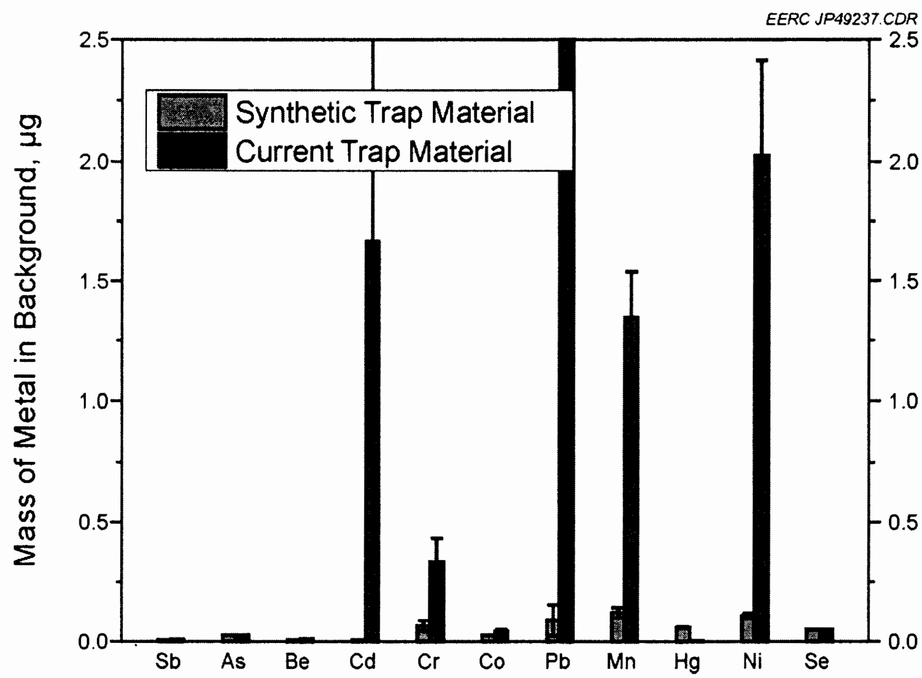

Figure 2. Comparison of background contribution between synthetic and currently used trap material.

Task 4 – Data Reduction and Statistical Analysis. As samples are collected, they will be sent to the EERC's Analytical Research Laboratory (ARL) for analysis. The ARL is equipped with all of the necessary laboratory instrumentation required for the analysis of all samples in the proposed work. A complete description of the ARL's facility and resources is provided in Appendix A. The M26a (and possibly M29) samples will be analyzed according to the instructions in their corresponding method. The trace element and halogen MEST samples will be analyzed by EERC-developed methods from previous projects. The halogen data will be reported on a ppmv 3% O_2 basis and will allow for a direct comparison between the MEST-H and M26a data. All of the trace element data will be reported on a $\mu g/dNm^3$ at 3% O_2 basis so that the data from both the M29 and MEST-M methods can be directly compared.

After the samples are analyzed in the ARL, the data will be incorporated into spreadsheets along with the relevant sampling data such as flue gas volume, stack moisture, percent O_2, etc., designed for each specific method. The spreadsheets will combine the laboratory data with the sampling data in order to calculate the flue gas concentrations for each analyte.

After all of the data are in their final reduced state, a M301 statistical analysis will be performed on each data set. The statistical analysis will include the average, range, standard deviation, precision, and bias for each data set. The relative difference between MEST-H and M26a data will also be determined. Plots will be generated from the statistical data. Data from previous projects and this project will compiled and submitted in a format that allows EPA to evaluate MEST-H to make a determination as to its suitability as an alternative method to M26 (and M26a).

Task 5 – Project Management and Reporting. Task 5 is the management and reporting task of the proposed work. The success of this task will be demonstrated by the timely and cost-effective accomplishment of contractual deliverables and milestones as outlined in the project management plan (described in more detail in a later section). Task 5 includes the following main subtasks:

1. Interaction with EPA. The EERC will interact with EPA as needed to discuss:
   a. The MEST method.
   b. M301 guidelines and requirements.
   c. Data gaps/needs.
   d. Generation of additional data.
   e. Reduction of data according to M301.
   f. Submission of data as requested by EPA.
   g. Questions as they arise.
2. Management and Quarterly Progress Reporting. Quarterly reports will be provided as required. Additionally, regular conference calls with project participants will be conducted to allow for the exchange of information and input on test plans.
3. Presentation at National Conferences. In order to disseminate the data and results to a wide audience, presentations will be given at national conferences after all of the data are collected and the results analyzed.
4. Final Report. This subtask will provide a detailed final report discussing all of the project results.

Deliverables

The main deliverables of this project are as follows:

- Pilot-scale testing and sampling in accordance with M301 guidelines.
- Ruggedness test data for MEST-H.
- Spiking test data for MEST-H.
- A minimum of ten quadruplet MEST-H and M26 samples collected under controlled test conditions.
- M301 statistical analysis.
- Coal sample analysis.
- Data of high quality passing quality assurance/quality control measures.
- Submission of data to EPA for consideration and determination of acceptance of MEST-H as an alternative method.
- Detailed procedure for MEST-H method. Submission to EPA for consideration as a formal method.
- Final report that summarizes all test data and results.

STANDARDS OF SUCCESS

The successful outcome of this project will be a fully validated and EPA-accepted MEST-H alternative method that can be used in place of M26 (and M26a). This alternative MEST method for measurement of HCl will allow power plants to reduce sampling costs significantly while providing EPA-accepted compliance data. The data collected using EPA methods and the MEST method will be of high quality and subject to all quality assurance/quality control standards, as defined by EERC's quality assurance program. Details of the EERC's quality assurance program are available on request.

Data collected from the novel MEST method will be compared to EPA M26 and M29 data for precision and accuracy. Data collected using the MEST method determined to be within

M301 criteria will be deemed acceptable and meet the standards of success defined for this project. Given the data gathered to date, the goal will be to achieve data agreement within 20%.

BACKGROUND

EPA National Emission Standards for Hazardous Air Pollutants (NESHAPs) from Coal- and Oil-Fired Electric Utility Steam Generating Units, or more commonly referred to MATS (U.S. Environmental Protection Agency, 2012a, b), will have a significant cost impact on electric utilities.

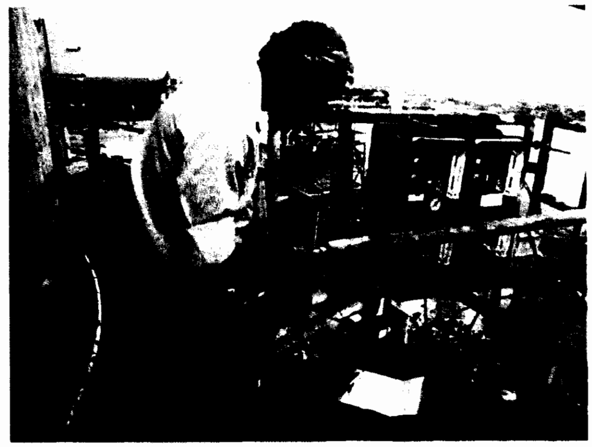

Figure 3. Comparative evaluation of MEST and EPA methods.

To comply with the new nonmercury metal and HCl emission standards, utilities will need to monitor and/or perform quarterly measurements to demonstrate compliance (Figure 3). To meet the new MATS HCl standards, plants must reduce HCl emissions to below 0.002 lb/MMBtu (or 0.02 lb/MWh).

For nonmercury metals, plants can comply with metal emissions using particulate matter as a surrogate (limit of 0.03 lb/MMBtu [or 0.3 lb/MWh]) or limit individual or total metals (limits shown in Appendix B). The plant owner/operator must demonstrate compliance with these limits either using CEMs or quarterly sampling using EPA-approved methods, such as M29 for multimetals (U.S. Environmental Protection Agency, 1996) and M26a for halogens (U.S. Environmental Protection Agency, 1994). For units that elect to use CEMs, the CEMs must be certified and validated using EPA-approved methods (e.g., M29, M26a). For units that elect to comply with the total or individual nonmercury metal emissions, the unit must conduct metal emission testing every quarter using M29. Since HCl monitors (e.g., FT-IR [Fourier transform infrared]) are still being developed and tested for utility application, most utilities have expressed that they will be conducting quarterly sampling using M26.

Adherence to the MATS will lead to a significant increase in EPA M29 and M26 sampling to demonstrate compliance, regardless of whether a utility chooses quarterly sampling or use of CEMs. These wet-chemistry methods are expensive because of the personnel hours needed for sampling and the complicated setup and recovery involved with both M29 and M26. The EERC, through CATM®, has developed a simpler, lower-cost, and more robust sampling method for measuring halogen (i.e., HCl) and metals. Costs and labor as projected from previous projects are expected to be 3–5 times less using the MEST method. The illustrations below show the simplicity of the MEST approach versus using the wet-chemistry EPA-approved methods (Figure 4).

As a potential alternative to EPA M29 and EPA M26/26A, the EERC developed the MEST method with two separate sampling applications: one for metals (MEST-M) and one for halogens (MEST-H), in particular HCl. Although the sorbent trap materials differ, the sampling

EERC JP49236.CDR

Figure 4. MEST sampling (left) and EPA M26 sampling (right).

procedures used to capture HCl and trace metals are very similar. As illustrated, both the MEST-M and MEST-H methods use similar equipment to draw an isokinetic or nonisokinetic flue gas sample through a series of plugs (quartz for MEST-M and glass for MEST-H) and beds of sorbent material. Both the MEST-M and MEST-H methods can easily be deployed in the field without the use of strong acids, bases, or solvents. In addition, the sorbent traps are small and can easily be transported to a laboratory for analysis or, for HCl, analyzed on-site.

