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

June 1, 2011

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

Dear Ms. Fine:

Subject: EERC Proposal No. 2011-0253 Entitled "Demonstration of Gas-Powered Drilling Operations for Economically Challenged Wellhead Gas and Evaluation of Complementary Platforms" in Response to the North Dakota Industrial Commission Oil and Gas Research Program Solicitation

The Energy & Environmental Research Center (EERC) is pleased to propose a research program designed to encourage and promote the use of new technologies that have a positive economic and environmental impact on oil and gas exploration and production in North Dakota. A qualified team has been assembled to demonstrate the fueling of drilling operations with wellhead gas and to consider additional markets. The team includes a leading Williston Basin operator, drilling contractor, compressed natural gas company, qualified engineers, and technology supply companies.

Enclosed please find an original and one copy of the subject proposal along with a check for $100. The EERC, a research organization within the University of North Dakota, an institution of higher education within the state of North Dakota, is not a taxable entity; therefore, it has no tax liability.

This transmittal letter represents a binding commitment by the EERC to complete the project described in this proposal. If you have any questions, please contact me by telephone at (701) 777-5157, by fax at (701) 777-5181, or by e-mail at jharju@undeerc.org.

Sincerely,

John A. Harju
Associate Director for Research

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

JAH/hmv

Enclosures

Oil and Gas Research Program

North Dakota

Industrial Commission

Application

Project Title: Demonstration of Gas-Powered Drilling Operations for Economically Challenged Wellhead Gas and Evaluation of Complementary Platforms

Applicant: Energy & Environmental Research Center

Principal Investigator: Darren D. Schmidt

Date of Application: June 1, 2011

Amount of Request: $750,000

Total Amount of Proposed Project: $1,900,000

Duration of Project: 12 months

Point of Contact (POC): Darren D. Schmidt

POC Telephone: (701) 777-5120

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ABSTRACT

Objective:

This project is designed to explore and demonstrate utilization of wellhead gas in North Dakota where circumstances temporarily preclude gas gathering and to seek new strategies to utilize Bakken Formation associated gas. The proposed work will 1) demonstrate a safe and robust method for powering drilling rigs with gaseous fuels, including the procurement and delivery of compressed natural gas (CNG) and 2) investigate the technical and economic viability of end-use technologies that utilize associated gas.

Expected Results:

1. A demonstration of bi-fuel-powered drilling operations using pipeline-quality natural gas.
2. Research to identify performance limits of Bakken Formation gas in bi-fuel (definition of bi-fuel in Appendix A) technology and appropriate safeguard strategies.
3. A demonstration of bi-fuel-powered drilling operations using Bakken Formation gas.
4. Published study results that highlight potentially viable end-use technologies that utilize Bakken Formation associated gas.

Duration: 12 months

Total Project Cost: $1,900,000; **$750,000** requested from the North Dakota Industrial Commission (NDIC) Oil and Gas Research Council; $400,000 provided from the U.S. Department of Energy–Energy & Environmental Research Center Jointly Sponsored Research Program; $750,000 cost share provided from Continental Resources.

Participants:

The project participants include Continental Resources, the Energy & Environmental Research Center, Bakken Express, the National Energy Technology Laboratory of the U.S. Department of Energy, North Dakota Industrial Commission, and GTI. Letters of support can be found in Appendix B.

PROJECT DESCRIPTION

Objectives

The mission of the Oil and Gas Research Council (OGRC) is to promote the growth of the oil and gas industry through research and education. The proposed project will explore, identify, and demonstrate technologies for utilizing wellhead gas. The results are intended to encourage and promote the use of new technologies that have a positive economic and environmental impact on oil and gas exploration. Results will provide producers with a technical evaluation of gas-fired bi-fuel (firing of natural gas and diesel fuel simultaneously in a diesel engine) diesel power for drilling operations, a demonstration of compressed natural gas (CNG) transport and delivery, and expanded markets for Bakken Formation associated gas. Project-specific objectives are as follows:

1. Where technically appropriate and economically compelling, encourage the application of CNG and utilization of associated gas that will create jobs in the production and utilization of North Dakota's oil and gas resources.
2. Seek growth and opportunity in the oil and gas industry by demonstrating the economic delivery of CNG and its utilization in drilling operations.
3. Promote public awareness that North Dakota's oil and gas industry is actively involved in moving gas to market (associated with oil production); and that the practices minimize flaring in an economic and environmentally sound manner.