Over the last 5 years, the EERC has performed pilot- and full-scale testing to evaluate the applicability of the MEST method to utility plants. Over the last 2 years, the EERC completed five full-scale tests at three lignite and two bituminous coal-fired units (Pavlish and others, 2013a, b). The results in Figures 5–8 show that the MEST-H data are in very good agreement with the M26a data and demonstrate the feasibility and applicability of the MEST method in a combustion setting. Additionally, the MEST-H detection limit is lower compared to M26a by almost 10×.

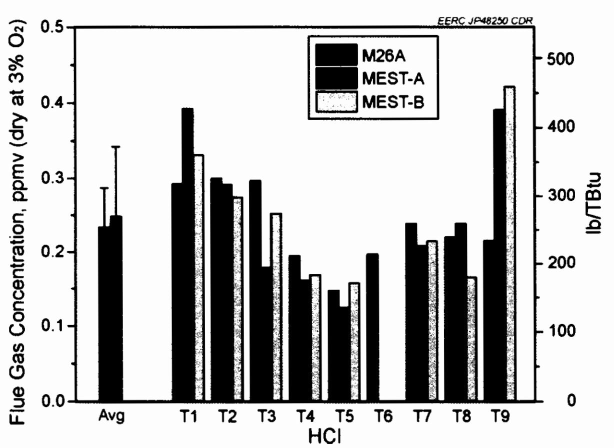

Figure 5. Lignite coal-fired Plant 1 showing comparative results between MEST-H and M26a.

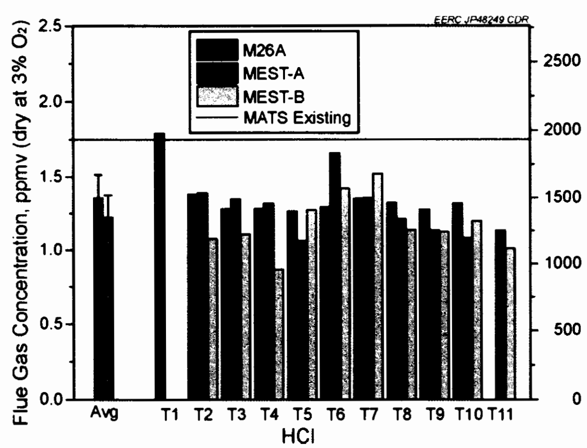

Figure 6. Lignite coal-fired Plant 2 showing comparative results between MEST-H and M26a.

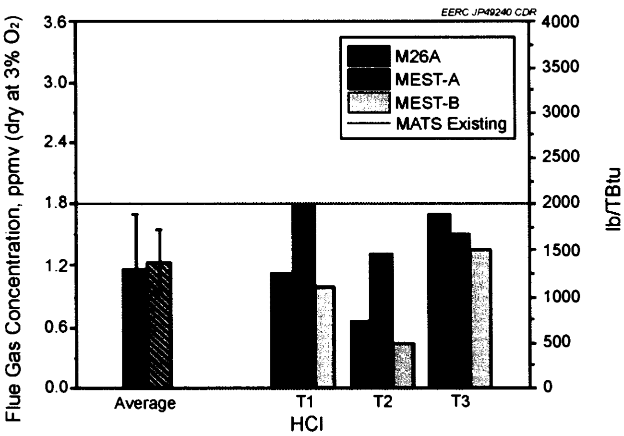

Figure 7. Bituminous coal-fired Plant 1 showing comparative results between MEST-H and M26a.

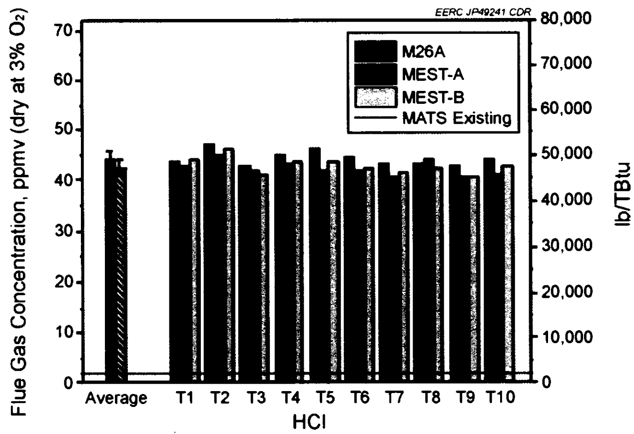

Figure 8. Bituminous coal-fired Plant 2 showing comparative results between MEST-H and M26a.

Data for metals in Figures 9 and 10 show general agreement with M29 but are more variable primarily because of high metal variability in coal, measurement values near detection limits of both M29 and MEST-M, and relatively high background concentrations.

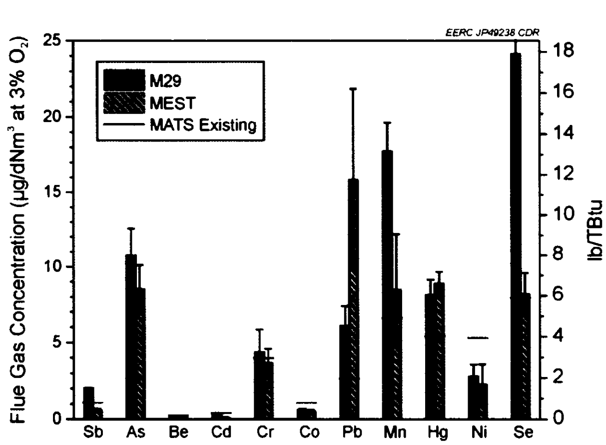

Figure 9. Lignite coal-fired plant showing comparative results between MEST-M and M29.

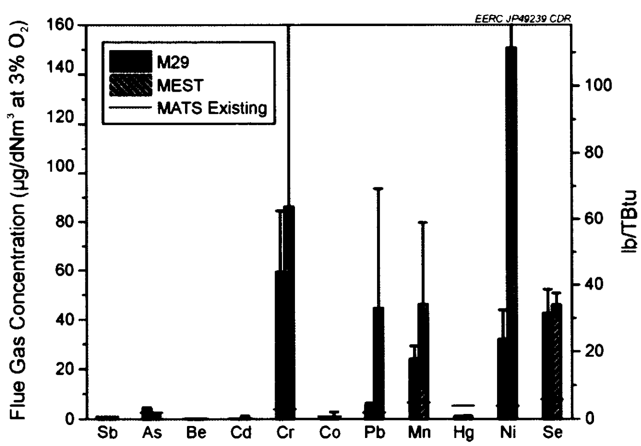

Figure 10. Bituminous coal-fired plant showing comparative results between MEST-M and M29.

Recent discussions with EPA suggest that the MEST-H method is a good potential candidate for consideration as an alternative method. As shown in Table 2, the cost per sample for MEST-H is estimated from the previously mentioned projects (Pavlish and others, 2013a, b) to be 3–5 times less than M26A. Consequently, if approved by EPA, utilities will save millions of dollars annually on compliance measurements.

Table 2. Estimated Cost per Sample

	M29	**MEST-M**	**M26A**	**MEST-H**
Labor, minutes	810	360	570	240
Labor Cost	$1320	$610	$930	$400
Supplies	$325	$100	$210	$50
Misc.[1]	$560	$100	$450	$80
Analysis[2]	$330	$440	$20	$40
Total	**$2535**	**$1250**	**$1610**	**$570**

[1] Shipping samples, sample disposal, disposal of analytical waste, reporting, contingency.
[2] Includes analyses of A and B traps for MEST.

Additional information on MEST developments and sampling results can be found at the following:

- Pavlish, J.H.; Lentz, N.B.; Martin, C.L.; Ralston, N.V.C.; Zhuang, Y.; Hamre, L.L. *Subtask 4.8 – Fate and Control of Mercury and Trace Elements*; Final Report (July 1, 2009 – Dec 31, 2011) for U.S. Department of Energy National Energy Technology Laboratory Cooperative Agreement No. DE-FC26-08NT43291; EERC Publication 2011-EERC-12-09; Energy & Environmental Research Center: Grand Forks, ND, Dec 2011.

- Pavlish, J.H. Field Evaluation of Novel Approach for Obtaining Metal and Halogen Emission Data. Presented at Energy, Utility, and Environment Conference (EUEC), Phoenix, AZ, Jan 30 – Feb 1, 2012.
- Pavlish, J.H. Development and Testing of a Multielement Sorbent Trap Sampling Method for Halogen and Trace Metal Emissions. Presented at 36th Stationary Source Sampling and Analysis for Air Pollutants, Horseshoe Bay, TX, Feb 4–9, 2012.
- Thompson, J.T.; Pavlish, J.H. A Novel Multielement Sorbent Trap Sampling Method for Halogen and Trace Metal Emissions. Presented at Sorbent Trap Interest Group, EPRI CEM Conference, May 8–10, 2012.
- Pavlish, J.H. A Multielement Sorbent Trap Sampling Method for Measurement of Metal and Halogen Emissions. Presented at 9th Mercury Emissions from Coal (MEC9) Working Group, St. Petersburg, Russia, May 22–24, 2012.
- Pavlish, J.H. Full-Scale Multisite Evaluation of the Multielement Sorbent Trap Sampling (ME-ST) Method for Halogen. Presented at EUEC 2013: Energy, Utility & Environment Conference, Phoenix, AZ, Jan 28–30, 2013.
- Pavlish, J.H. An Update on the Multi-Element Sorbent Trap Sampling Method for Halogen and Metal Emissions. Presented at the 37th Stationary Source Sampling and Analysis for Air Pollutants Conference, Hilton Head Island, SC, March 24–29, 2013.
- Pavlish, J.H. Measurement of Halogens and Metals Using a Sorbent Trap Approach. Presented at Continuous Emissions Monitoring User Group (CEMUG) Conference, Raleigh, NC, May 8–9, 2013.
- Pavlish, J.H.; Thompson, J.S. The Multielement Sorbent Trap Sampling Method for Halogen and Metal Emissions. In *Proceedings of Air Quality IX: An International*

Conference on Environmental Topics Associated with Energy Production; Arlington, VA, Oct 21–23, 2013.