Methodology

The effort is designed to address unique aspects of the rapidly developing Bakken Formation play. A detailed work plan is provided in Appendix C. The project results will encourage the utilization of Bakken Formation wellhead gas in drilling operations and enable producers to realize economic and environmental benefits. Additionally, the project seeks to identify viable end-use technologies that utilize gas associated with oil production from the Bakken Formation. Specific activities include:

Activity 1 – Lean-Gas Demonstration. Demonstrate collection, transportation, and fueling of a diesel engine power system for a drilling operation using pipeline or "lean" gas.

Activity 2 – Bakken Gas Research. Conduct characterization, analysis, and test-firing of a simulated Bakken Formation gas in a diesel engine generator fitted with a bi-fuel system.

Activity 3 – Rich-Gas Demonstration. Demonstrate the powering of a drilling operation utilizing delivery of compressed Bakken Formation associated gas.

Activity 4 – End-Use Technology Study. Complete a study focused on viable end uses for associated gas from the Bakken Formation.

The driver for the proposed methodology is to identify the most compelling utilization strategies for associated gas with the highest likelihood of commercial practice. A number of factors have guided the project team to develop a quality methodology.

- The economics for gas utilization in drilling rigs is compelling. Encana and its drilling contractor, Ensyn, have been the first to publish experience using pipeline natural gas and bi-fuel technology in drilling operations (Hill and others, 2011). Depending on project logistics, capital costs range from $300,000–$600,000, and savings can range from $3200–$9600/day creating paybacks in the range of 1–6 months.
- Utilization of CNG resolves problems surrounding temporary routing of energy to the drilling location and logistically augments current diesel fuel delivery practices. During the development of this proposal, consideration was given for generating power at the source of the gas and running electrical lines to the drilling location; however, these presented logistical and safety concerns. The proposed details regarding CNG delivery logistics are provided in Appendix D.
- Associated gas produced from the Bakken Formation is rich in natural gas liquids (NGLs), including hydrocarbons from light to heavy, such as ethane to heptane. Hydrocarbon vapors other than methane can have a propensity to knock (issues associated with knock provided in Appendix E) in

piston engines. The project is, therefore, staged to incrementally demonstrate gas utilization in drilling operations specific to North Dakota. While acquiring equipment and demonstrating drilling rig operation with pipeline-quality gas, the project team will test-fire Bakken Formation gas in a bi-fuel diesel engine. The test will develop and demonstrate appropriate safeguards and translate the practices for a full-scale demonstration of Bakken Formation gas in a subsequent drilling operation.

- Additional markets beyond using associated gas in drilling operations are desired. Although drilling activity can be an end use that tends to coincide with gas flaring, because of location, some wells may remain uneconomic for gas gathering. Seeking attractive end-use technologies is desired and could be a promising opportunity, given the high NGL concentration in Bakken Formation gas.

Anticipated Results:

The results are intended to encourage and promote the use of new technologies that have a positive economic and environmental impact on oil and gas exploration. Results will provide producers with a technical evaluation of gas-fired bi-fuel diesel power for drilling operations, demonstrate CNG transport and delivery, and enable consideration of expanded markets for Bakken Formation associated gas.

1. Utilization of associated gas to power drilling operations by using dual fuel or bi-fuel technology is expected to produce a cost differential relative to diesel fuel in the range of $3200–$9600/day and a payback in the range of 1 to 6 months.
2. Although a significantly larger number of fuel deliveries are required for CNG relative to diesel fuel, procurement of wellhead gas close to the drilling location may demonstrate an equal or modest increase in total road miles.
3. Promote public awareness that the North Dakota oil and gas industry is actively involved in moving gas to market (associated with oil production) and that the practices minimize flaring in an economic and environmentally sound manner.