QUALIFICATIONS

The following is a brief description of the EERC's qualifications and experience as they relate to the testing that is proposed. Additional information can be found at the EERC's Web site, www.undeerc.org.

The University of North Dakota's (UND's) EERC is one of the world's major energy and environmental research organizations. Since its founding in 1951, the EERC has conducted research, testing, and evaluation of fuels, combustion and gasification technologies, emission control technologies, ash use and disposal, analytical methods, groundwater, waste-to-energy systems, and advanced environmental control systems. Today's energy and environmental research needs typically require the expertise of a total-systems team that can focus on technical details while retaining a broad perspective.

The EERC has over 65 years of coal research, with extensive experience on low-rank coals (lignite and subbituminous). The EERC has conducted measurement sampling at over 80 coal-fired units at utilities since 1996. The EERC has developed several new methods (in particular for mercury, Ontario Hydro [OH], M30B) over the years and routinely is called upon to evaluate measurement errors and biases that can be introduced during measurement and ways to overcome sampling problems. On projects, the EERC goes significantly beyond the requirements of the sampling methods to ensure that the lessons learned over the years result in quality, reliable data.

Over the last decade, the EERC has conducted evaluation of several CEMs and routinely provides training sessions for government, research, and utility personnel. While the EERC is proud of its ability to deliver quality research outcomes in measurement, analysis, and interpretation to government entities in both the United States and Canada, almost all EERC projects have been at least partially funded by industrial sources, including the Electric Power Research Institute (EPRI), many power companies, and vendors of control technologies.

CATM is under the Emission Control Technologies Center, one of the EERC's designated Centers of Excellence; CATM has had a primary mission of understanding and developing control strategies for potentially toxic trace metals. Over nearly two decades, CATM researchers have provided research on the fate and formation of trace metals, evaluated and developed sampling methods, tested and refined control technologies, and performed many projects to evaluate the role of trace metals in the environment.

The EERC, especially through CATM, has placed a great deal of emphasis on developing reliable and valid measurement and analytical methods and instruments. From the beginning of the CATM Program, it has worked as a partner with key stakeholders, including the research community, regulators, vendors, and end users to evaluate various sampling and analytical methods and develop better methods:

1. The EERC, through CATM, brings over 20 years of experience in characterization, measurement, development, and testing of measurement and control technologies for trace metals and halogens.
2. For over 20 years, the EERC and CATM have worked with every major continuous mercury monitor vendor to develop and refine continuous emission sampling methods and eliminate biases and interferences.
3. The EERC validated the OH mercury speciation method and authored ASTM International Method D6784-02.

4. CATM conducted extensive evaluations of EPA M29 and its benefits and shortcomings.
5. The EERC was an early evaluator and adopter of sorbent trap methods, from Appendix K and EPA Method 30B through current adaptations.
6. The MEST method has been developed and is being evaluated as an alternative method for halogen and metal sampling.

VALUE TO NORTH DAKOTA

North Dakota power utilities will be significantly impacted by the MATS and will be required to spend millions of dollars both in installing emission reduction technologies and in addressing compliance monitoring requirements and reporting. While the initial NDIC-funded project did evaluate the MEST method and provide some initial validation data, additional data are needed before EPA will accept the MEST method as an alternative method. This follow-on project proposes to fill in data gaps, generate lacking data, and work with EPA to define an alternative method that is more cost-effective (significantly lower in cost), which will be of value and benefit to North Dakota utilities. Costs related to compliance sampling for HCl are expected to be reduced by a factor of 3–5, based on estimates developed under the previous project. The MEST method is much simpler to use, thereby minimizing training and requirements for especially skilled labor. The data collected will be of high quality, allowing for a formal validation of the MEST method for measurement of HCl. The project is of value to North Dakota industry as evident by the letters of support provided in Appendix C.

MANAGEMENT AND ORGANIZATION

The overall project is organized as shown in Figure 11, with the roles and responsibilities defined as follows.

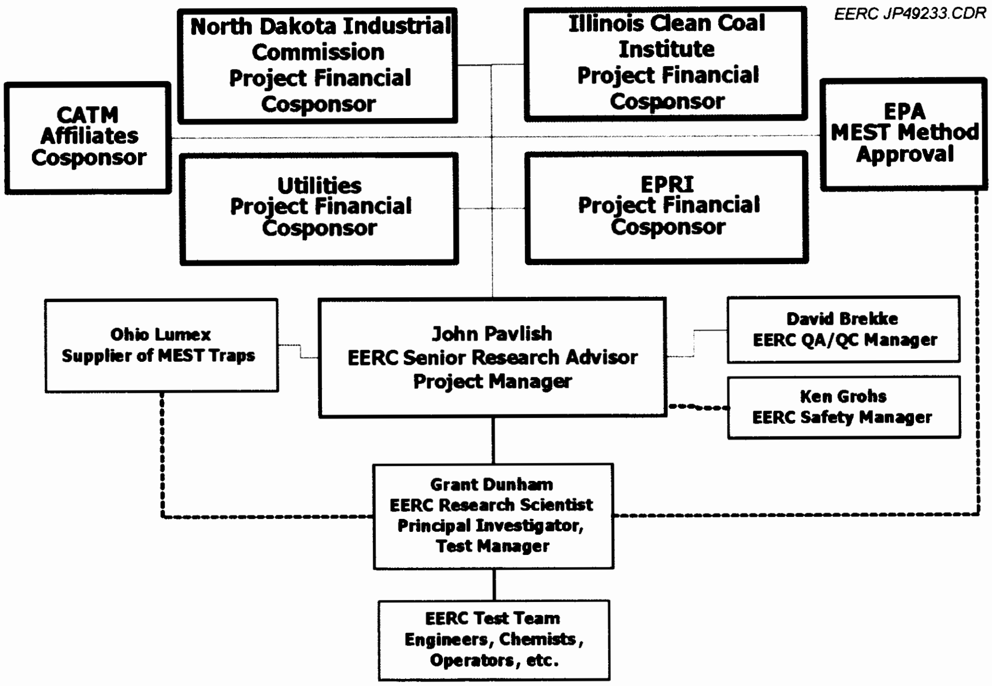

Figure 11. Organization of the EERC project team.

EERC

The EERC will manage the overall project and coordinate all sampling activities as described above. Sampling activities will be determined and finalized based on discussions with NDIC, EPA, and project sponsors. The EERC has worked with all of the North Dakota utilities and has performed sampling at most, if not all, of the plants within North Dakota.

Consequently, the EERC is quite familiar with the plant configurations and the potential application of MEST at these plants. The EERC project manager will communicate directly with sponsors to ensure that the project goals are being met and that they are fully aware of all test plans and requirements. The EERC test manager will manage day-to-day activities to carry out the test plan and oversee test activities, as well as assist in data reduction and reporting. Prior to testing, the EERC will develop a more detailed day-by-day test plan based on input and discussions with EPA and project sponsors. Prior to testing and based on input from EPA and the project sponsor, the EERC will facilitate the creation of the detailed test plan to ensure that all testing/sampling is sufficiently planned, that resources are allocated in a timely manner, and to prepare for necessary analyses.

NDIC

NDIC will assign a performance monitor who will be involved in the discussions and plans related to this project, as well as ongoing evaluation of the sampling results. This involvement will include finalizing details for the test plan, participation in regular conference calls to update the team on project progress, and receiving and reviewing regular reports. It is possible that the NDIC representative may choose to conduct a site visit during the course of sampling, which will be coordinated by the EERC.

ICCI

Illinois Clean Coal Institute (ICCI) will assign a performance monitor who will be involved in the discussions and plans related to this project, as well as ongoing evaluation of the sampling results. This involvement will include finalizing details for the test plan, participating in regular conference calls to update the team on project progress, and receiving and reviewing regular reports. It is possible that the ICCI representative may choose to conduct a site visit during the course of sampling, which will be coordinated by the EERC.

EPRI

EPRI will assign a performance monitor who will be involved in the discussions and plans related to this project, as well as ongoing evaluation of the sampling results. This involvement will include finalizing details for the test plan, participating in regular conference calls to update the team on project progress, and receiving and reviewing regular reports. It is possible that the EPRI representative may choose to conduct a site visit during the course of the sampling, which will be coordinated by the EERC.

Ohio Lumex

Through an ongoing collaborative effort, Ohio Lumex has been involved in the evaluation and testing of the MEST method. As a vendor, Ohio Lumex is particularly interested in providing traps and analyses that serve the power industry. Ohio Lumex will be available for technical guidance and will provide sorbent traps for this project.

Regular meetings via conference calls will be held to share information, facilitate communication among all project participants, and guide project decisions. Reports and presentations will be issued to update the project participants on project status and results. Based on test milestones, periodic review meetings will be held to present data and allow participants to provide feedback and direction.

KEY PERSONNEL

The following are the key personnel involved in the project; more detailed resumes and relevant publications are found in Appendix D of this proposal.

Mr. John Pavlish, EERC Senior Research Advisor, will serve as manager of the project and also serves as the Director of the EERC's CATM. Mr. Pavlish has over 25 years of advanced engineering experience in the coal-fired power sector, 17 of which are directly related to metals research, and has been the project manager for several emission control projects in both the United States and Canada at all scales of testing. Prior to his employment at the EERC, he was a key consultant in advanced power systems at Black & Veatch, where he was responsible for plant performance and emission evaluations for coal-fired power generators.