4. Publish the first data for firing a mix of NGLs from Bakken Formation gas in a diesel engine equipped with bi-fuel technology, and characterize the performance characteristics relative to knock, emissions, and fuel usage. Details regarding engine emissions are provided in Appendix F.
5. Publish study results that highlight potentially viable end-use technologies that utilize Bakken Formation associated gas.

Facilities:

The drilling locations will be identified by Continental Resources. Based on location, Bakken Express will identify where to install the gas compression skid and attendant delivery. Mobile laboratory equipment owned by the Energy & Environmental Research Center (EERC) will be used in the field at the chosen North Dakota locations and at the GTI test facility in Ohio**.**

Resources:

The project team includes personnel from the EERC, Continental Resources, Bakken Express, and other industry consultants. Non-NDIC OGRC cost share for the project will be provided by Continental Resources and the U.S. Department of Energy (DOE) through the EERC's Jointly Sponsored Research Program. The project team will work closely with the OGRC through project meetings and quarterly reporting to ensure project quality. Project outreach will result in a number of conference presentations and publications including the Society of Petroleum Engineers (SPE), public reporting to DOE, and the contractual reporting obligations of the OGRC. The project team has demonstrated experience and history managing both commercial and research projects. Resumes are included in Appendix G.

Techniques to Be Used, Their Availability and Capability:

The success of this project requires the procurement and installation of equipment, the generation of performance data, and quality assurance from experienced personnel. Bakken Express is currently engaged in arranging compression, transport, and delivery from Bakken Formation wells to the pipeline starting in July of 2011. Continental Resources is actively drilling at least 22 wells and continues to

increase activity. Cyclone Drilling, based in Gillette, Wyoming, is Continental's primary contractor, including 13 rigs in North Dakota, which represents 40% of Cyclone's fleet. Caterpillar engines are used in 90% of Cyclone's fleet in North Dakota. Other drillers working for Continental include Paramount, Patterson, Precision, and Trinidad. Patterson and Precision each have more than 10 rigs drilling in North Dakota. The lean-gas demonstration will occur 4 months after the project start and allow time for Continental and the drilling contractor to prepare and select the location. Data acquisition, instrumentation, and analysis will be conducted by the EERC with staff trained in emission measurement and power generation hardware. The EERC maintains a wide array of measurement equipment and sufficient technical staff.

Environmental and Economic Impacts while Project Is Under Way:

Potential environmental effects of engine operation with bi-fuel technology include a favorable decrease of NO_x and particulate matter (PM) exhaust emissions and an unfavorable increase in exhaust emissions of carbon monoxide and nonmethane hydrocarbons, which can be mitigated with a catalytic muffler. Other impacts include increased traffic of CNG to the project site. The contracting for delivery and hauling of CNG and the use of local contractors to transport and install equipment will contribute to job creation during the project. The project will result in immediate savings relative to fuel purchases for drilling rig operation and a highly favorable economic return on the cost of equipment modifications. Additionally, the project will help to jump start greater associated gas utilization, CNG market development, and reduction of emissions from gas flaring.

Ultimate Technological and Economic Impacts:

The project will facilitate and encourage development of an infrastructure in the state of North Dakota aimed at utilizing associated gas that is otherwise flared and will create additional economic incentives for gas gathering by identifying viable end-use technologies for the resource. The technological and economic impacts are as follows:

- Approximately 30,000 MMcf/yr (Figure 1) of currently flared Bakken Formation gas presents a total revenue of approximately $90 million a year, assuming a sale price of $3.00/Mcf.
- Cost savings to drilling operations for delivered CNG versus diesel is on the order of $3000–$9000 a day.
- Knowledge of NGL performance relative to bi-fuel technology is gained, leading to a better understanding of how to robustly apply the technology.

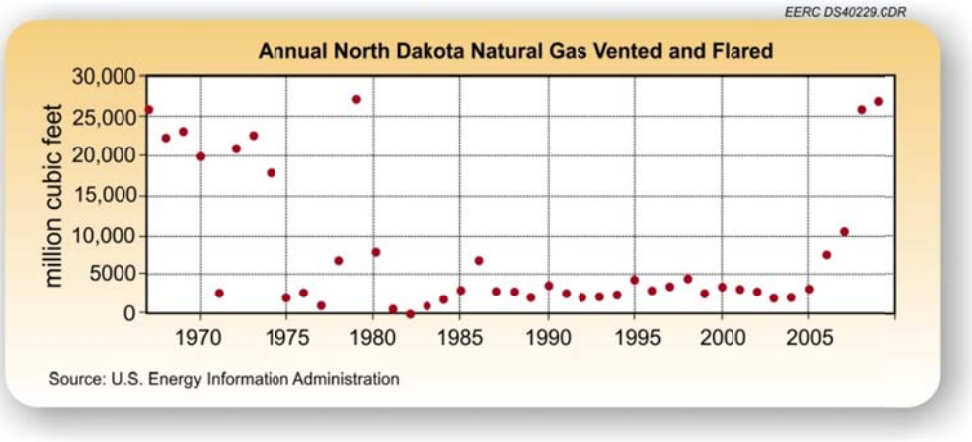


Figure 1. Flaring of associated gas in North Dakota (Energy Information Administration, 2011).

Why the Project Is Needed:

The project is intended to encourage and promote the use of new technologies that have a positive economic and environmental impact on oil and gas production. Demonstrating the use of gas-fired bi-fuel diesel power for drilling operations and CNG transport and delivery and identifying viable end-use technologies will help to utilize associated gas and decrease flaring.

Flaring is regulated by the Department of Mineral Resources to encourage economic application of gas gathering. After commissioning two new natural gas plants (Robinson Lake and Stanley) in 2008 and expanding the associated gas-gathering systems, Mountrail County was able to reduce its flaring 62% from December 2008 to December 2009 (Kringstad, 2010). During the same time period, oil production had continued to dramatically increase. Although the development of gas-processing facilities mitigates

flaring, the development of acreage in North Dakota that does not have gas-gathering infrastructure continues. As demonstrated in Figure 1, approximately 2500 MMcf/year or about 3% of gas production appears to be available on a consistent basis.

The reason for the near-term focus on drilling operations is the compelling economic case for increased associated gas utilization. However, the economics alone are not sufficient to fully engage the drilling community. Encana and its drilling contractor, Ensyn, have been the first to publish (Hill and others, 2011) their experience using pipeline natural gas and bi-fuel technology in drilling operations. Their experience has been largely driven by environmental constraints in Wyoming and a company "gas-only" emphasis. The associated gas from the Bakken Formation presents new challenges that increase the technical risks of utilization, namely the concentration of NGLs and their propensity to cause knock in engines. Drilling contracts pass fuel costs to the operating company and, therefore, have little incentive to garner cost savings, especially in an environment where work abounds; time is money; and known, proven procedures keep drilling contractors competitive by minimizing nonproductive time. Therefore, a public project with investment on behalf of the OGRC is necessary to help improve utilization and the environmental impact of new practices and technologies for oil and gas exploration and production.

References

Energy Information Administration. Natural Gas Production Data: accessed May 2011.

Hill, D., Johnson, J., Bell, J., Mayer, N., Giberson, H., Hessler, R., Matthews, W., 2011, Natural gas as a fuel in drilling operations–analysis, testing and implementation: SPE/IADC SPE-140357-PP.

Kringstad, J.J., 2010, An update on North Dakota's natural gas infrastructure: North Dakota Pipeline Authority; Industrial Commission of North Dakota, May 2010.

STANDARDS OF SUCCESS

Deliverables

1. Quarterly report highlighting results of "lean-gas" utilization and attendant cost savings.
2. Quarterly report highlighting results of "rich-gas" utilization and attendant cost savings.
3. Topical report identifying viable end-use technologies utilizing Bakken Formation associated gas.
4. Topical report outlining experimental outcomes for firing NGLs in a dual-fuel application.
5. Final report and publications at technical conferences.