He has several patent applications for mercury control technologies, other emission control technologies, and sampling methods. Through the CATM Program, he has been responsible for overseeing both fundamental and applied research that has included numerous mercury-related research activities.

Mr. Grant Dunham is a research engineer at the EERC and will serve as the test manager for this project. Mr. Dunham has more than 20 years of experience both in the laboratory and in the field related to mercury sampling and demonstration of mercury control technologies. As test manager, he will be responsible to coordinate and oversee all test activities, sample tracking, and analyses. He will also be assisting in data compilation, reduction, evaluation of data, and reporting.

Detailed resumes can be found in Appendix D.

TIMETABLE

The project time frame for this proposed work is estimated to be 18 months (Table 3), allowing for adequate (additional) time to interact with EPA and gain approval as an alternative method. Sampling activities and the project schedule may be adjusted based on discussions with project sponsors and EPA.

BUDGETED COSTS/MATCHING FUNDS

The EERC is requesting $245,000 from NDIC to support the proposed effort, with a total estimated cost of the project being $860,000. The remaining amount of $615,000 will be sought from the following:

- $200,000 from ICCI. ICCI has expressed interest in the project. An official proposal will be submitted to ICCI in May requesting the funds.
- $415,000 from industry. Of this amount, $125K is already committed from Basin Electric Power Cooperative ($25K), Minnesota Power ($25K), Otter Tail Power Company ($15K), and the CATM Affiliates Program ($60K). There is strong support

for the project as shown in Appendix C. EPRI is considering commitment of $200K to support the project and is seeking official approval. The National Rural Electric Cooperative Association is considering commitment of $50K; refer to Appendix C for letter of support. Several other utilities have expressed interest and are seeking formal approval.

Additional in-kind cost share will be provided by Ohio Lumex in the form of approximately 200 sorbent traps, at a discounted price, although this will not constitute formal cost share. If the full funding is not secured, the scope of work will be amended commensurate with the funding available. Initiation of the proposed work is contingent upon the execution of a mutually negotiated agreement or modification to an existing agreement between the EERC and each of the project sponsors. If project funding cannot be secured through the current industrial consortium members, this would delay the start of the project until new consortium members can be identified, but the EERC does not anticipate this will be a problem. Letters of interest and/or commitment showing support for this project are found in Appendix C. The EERC will continue to secure more solid commitments, which will be in place prior to establishing a contract with NDIC.

It should be noted that the EERC has all facilities, equipment, and laboratories in house to perform the work proposed herein. Consequently, no additional equipment is needed. A detailed budget and budget notes for the proposed project can be found in Appendix E. Initiation of the proposed work is contingent upon the execution of a mutually negotiated agreement or modification to an existing agreement between our organizations.

Fiscal Oversight, Responsiveness to Clients, and Account Management

The EERC is a research arm of UND and operates as a fee-for-contract partner with private and public entities. The EERC is structured as a nonprofit educational institution. Through the EERC Foundation®, and in partnership with commercial vendors and engineering firms, technological solutions are developed, tested, and commercialized for use in client organizations.

Although part of UND and, therefore, subject to University policies and state guidelines for North Dakota, the EERC has several systems in place, including redundant business systems, which allow the EERC to act in a very responsive way to its clients, both in regard to execution of agreements and to resolve any issues or questions that may arise during the course of the project.

Within the EERC, administrative personnel, the technical project manager, contract agents, and accounting personnel work closely to administer the fiscal and contract responsibilities related to client projects, offering quick access to decision makers and quick resolution of issues. Contract officers within the EERC are authorized to negotiate directly with the sponsoring organization's contract agent to arrive at a mutually beneficial agreement in the shortest time possible. All accounts are managed directly within the EERC, with joint oversight by the project manager, budgeting personnel, contracts, and the EERC accounting department. This allows close oversight of the project budget and costs.

One such redundant system that facilitates direct management is the resource management system (RMS), an EERC project management system that receives daily imports of project expenditures and budget changes from UND's financial system. RMS is updated regularly with financial data, such as payroll encumbrances, that are not obligated in UND's financial system.

Table 3. Project Schedule

	2014–2015																	
Project Activity	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
Award by NDIC		a																
Contract negotiations leading to signed agreements with all project sponsors			a															
Task 1 – Perform Ruggedness Tests							b											
Task 2 – Perform Spiking Tests										c								
Task 3 – Perform Validation Tests												d						
Task 4 – Data Reduction and Statistical Analysis																ef		
Task 5 – Management and Reporting																		

Milestones	
a	Contracts signed
b	Complete ruggedness tests
c	Complete spiking tests
d	Complete validation tests
e	Complete data reduction
f	Complete statistical analysis

RMS provides the information necessary to keep track of expenditures by project. Each project is assigned a control account in which budgets, expenses, and remaining balances are tracked by cost element. Project managers are provided with updates on a semimonthly basis, but up-to-date information is available at any time, if necessary.

UND uses the PeopleSoft Grants Suite to meet the accounting and fiscal reporting requirements of sponsored agreements, including grants, contracts, and cooperative agreement awards. This system, which is maintained by professional accountants and grants and contracts officers, will handle the fiscal management and accounting aspects of this project. The system allows for such items as proper segregation of direct costs from indirect, identification and accumulation of direct costs by project, accumulations of costs under general ledger control, and a timekeeping system that identifies employee labor by final cost objectives.

Several systems are in place to track project costs to ensure that cost accounting is appropriate and that only expenses related to the project are charged to the project. Purchasing and procurement are covered by UND's policies, which can be accessed at www.und.edu/dept/purchase/docs/U2%20Purch%20Policy%20Procedure%2010.16.2007.ppt.

TAX LIABILITY

The EERC does not have an outstanding tax liability owed to the state of North Dakota or any of its political subdivisions.

CONFIDENTIAL INFORMATION

This proposal does not contain confidential information.

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APPENDIX A

EERC PILOT TEST COMBUSTOR ARL FACILITY AND CAPABILITIES

PILOT-SCALE TEST COMBUSTOR

The pilot furnace, known as the particulate test combustor (PTC) and shown in Figure A-1, is a 550,000-Btu/hr pulverized coal (pc)-fired unit designed to generate fly ash representative of that produced in a full-scale utility boiler. The combustor is oriented vertically to minimize wall deposits. A refractory lining helps to ensure adequate flame temperature for complete combustion and prevents rapid quenching of the coalescing or condensing fly ash. Based on the superficial gas velocity, the mean residence time of a particle in the combustor is approximately 3 seconds. The coal nozzle of the PTC fires axially upward from the bottom of the combustor, and secondary air is introduced concentrically to the primary air with turbulent mixing. Coal is introduced to the primary air stream via a screw feeder and eductor. An electric air preheater is used for precise control of the combustion air temperature. Originally, the PTC used cold-water

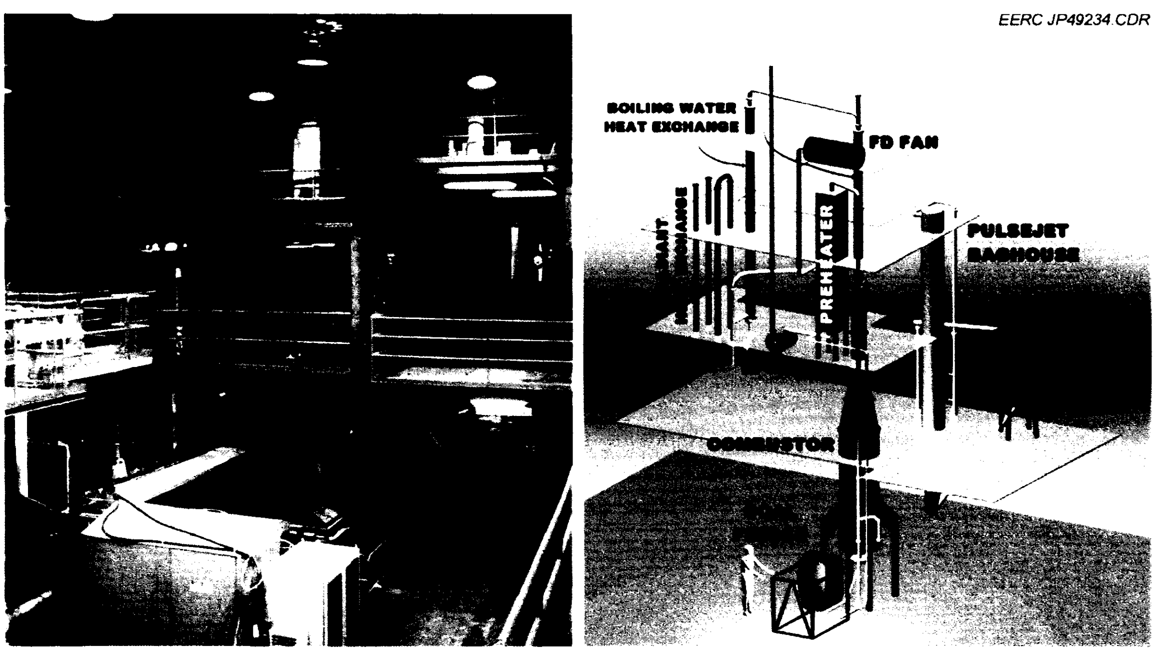

Figure A-1. PTC.

annular heat exchangers to provide flue gas temperature control to the baghouse or electrostatic precipitator (ESP). However, analysis of ash deposits collected from the heat exchangers indicated that some mercury was collected on the duct walls. To minimize this effect, the heat exchangers were modified to provide for higher duct wall temperatures.