Success Measures

The value to North Dakota is measured in the increased utilization of associated gas. Results will encourage the use of bi-fuel technology for drilling operations. Results will be readily accessible through EERC publications that are downloadable from the OGRC Web site. Technical publications peer-reviewed by organizations such as SPE will be targeted at the oil and gas industry to translate research findings to practice in the field.

BACKGROUND/QUALIFICATIONS

Resumes of key personnel are provided in Appendix G.

Energy & Environmental Research Center

The EERC is a high-tech, nonprofit branch of the University of North Dakota (UND), exclusively conducting contract research for a multinational client base. The EERC's oil and gas experience can be highlighted within the Center for Oil and Gas and the Plains CO_2 Reduction (PCOR) Partnership. The Center for Oil and Gas is a specialized technical group focusing on design and implementation of new approaches to the exploration, development, and production of oil and gas. Background data collection, design and implementation of pilot studies, full-scale demonstrations, and analysis of results are typical activities conducted in the Center for Oil and Gas.

The EERC is currently leading one of the world's largest programs dedicated to developing and demonstrating technologies to reduce CO_2 emissions to the atmosphere from large-scale sources. The EERC's PCOR Partnership is one of seven regional partnerships operating under the DOE National Energy Technology Laboratory Regional Carbon Sequestration Partnership Program. Since its inception, the PCOR Partnership's nearly 100 private and public sector members have provided data, guidance, financial resources, and practical experience with CCS. The PCOR Partnership region includes all or part of nine states and four Canadian provinces.

Continental Resources

Continental Resources is an independent oil and natural gas exploration and production company with the largest acreage positions in the Bakken Formation and Anadarko Woodford resource plays. Continental is the No. 2 oil producer in the Rocky Mountains and has maintained a crude oil-focused growth strategy since the late 1980s. The company is poised to triple in the next 5 years with strengths in production and reserves.

Bakken Express

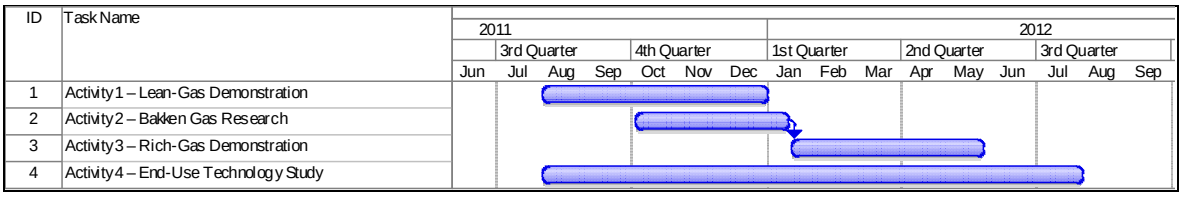
Bakken Express, LLC, provides a turn-key service to Williston Basin producers to capture, compress, and transport stranded Bakken Formation gas. The principal, Tim Maloney, has extensive experience in oil field engineering and operations in the United States and internationally with Chevron and Hess Corporation. His particular strengths include production operations, metering, fluid separation and processing, well completions, and field development. Maloney was Director of Operations for Hess from 2008 to 2010, supporting the company's Bakken Formation development.

MANAGEMENT

The EERC manages on the order of 300 contracts a year, with a total of more than 1100 clients in 51 countries and all 50 states. Best practices are provided to EERC project managers and clients with regard to fund accounting, budget reporting, contract milestone tracking, and contract services. The

deliverables of this proposal will be incorporated into a contract agreement ensuring timely accomplishment of milestones and fund management on a cost-reimbursable basis. The evaluation points are identified in the following project Gantt chart.

TIMETABLE (GANTT CHART)



BUDGET

Project Associated Expense	NDIC's Share	Continental's Share (In-Kind)	Federal Share (Cash)
Total Direct Salaries	$267,527		$85,686
Total Fringe	$141,724		$47,128
Total Labor	$409,251		$132,814
Travel	$17,650		$31,565
Equipment > $5000	–		$70,000
Supplies	$4,094		$13,410
Consultant – Engineering	$20,000		$35,000
Communication	$50		$400
Printing and Duplicating	$30		$195
Food	$550		–
Operating Fees and Services	$17,123		$6,615
Total Direct Costs	$468,748		$289,999
Total Indirect Costs (F&A)	$281,252		$110,001
Noncash Cost Share	–	$750,000	–
Total Project Cost	$750,000	$750,000	$400,000

A detailed budget is provided in Appendix H to justify project-associated expenses. The labor associated with the project budget is primary targeted at providing project management, in-house along with subcontracted engineering, and experimental and public outreach services throughout the period of performance. Equipment, as specified in the budget, includes a data acquisition system and instrumentation hardware comprising signal processing, computer hardware, data storage, communications interface, temperature sensors, pressure sensors, flow sensors, level indications, and emission sensors. The equipment will be used to acquire engine performance and emission data during

field demonstration and pilot testing. Equipment provided to the project on behalf of Continental includes the bi-fuel system, on-site gas handling equipment, and supporting supplies. If less funding is available than requested, a decrease in the scope of Activity 4 would be anticipated.

CONFIDENTIAL INFORMATION

None.

PATENTS/RIGHTS TO TECHNICAL DATA

None.

STATUS OF ONGOING PROJECTS (IF ANY)

G-015-030 "Plains CO_2 Reduction Partnership Program – Phase III"; OGRP funding $500,000; Total project cost $135,731,052. Status: Project ongoing. Phase III is a 10-year project running from October 1, 2007, to September 30, 2017. The activities for Phase III of the PCOR Partnership include two large-volume carbon dioxide (CO_2) storage demonstration tests. Regional characterization and outreach activities to support the demonstrations located in Fort Nelson, British Columbia, and Bell Creek, Montana, are under way.

G-018-036 "Bakken Water Opportunities Assessment"; OGRP funding $110,000; Total project cost $230,000; this project is part of the Northern Great Plains Water Consortium Program and is the investigation of the recycling of water flowback after Bakken fracture stimulation. Status: Project ongoing. A final report for Phase 1 was issued April of 2010, and Phase 2 activity is ongoing to test upgrading of water from a saline aquifer for potential fracturing fluid use in the Bakken.

"Investigation of Improved Conductivity and Proppant Applications in the Bakken Formation"; OGRP funding $150,000; Total project cost $332,432; Proposal selected for award; Application date October 29, 2010. Status: OGRC contract in process, cofunding under contract as of May 1, 2011.

APPENDIX A

BI-FUEL SYSTEMS

BI-FUEL SYSTEMS

Modification of the diesel engines on the drilling rig includes what is known as dual-fuel or bi-fuel technology. The terminology is used interchangeably and is intended to refer to the firing of diesel fuel and natural gas simultaneously in a diesel engine. The International Association for Natural Gas Vehicles defines the terms differently from the U.S. Environmental Protection Agency (EPA) and the California Air Resources Board (CARB). What is important to understand is that dual fuel (simultaneous firing) is marketed as a "bi-fuel" system in the United States because of the EPA and CARB definitions, which define a dual-fuel vehicle as having the option to fire only one fuel at a time.

The suppliers of dual-fuel systems in the United States include companies such as GTI-Altronics, Energetech LLC, Energy Conversions Inc., and Generac. GTI-Altronics is of particular interest because the product is commercially available from major Caterpillar dealers in Bismarck, Minot, Williston, and Dickinson, providing convenient service to the Williston Basin. Additionally, many rigs in North Dakota are powered with Caterpillar diesel engines.