The PTC instrumentation permits system temperatures, pressures, flow rates, flue gas constituent concentrations, and particulate control device (baghouse, advanced hybrid particulate collector [AHPC], and/or electrostatic precipitator [ESP]) operating data to be monitored continuously and recorded on a data logger.

Flue gas samples can be taken at any combination of two of three available system sample points: the furnace exit, the particulate control device inlet, and the particulate control device outlet. After passing through sample conditioners to remove the moisture, the flue gas is typically analyzed for O_2, CO, CO_2, SO_2, and NO_x. Except for CO and CO_2, each constituent is normally analyzed at both the furnace exit and the outlet of the particulate control device simultaneously, using two analyzers. The concentration values from all of the instruments are recorded continuously, using circular charts. In addition, data are manually recorded at set time intervals. NO_x is determined using two Thermoelectron chemiluminescent NO_x analyzers. The O_2 and CO_2 analyzers are made by Beckman, and the SO_2 analyzers are manufactured by DuPont. Each of these analyzers is regularly calibrated and maintained to provide accurate flue gas concentration measurements.

The baghouse vessel is a 20-in.-ID chamber that is heat-traced and insulated, with the flue gas introduced near the bottom. Since the combustor produces about 200 acfm of flue gas at 300°F, three 13-ft by 5-in. bags provide an air-to-cloth ratio of 4 ft/min. Each bag is cleaned separately with its own diaphragm pulse valve. In order to quantify differences in pressure drop for different test conditions, the bags are cleaned on a time basis, rather than with the cleaning cycle initiated by pressure drop. Once bag cleaning is initiated, all three bags are pulsed in rapid succession on-line.

Instead of directing the flue gas through a fabric filter, a single-wire, tubular ESP can be used. The unit is designed to provide a specific collection area of 125 at 300°F. Since the flue gas flow rate for the PTC is 130 scfm, the gas velocity through the ESP is 5 ft/min. The plate spacing for the unit is 11 in.

The ESP as shown in Figure A-2 has an electrically isolated plate that is grounded through an ammeter, allowing continual monitoring of the actual plate current to ensure consistent operation of the ESP from test to test. The tubular plate is suspended by a load cell which will help to monitor rapping efficiency. In addition, sight ports are located at the top of the ESP to

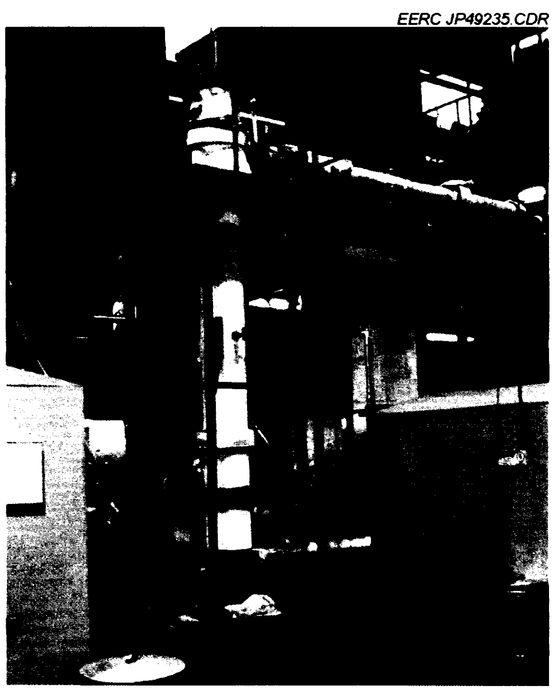

Figure A-2. PTC ESP.

allow for on-line inspection of electrode alignment, sparking, rapping, and dust buildup on the plate. The ESP was designed to facilitate thorough cleaning between tests so that all tests can begin on the same basis.

ANALYTICAL RESEARCH LABORATORY

Laboratory Capabilities

The Analytical Research Laboratory (ARL) provides quality data, flexibility, and rapid turnaround time in support of research activities at the Energy & Environmental Research Center (EERC). The lab is equipped for routine and specialized analyses of inorganic and organic constituents, which are performed using classical wet-chemistry and state-of-the-art instrumental procedures. Established analytical techniques allow for the chemical characterization of a variety of environmental and biological sample types, including fossil fuels, biomass, combustion by-products, geologic materials, fine particulate matter, groundwater, wastewater, fish tissue, and plant materials. Particular attention is directed toward trace element analysis, including arsenic, mercury, and selenium.

Quality Assurance

The EERC laboratory staff follows U.S. Environmental Protection Agency (EPA), ASTM International, and other standard methods for the analysis of samples. Analytical methods are routinely monitored for precision and accuracy with certified reference materials from the National Institute of Standards and Technology (NIST), the South African Bureau of Standards (SABS), the International Atomic Energy Agency (IAEA), and other sources. The ARL analyzes certified parameters annually in a water pollution study acquired from a NIST/National Voluntary Laboratory Accreditation Program (NVLAP)-accredited provider. Additional external quality assurance is maintained by participating in interlaboratory studies and proficiency programs such as the Coal and Ash Sample Proficiency Exchange™ (CANSPEX™). This participation allows the ARL to demonstrate competence in methods of analysis by comparing analytical results and techniques with other laboratories throughout the United States and Canada.

Research Activities

- Mercury: The ARL plays a major role in the support of mercury research at the EERC. With several EERC projects focusing on the occurrence and fate of mercury in combustion systems, as well as the evaluation of mercury control technologies, the ARL staff has gained considerable experience in mercury chemistry and analytical techniques for providing precise and accurate data.
- Center for Air Toxic Metals® (CATM®): The analytical efforts that support CATM projects include nickel speciation of particulate matter emitted from oil-fired units; mercury determination in alternative fuel sources such as biomass, oil/tar sands, and oil shale; low-level halogen determination in coal; and mercury and selenium determination in biological matrices to help evaluate the effect of selenium on mercury toxicity.
- Measurement of hazardous air pollutants (HAPs) from combustion systems: The ARL supports research at the EERC related to the fate of HAPs in combustion systems by thoroughly characterizing the fuel, ash by-products, and stack emissions. Several EERC projects have evaluated the impact of mercury control technologies on the fate of other inorganic HAPs which include As, Be, Cd, Co, Cr, Mn, Ni, Pb, Sb, and Se.
- Solid waste characterization: toxicity characteristic leaching procedure (TCLP) and other leaching procedures are employed for determining the leachability of RCRA (Resource Conservation and Recovery Act) metals and other constituents of environmental concern.

- Biomass characterization: The ARL employs a variety of sample preparation and analytical techniques for the determination of major, minor, and trace constituents in biomass materials such as wood chips, switchgrass, and corn stover.
- Biological sample analysis: To support research related to the health impacts of environmental pollutants, the ARL has capabilities for the preparation and analysis of biological tissues such as hair, blood, fish, and plant materials.

Laboratory Equipment

- 4200-ft^2, fully equipped, clean laboratory with seven fume hoods
- VG PQ ExCell inductively coupled plasma mass spectrometer (ICP–MS) with collision cell technology
- Perkin Elmer Optima 2100 ICP–AES
- CETAC M6000A cold-vapor atomic absorption spectrometer (CVAAS) mercury analyzer
- PS Analytical Millennium Merlin cold-vapor atomic fluorescence spectrometer (CVAFS)
- PS Analytical Millennium Excalibur hydride generation atomic fluorescence spectrometer (HGAFS)
- Spectra AA-880Z graphite furnace atomic absorption spectrometer (GFAAS)
- Mitsubishi TOX-100 chlorine analyzer with oxidative hydrolysis microcoulometry
- Dionex ISC3000 ion chromatograph (IC) with conductivity detection.
- Dionex 2020i ion chromatograph (IC) with UV–VIS, conductivity, and electrochemical detection
- CEM MDS 2100 microwave with temperature and pressure control
- Pyrohydrolysis/ion-specific electrode for fluorine analysis of fossil fuels

- Agilent 1200/Applied Biosystems API 2000 triple quadrupole LC–MS system with a degasser, autosampler, column compartment, binary pump, and DAD detector. The MS has a scan range of 5–1800 m/z and is equipped with both ESI and APCI sources.

EERC
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APPENDIX B

ALTERNATIVE EMISSION LIMITATIONS FOR EXISTING COAL- AND OIL-FIRED ELECTRIC GENERATING UNITS

ALTERNATIVE EMISSION LIMITATIONS FOR EXISTING COAL- AND OIL-FIRED ELECTRIC GENERATING UNITS (1)

Subcategory	Coal-Fired EGUs	IGCC	Liquid Oil, Continental	Liquid Oil, Noncontinental	Solid Oil-Derived
SO_2	2.0E–1 lb/MMBtu (1.5 lb/MWh)	NA[a]	NA	NA	3.0E–1 lb/MMBtu (2.0 lb/MWh)
Total Nonmercury Metals	5.0E–5 lb/MMBtu (5.0E–1 lb/GWh)	6.0E–5 lb/MMBtu (5.0E–1 lb/GWh)	8.0E–4 lb/MMBtu (8.0E–3 lb/MWh)[b]	6.0E–4 lb/MMBtu (7.0E–3 lb.MWh)[b]	4.0E–5 lb/MMBtu (6.0E–1 lb/GWh)
Antimony, Sb	8.0E–1 lb/TBtu (8.0E–3 lb/GWh)	1.4 lb/TBtu (2.0E–2 lb/GWh)	1.3E+1 lb/TBtu	2.2E0 lb/TBtu (2.0E–2 lb/GWh)	8.0E–1 lb/TBtu (8.0E–3 lb/GWh)
Arsenic, As	1.1 lb/TBtu (2.0E–2 lb/GWh)	1.5 lb/TBtu (2.0E–2 lb/GWh)	(2.0E–1 lb/GWh) 2.8 lb/TBtu	4.3E0 lb/TBtu (8.0E–2 lb/GWh)	3.0E–1 lb/TBtu (5.0E–3 lb/GWh)
Beryllium, Be	2.0E–1 lb/TBtu (2.0E–3 lb/GWh)	1.0E–1 lb/TBtu (1.0E–3 lb/GWh)	(3.0E–2 lb/GWh) 2.0E–1 lb/TBtu	6.0E–1 lb/TBtu (3.0E–3 lb/GWh)	6.0E–2 lb/TBtu (6.0E–4 lb/GWh)
Cadmium, Cd	3.0E–1 lb/TBtu (3.0E–3 lb/GWh)	1.5E–1 lb/TBtu (2.0E–3 lb/GWh)	(2.0E–3 lb/GWh) 3.0E–1 lb/TBtu	3.0E–1 lb/TBtu (3.0E–3 lb/GWh)	3.0E–1 lb/TBtu (4.0E–3 lb/GWh)
Chromium, Cr	2.8 lb/TBtu (3.0E–2 lb/GWh)	2.9 lb/TBtu (3.0E–2 lb/GWh)	(2.0E–3 lb/GWh) 5.5 lb/TBtu	3.1E+1 lb/TBtu (3.0E–1 lb/GWh)	8.0E–1 lb/TBtu (2.0E–2 lb/GWh)
Cobalt, Co	8.0E–1 lb/TBtu (8.0E–3 lb/GWh)	1.2 lb/TBtu (2.0E–2 lb/GWh)	(6.0E–2 lb/GWh) 2.1E+1 lb/TBtu	1.1E+2 lb/TBtu (1.4E0 lb/GWh)	1.1 lb/TBtu (2.0E–2 lb/GWh)
Lead, Pb	1.2 lb/TBtu (2.0E–2 lb/GWh)	1.9E+2 lb/MMBtu (1.8 lb/MWh)	(3.0E–1 lb/GWh) 8.1 lb/TBtu	4.9E0 lb/TBtu (8.0E–2 lb/GWh)	8.0E–1 lb/TBtu (2.0E–2 lb/GWh)
Manganese, Mn	4.0 lb/TBtu (5.0E–2 lb/GWh)	2.5 lb/TBtu (3.0E–2 lb/GWh)	(8.0E–2 lb/GWh) 2.2E+1 lb/TBtu	2.0E+1 lb/TBtu (3.0E–1 lb/GWh)	2.3 lb/TBtu (4.0E–2 lb/GWh)
Mercury, Hg	NA	NA	(3.0E–1 lb/GWh) 2.0E–1 lb/TBtu	4.0E–2 lb/TBtu (4.0E–4 lb/GWh)	NA
Nickel, Ni	3.5 lb/TBtu (4.0E–2 lb/GWh)	6.5 lb/TBtu (7.0E–2 lb/GWh)	(2.0E–3 lb/GWh) 1.1E+2 lb/TBtu	4.7E+2 lb/TBtu (4.1E0 lb/GWh)	9.0 lb/TBtu (2.0E–1 lb/GWh)
Selenium, Se	5.0 lb/TBtu (6.0E–2 lb/GWh)	2.2E+1 lb/TBtu (3.0E–1 lb/GWh)	(1.1 lb/GWh) 3.3 lb/TBtu (4.0E–2 lb/GWh)	9.8E0 lb/TBtu (2.0E–1 lb/GWh)	1.2 lb/TBtu (2.0E–2 lb/GWh)

[a] Not applicable.
[b] Includes Hg.

APPENDIX C

LETTERS OF SUPPORT

Basin Electric Power Cooperative
Minnesota Power
Otter Tail Power Company
Center for Air Toxics® Affiliates
Great River Energy
Montana–Dakota Utilities Co.
National Rural Electric Cooperative Association

BASIN ELECTRIC
POWER COOPERATIVE
1717 EAST INTERSTATE AVENUE
BISMARCK, NORTH DAKOTA 58503
PHONE 701-223-0441 FAX: 701-557-5336

March 28, 2014

Mr. John Pavlish
Director of Center for Air Toxic Metals
Energy & Environmental Research Center
15 North 23rd Street
Grand Forks, ND 58202

RE: EERC Proposed Project Entitled "Validation of the Multielement Sorbent Trap (MEST) Method for Measurement of HCl and Metals"

Dear Mr. Pavlish:

Thank you for the opportunity to participate in this project. As Senior Vice President of Engineering and Construction of Basin Electric Power Cooperative (BEPC), I am pleased to submit this letter of support and interest to participate in the "Validation of the Multielement Sorbent Trap (MEST) Method for Measurement of HCl and Metals" project. To comply with the U.S. Environmental Protection Agency (EPA) Mercury and Air Toxic Standard (MATS), BEPC will be required to increase sampling, measurement, and monitoring activities to show compliance with regulatory reductions of hazardous air pollutant (HAP) metal and halogen (HCl) emissions. This project offers the opportunity to continue to develop a simpler, lower cost option than EPA's reference methods, which are complicated, often use hazardous chemicals, and are relatively expensive to use.

BEPC considers the project to be of great value to the industry and is willing to commit $25,000.00 towards supporting the project. We hope that the North Dakota Industrial Commission and other funding agencies give careful consideration to this project, as there is a significant need for simpler, lower cost compliance methods. Again, we express our support and look forward to working with the EERC on this project.

Sincerely,

Matt Greek
Senior Vice President of Engineering and Construction
Basin Electric Power Cooperative

/ser

minnesota power

AN ALLETE COMPANY

Allan S. Rudeck, Jr., Vice President – Strategy & Planning

April 1, 2014

Mr. John Pavlish
Director of Center for Air Toxic Metals
Energy & Environmental Research Center
15 North 23rd Street
Grand Forks, ND 58202

Dear Mr. Pavlish:

Subject: EERC Proposed Project Entitled "Validation of the Multielement Sorbent Trap (MEST) Method for Measurement of HCl and Metals"

As Vice President of Strategy and Planning for Minnesota Power, I am pleased to submit this letter of support and interest to participate in the "Validation of the Multielement Sorbent Trap (MEST) Method for Measurement of HCl and Metals" project. As you know our current power supply mix includes both renewables and fossil fuels, and our forward resource strategy, called EnergyForward will deliver a balanced mix of 1/3 coal, 1/3 natural gas and 1/3 renewables over the long term. We fundamentally believe having reliable thermal plants powered by natural gas, biomass and coal are critical to our overall ability to deliver affordable, reliable and increasingly clean energy for our customers.

As we prepare to comply with the U.S. Environmental Protection Agency (EPA) Mercury and Air Toxic Standard (MATS), Minnesota Power will be required to increase sampling, measurement, and monitoring activities to show compliance with regulatory reductions of hazardous air pollutant (HAP) metal and halogen (HCl) emissions. EPA reference methods are complicated, often use hazardous chemicals, and are relatively expensive to use. A simpler and lower cost option, as proposed by this project, offers the opportunity to reduce compliance costs, should the MEST method be accepted as an alternative method by EPA. Our customers demand that we work to keep our costs as low as possible. Your work in developing a scientifically sound and economically superior method to demonstrate environmental stewardship and confidence of air quality matters with our state and federal regulators is critical to our industry, and our company.

Minnesota considers the project to be of great value to the industry and is willing to commit $25,000 towards supporting the project and its outcomes of lower cost EPA approved measurement methods. We hope that the North Dakota Industrial Commission and other funding agencies give careful consideration to fund this project, as there is a significant need for simpler, lower cost compliance methods. Again, we express our support and look forward to working with the EERC on this project.

Sincerely,

OTTER TAIL POWER COMPANY

March 27, 2014

Mr. John Pavlish
Director of Center for Air Toxic Metals
Energy & Environmental
Research Center 15 North 23rd
Street
Grand Forks, ND 58202

Dear Mr. Pavlish:

Subject: EERC Proposed Project Entitled "Validation of the Multielement Sorbent Trap (MEST) Method for Measurement of HCl and Metals"

As Manager of Environmental Services for Otter Tail Power Company (Otter Tail), I am pleased to submit this letter of support and interest to participate in the "Validation of the Multielement Sorbent Trap (MEST) Method for Measurement of HCl and Metals" project. To comply with the U.S. Environmental Protection Agency (EPA) Mercury and Air Toxic Standards (MATS), Otter Tail will be required to significantly increase sampling, measurement, and monitoring activities to show compliance with regulatory reductions of hazardous air pollutant (HAP) metal and halogen (HCl) emissions. EPA reference methods are complicated, often use hazardous chemicals, and are relatively expensive to use. A simpler and lower cost option, as proposed by this project, offers the opportunity to reduce compliance costs, should the MEST method be accepted as an alternative method by EPA.

Otter Tail considers the project to be of great value to the industry and is willing to commit $15k ($7,500 in 2014 and $7,500 in 2015) towards supporting the project. We hope that the North Dakota Industrial Commission and other funding agencies give careful consideration to this project, as there is a significant need for simpler, lower cost compliance methods. Again, we express our support and look forward to working with the EERC on this project.

Sincerely,

Mark Thoma

Mark Thoma
Manager of Environmental Services

EERC®
Energy & Environmental Research Center
UNIVERSITY OF NORTH DAKOTA
15 North 23rd Street — Stop 9018 / Grand Forks, ND 58202-9018 / Phone: (701) 777-5000 Fax: 777-5181
Web Site: www.undeerc.org

March 31, 2014

North Dakota Industrial Commission
ATTN: Lignite Research Program
State Capitol – 14th Floor
600 East Boulevard Avenue, Department 405
Bismarck, ND 58505-0840

Dear NDIC:

Subject: CATM® Affiliate Funding Commitment for Project Entitled "Validation of the Multielement Sorbent Trap (MEST) Method for Measurement of HCl and Metals"

As Director of the Center for Air Toxic Metals® (CATM®) Program, I am pleased to commit $60,000 of funding from the CATM Affiliates Program toward the project named above, provided that the North Dakota Industrial Commission pledges funding for this project.

The CATM Affiliates Program, comprising industrial partners, has a history of funding research projects that involve air toxins, in particular trace metals. The project that is being funded has the potential to provide utilities and other stakeholders with a measurement technique that is an easier, faster, less costly, and a more flexible method that does not involve the use of caustic acids and base liquids in the field. Based on the intense interest in the development of this project, it is clearly in line with the most current needs of industry. The members representing the CATM Affiliates Program are very interested to participate in further evaluation and validation of the multielement sorbent trap method.

I am hopeful that the North Dakota Industrial Commission views this proposal favorably and look forward to supporting and participating in this project. If you have any questions, please feel free to contact me by phone at (701) 777-5268, by fax at (701) 777-5181, or by e-mail at jpavlish@undeerc.org.

Sincerely,

John H. Pavlish
Senior Research Advisor

JHP/bjr

E-mail of support from Great River Energy

-----Original Message-----
From: Archer, Gregory GRE-MG [mailto:garcher@GREnergy.com]
Sent: Tuesday, April 01, 2014 2:09 PM
To: Pavlish, John H.
Subject: MEST

John,

As you are well aware, Great River Energy (GRE) has supported the development of the Multielement Sorbent Trap by providing funds and by acting as a host test site. This alternative has proven to be viable, cost effective option for acid gas testing. While GRE is not in a position to provides funds at this time, GRE is very supportive of the project to validate the Multielement Sorbent Trap (MEST) Method. Given our interest, we encourage NDIC to fund the project as we believe it will provide a great value to ND industry, once accepted by EPA.

Greg Archer
Environmental Administrator
Great River Energy

MONTANA-DAKOTA
UTILITIES CO.
A Division of MDU Resources Group, Inc.

400 North Fourth Street
Bismarck, ND 58501
(701) 222-7900

April 2, 2014

John Pavlish
Director of Center for Air Toxic Metals
Energy & Environmental Research Center
University of North Dakota
15 North 23rd Street
Grand Forks, ND 58202-9018

RE: Funding Support for the Validation of the Multielement Sorbent Trap (ME-ST) Method for Measurement of HCl and Metals

Dear Mr. Pavlish:

Montana Dakota Utilities Co. (Montana-Dakota) is very interested in the Multielement Sorbent Trap (ME-ST) methodology and has supported the development and testing of it by providing funds and by acting as a host test site at Lewis & Clark Station located in Sidney, MT. Based on this experience, we believe the ME-ST has proven to be a viable, cost effective option and alternative for sampling Hydrogen Chloride (HCl), as required under the Mercury and Air Toxic Standards (MATS). A cost effective option is especially important for those units who are planning on performing quarterly stack testing to demonstrate compliance with the MATS emission standards. While Montana-Dakota is not in a position to provide funds at this time, Montana-Dakota is very supportive of the project to validate the ME-ST method. Given our interest, we encourage NDIC to fund the project as we believe it will provide a great value to North Dakota's industry, once accepted by U.S. Environmental Protection Agency (USEPA).

Please contact me at 701-222-7948, or Jon Madison at 701-222-7835, if you require additional information.

Sincerely,

Alan Welte
Director of Generation

CC: Abbie Krebsbach, Environmental Director
Jon Madison, Environmental Scientist

March 26, 2014

Mr. John Pavlish
Director of Center for Air Toxic Metals
Energy & Environmental Research
Center 15 North 23rd Street
Grand Forks, ND 58202

Dear Mr. Pavlish:

Subject: EERC Proposed Project Entitled "Validation of the Multi-element Sorbent Trap (MEST) Method for Measurement of HCl and Metals"

As a consultant to the National Rural Electricity Cooperative Association (NRECA) in the Generation, Environment, and Fuels area for a decade now, I am pleased to submit this letter of support and interest to participate in the "Validation of the Multi-element Sorbent Trap (MEST) Method for Measurement of HCl and Metals" project. To comply with the U.S. Environmental Protection Agency (EPA) Mercury and Air Toxic Standard (MATS), member utilities will be required to increase sampling, measurement, and monitoring activities to show compliance with regulatory reductions of hazardous air pollutant (HAP) metal and halogen (like HCl) emissions. EPA reference methods are complicated, often use hazardous chemicals, and are relatively expensive to use. A simpler and lower cost option, as proposed by this project, offers the opportunity to reduce compliance costs, should the MEST method be accepted as an alternative method by EPA.

NRECA considers the project to be of great value to the industry and its members and is very supportive of the project. We hope that the North Dakota Industrial Commission and other funding agencies gives careful consideration to this project, as there is a significant need for simpler, lower cost compliance methods. Again, we express our support and look forward to working with the EERC on this project.

Sincerely,

Dale t. Bradshaw

Dale Bradshaw
Consultant to
NRECA
Generation, Environment, and Environment
area Dale.bradshaw@nreca.coop

APPENDIX D

RESUMES OF KEY PERSONNEL

JOHN H. PAVLISH
Senior Research Advisor
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, North Dakota 58202-9018 USA
Phone: (701) 777-5268, Fax: (701) 777-5181, E-Mail: jpavlish@undeerc.org

Principal Areas of Expertise
Mr. Pavlish is a Senior Research Advisor and the Director of the multiyear, multimillion dollar Center for Air Toxic Metals® (CATM®) Program at the EERC. He has over 28 years of experience with advanced and conventional combustion systems to solve operational and environmental problems. His principal areas of interest and expertise include air toxic issues; hazardous air pollutants (HAPs) with special emphasis on mercury; CO_2 capture; and coal combustion process and power plant system performance, including economic and feasibility analyses.

Qualifications
B.S., Mechanical Engineering, North Dakota State University, 1984.
A.A.S., Power and Machinery, University of Minnesota – Crookston, 1979.
P.E., Kansas.

Professional Experience
2000–Present: Senior Research Advisor/CATM Director, EERC, UND. Mr. Pavlish's responsibilities include developing and managing an array of projects involving air toxic metals (mercury), fuel impacts on energy conversion systems, emission control technologies for power plant applications, biomass utilization, fuel cell applications, and technical and economic evaluations of various advanced emission control and energy conversion systems.

1994–2003: Senior Research Manager, EERC, UND. Mr. Pavlish's responsibilities included managing research programs related to emissions and control of air toxic substances. In an advisory role, Mr. Pavlish provided direction, vision, and technical review of future research programs. His responsibilities also included supervising research on the effects of fuel quality on combustion and gasification system performance; laboratory, pilot, and field testing; planning and performing specific research projects; evaluating the effects of coal quality and ash on power plant performance, generation recovery, steam generator performance and reliability, formation of HAPs, assessment of various control technologies, and flue gas-processing equipment; creating, developing, maintaining, testing, and validating innovative computer programs; identifying research opportunities and writing proposals and reports to meet client needs; and managing budgets and personnel on multiple projects.

1993–1994: Research Manager, Fuels and Materials Science, EERC, UND. Mr. Pavlish's responsibilities included supervising research on the effects of coal quality on coal combustion and gasification system performance; laboratory, pilot, and field testing; planning and performing specific research projects; evaluating the effects of coal quality and ash on power plant performance, generation recovery, steam generator performance and reliability, formation of HAPs, assessment of various control technologies, and flue gas-processing equipment; creating, developing, maintaining, testing, and validating innovative computer programs; identifying research opportunities and writing proposals and reports to meet client needs; and managing budgets and personnel on multiple projects.

1984–1993: Unit Leader/Systems Engineer, Black & Veatch Engineers–Architects. Mr. Pavlish's responsibilities included providing engineering/technical advice; determining and managing resources; developing and monitoring budgets; developing, overseeing, and maintaining project schedules; conducting formal/informal presentations to clients and at technical conferences; writing the technical scope of work, preparing cost estimates, and providing the supervision and organization of the proposal effort; assisting in the preparation and presentation of appropriate marketing material; planning, performing, and coordinating numerous coal quality impact studies; and creating, developing, maintaining, teaching, and validating innovative computer-based programs for evaluating the impacts that coal/ash constituents have on the combustion process, power plant equipment, overall plant performance, and unit/plant/system generation costs.

1979–1981: Diesel Power Technician, Crookston Implement, Inc., Crookston, Minnesota.

Professional Memberships

U.S. Representative, Mercury Emissions from Coal International Experts Working Group on Reducing Emissions from Coal, in association with the International Energy Agency Clean Coal Centre, 2004–present

United Nations Environment Programme Global Mercury Partnership, Reduction of Mercury Releases from Coal Combustion

Advisory Member, BiNational Strategy Utility Mercury Reduction Committee

Advisory Member, Minnesota Pollution Control Agency Research Advisory Committee

Advisory Member, Minnesota Taconite Mercury Control Advisory Committee

Advisory Member, Advanced Emissions Control Development Program

American Society of Mechanical Engineers

Air & Waste Management Association

Patents, Publications, and Presentations

Has authored and coauthored over 200 publications and presentations and holds several patents.

GRANT E. DUNHAM
Research Manager
Energy & Environmental Research Center (EERC), University of North Dakota (UND)
15 North 23rd Street, Stop 9018, Grand Forks, North Dakota 58202-9018 USA
Phone: (701) 777-5034, Fax: (701) 777-5181, E-Mail: gdunham@undeerc.org

Principal Areas of Expertise
Mr. Dunham's principal areas of interest and expertise include bench- and pilot-scale testing of sorbents for mercury control, including equipment design and procurement, data analysis, interpretation, and reporting; codevelopment of a pretreatment system for mercury continuous emissions monitors that removes moisture and acid gases from a sample stream and allows for speciation of mercury in the gas stream—this pretreatment system has been successfully demonstrated at the bench, pilot, and full scales; evaluation of different technologies for particulate control, including hot-gas filtration; catalytic fabrics for simultaneous removal of particulate and NO_x; high-efficiency fabric and ceramic filters; and modeling of particulate reentrainment.

Qualifications
M.S., Mechanical Engineering, University of North Dakota, 1991.
B.S., Mechanical Engineering, University of North Dakota, 1985.

Professional Experience
1992–Present: Research Manager, Gas Cleanup, EERC, UND. Mr. Dunham's responsibilities include leading bench- and pilot-scale test projects for evaluating simultaneous NO_x and particulate control, mercury control, and particulate sampling. Other responsibilities include equipment design and procurement; data analysis, interpretation, and reporting; and modeling of particle reentrainment. Mr. Dunham prepares technical reports and papers for presentation. He also modeled formation of N_2O in fluidized-bed combustion of coal.

1991–1992: Research Specialist, Environmental Systems, EERC, UND.

1990: Mechanical Engineer, Engineering Experiment Station, UND.

1990: Instructor, Mechanical Engineering, UND.

1989–1991: Graduate Teaching Assistant, UND.

1988–1989: Graduate Student, Arizona State University, Tempe, Arizona, and UND.

1986–1988: Energy Conservation Engineering, Naval Air Engineering Center, Lakehurst, New Jersey.

1985–1986: Research Assistant, Engineering Experiment Station, UND.

Publications and Presentations
Has coauthored numerous publications.

Energy & Environmental Research Center

APPENDIX E

BUDGET AND BUDGET NOTES

VALIDATION OF THE MULTIELEMENT SORBENT TRAP (MEST)
METHOD FOR MEASUREMENT OF HCI AND METALS
NDIC
PROPOSED PROJECT START DATE: 7/1/14
EERC PROPOSAL #2014-0147

BUDGET

CATEGORY	ICCI SHARE	INDUSTRY SHARE	NDIC SHARE	PROJECT TOTAL
Labor	$ 194,985	$ 306,988	$ 132,237	$ 634,210
Travel	$ 5,002	$ -	$ 7,417	$ 12,419
Supplies	$ -	$ 36,194	$ 21,803	$ 57,997
Other*	$ 13	$ 202	$ 551	$ 766
Laboratory Fees & Services				
Fuels & Materials Research Lab	$ -	$ 3,470	$ -	$ 3,470
Analytical Research Lab	$ -	$ 10,771	$ 6,971	$ 17,742
Combustion Test Service	$ -	$ 22,803	$ 34,320	$ 57,123
Particulate Analysis Lab	$ -	$ 10,899	$ 38,417	$ 49,316
Fuel Preparation Service	$ -	$ 10,354	$ -	$ 10,354
Graphics Service	$ -	$ 1,165	$ 3,284	$ 4,449
Shop & Operations Fee	$ -	$ 12,154	$ -	$ 12,154
Total Project Costs – U.S. Dollars	$ 200,000	$ 415,000	$ 245,000	$ 860,000

Labor Categories	**Labor Hours**			
	ICCI	**Industry**	**NDIC**	**Total**
Research Scientists/Engineers	710	1,118	632	2,460
Research Technicians	83	218	27	328
Mechanics/Operators	468	442	-	910
Senior Management	30	57	43	130
Technical Support Services	39	58	152	249
	23.3%	48.3%	28.5%	100.0%

*May include costs such as food, printing, communications, or other miscellaneous expenses.

BUDGET JUSTIFICATION

ENERGY & ENVIRONMENTAL RESEARCH CENTER (EERC)

BACKGROUND

The EERC is an independently organized multidisciplinary research center within the University of North Dakota (UND). The EERC is funded through federal and nonfederal grants, contracts, and other agreements. Although the EERC is not affiliated with any one academic department, university faculty may participate in a project, depending on the scope of work and expertise required to perform the project.

INTELLECTUAL PROPERTY

The applicable federal intellectual property (IP) regulations will govern any resulting research agreement(s). In the event that IP with the potential to generate revenue to which the EERC is entitled is developed under this project, such IP, including rights, title, interest, and obligations, may be transferred to the EERC Foundation, a separate legal entity.

BUDGET INFORMATION

The proposed work will be done on a cost-reimbursable basis. The distribution of costs between budget categories (labor, travel, supplies, equipment, etc.) and among funding sources of the same scope of work is for planning purposes only. The project manager may incur and allocate allowable project costs among the funding sources for this scope of work in accordance with Office of Management and Budget (OMB) Circular A-21.

Escalation of labor and EERC recharge center rates is incorporated into the budget when a project's duration extends beyond the university's current fiscal year (July 1 – June 30). Escalation is calculated by prorating an average annual increase over the anticipated life of the project.

The cost of this project is based on a specific start date indicated at the top of the EERC budget. Any delay in the start of this project may result in a budget increase. Budget category descriptions presented below are for informational purposes; some categories may not appear in the budget.

Salaries: Salary estimates are based on the scope of work and prior experience on projects of similar scope. The labor rate used for specifically identified personnel is the current hourly rate for that individual. The labor category rate is the average rate of a personnel group with similar job descriptions. Salary costs incurred are based on direct hourly effort on the project. Faculty who work on this project may be paid an amount over the normal base salary, creating an overload which is subject to limitation in accordance with university policy. As noted in the UND EERC Cost Accounting Standards Board Disclosure Statement, administrative salary and support costs which can be specifically identified to the project are direct-charged and not charged as facilities and administrative (F&A) costs. Costs for general support services such as contracts and IP, accounting, human resources, procurement, and clerical support of these functions are charged as F&A costs.

Fringe Benefits: Fringe benefits consist of two components which are budgeted as a percentage of direct labor. The first component is a fixed percentage approved annually by the UND cognizant audit agency, the Department of Health and Human Services. This portion of the rate covers vacation, holiday, and sick leave (VSL) and is applied to direct labor for permanent staff eligible for VSL benefits. Only the actual approved rate will be charged to the project. The second component is estimated on the basis of historical data and is charged as actual expenses for items such as health, life, and unemployment insurance; social security; worker's compensation; and UND retirement contributions.

Travel: Travel may include site visits, fieldwork, meetings, and conferences. Travel costs are estimated and paid in accordance with OMB Circular A-21, Section 53, and UND travel policies, which can be found at http://und.edu/finance-operations (Policies & Procedures, A–Z Policy Index, Travel). Daily meal rates are based on U.S. General Services Administration (GSA) rates unless further limited by UND travel policies; other estimates such as airfare, lodging, etc., are based on historical costs. Miscellaneous travel costs may include taxis, parking fees, Internet charges, long-distance phone, copies, faxes, shipping, and postage.

Equipment: If equipment (value of $5000 or more) is budgeted, it is discussed in the text of the proposal and/or identified more specifically in the accompanying budget detail.

Supplies: Supplies include items and materials that are necessary for the research project and can be directly identified to the project. Supply and material estimates are based on prior experience with similar projects. Examples of supply items are chemicals, gases, glassware, nuts, bolts, piping, data storage, paper, memory, software, toner cartridges, maps, sample containers, minor equipment (value less than $5000), signage, safety items, subscriptions, books, and reference materials. General purpose office supplies (pencils, pens, paper clips, staples, Post-it notes, etc.) are included in the F&A cost.

Subcontracts: Not applicable.

Professional Fees: Not applicable.

Communications: Telephone, cell phone, and fax line charges are included in the F&A cost; however, direct project costs may include line charges at remote locations, long-distance telephone charges, postage, and other data or document transportation costs that can be directly identified to a project. Estimated costs are based on prior experience with similar projects.

Printing and Duplicating: Page rates are established annually by the university's duplicating center. Printing and duplicating costs are allocated to the appropriate funding source. Estimated costs are based on prior experience with similar projects.

Food: Expenditures for project partner meetings where the primary purpose is dissemination of technical information may include the cost of food. The project will not be charged for any costs exceeding the applicable GSA meal rate. EERC employees in attendance will not receive per diem reimbursement for meals that are paid by project funds. The estimated cost is based on the number and location of project partner meetings.

Professional Development: Fees are for memberships in technical areas directly related to work on this project. Technical journals and newsletters received as a result of a membership are used throughout the development and execution of the project by the research team.

Operating Fees: Operating fees generally include EERC recharge centers, outside laboratories, and freight.

EERC recharge center rates are established annually.

Laboratory and analytical recharge fees are charged on a per-sample, hourly, or daily rate. Additionally, laboratory analyses may be performed outside the university when necessary. The estimated cost is based on the test protocol required for the scope of work.

Graphics recharge fees are based on an hourly rate for production of such items as report figures, posters, and/or images for presentations, maps, schematics, Web site design, brochures, and photographs. The estimated cost is based on prior experience with similar projects.

Shop and operation recharge fees are for expenses directly associated with the operation of the pilot plant, including safety training, personal safety items (protective eyeglasses, boots, gloves), and annual physicals for pilot plant personnel. The estimated cost is based on the estimated hours for pilot plant personnel.

Freight expenditures generally occur for outgoing items and field sample shipments.

Facilities and Administrative Cost: The F&A rate proposed herein is approved by the U.S. Department of Health and Human Services and is applied to modified total direct costs (MTDC). MTDC is defined as total direct costs less individual capital expenditures, such as equipment or software costing $5000 or more with a useful life of greater than 1 year, as well as subawards in excess of the first $25,000 for each award.