A bi-fuel system operates by injecting natural gas into the air intake of the diesel engine. Combustion of the natural gas is initiated from the pilot ignition of diesel fuel injected in the combustion cylinder. A bi-fuel system has the ability to switch fuel modes without interruption in engine power output. The engine can be switched between diesel and gas automatically while maintaining speed and load. Controls also allow the engine to maintain power levels while operating in gas mode between the "continuous" and "prime" ratings of the engine. The engine can be automatically switched to 100% diesel mode during operations above the programmed power limit, thus avoiding the necessity to derate the engine. In drilling applications where the load varies substantially, a dynamic gas control (DGC) system provides for adjustment of the gas substitution rate according to a programmed map of fuel vs. load. This feature may prove vitally important relative to the natural gas liquids in Bakken Formation gas that have a knocking propensity. The various components of the bi-fuel system are

installed externally of the engine. No engine disassembly is required and no engine modifications are required for installation. All original equipment manufacturer (OEM) engine specifications for injection timing, valve timing, and compression ratio are expected to remain unchanged after installation. The bi-fuel system requires a low-pressure natural gas supply (approximately 2–3 psi) with a flow rate of approximately 8 scfh/kW. The control panel is Class 1 Division 2 Group D, suitable for environments where petroleum vapors may be present at less than 10 hours a year. A schematic of the GTI Bi-Fuel System is provided in Figure A-1. The DGC system monitors gas pressure, manifold pressure, temperatures, and engine vibration to control gas injection.

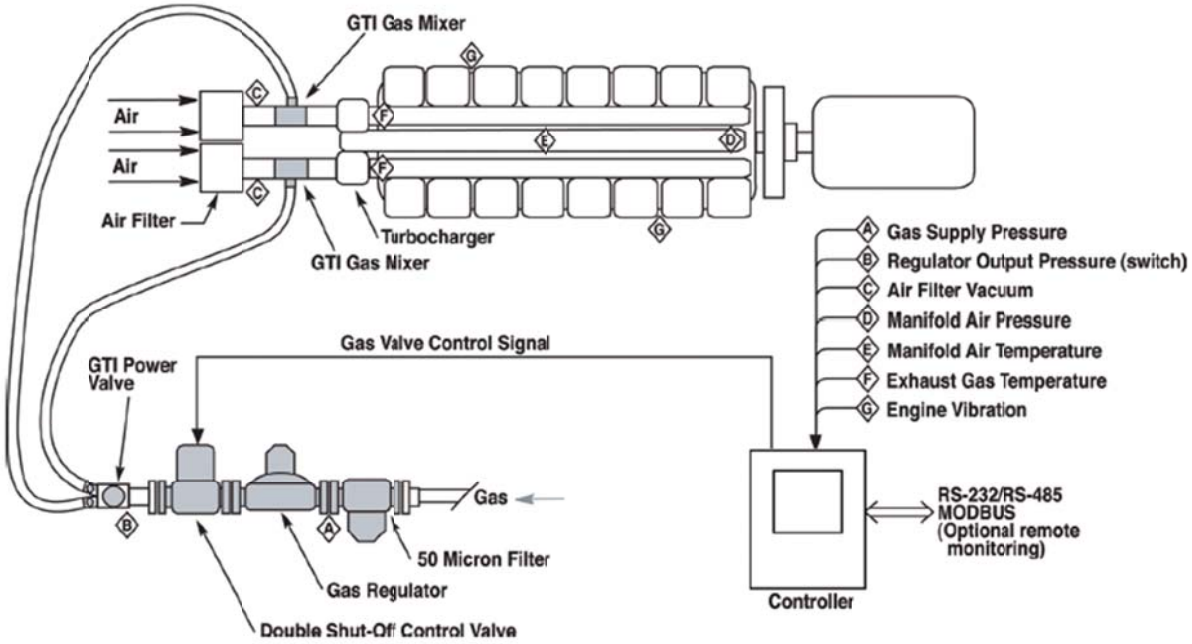


Figure A-1. GTI Bi-Fuel System schematic (www.gti-altronic.com)

APPENDIX B

LETTERS OF SUPPORT

Continental
RESOURCES

June 1, 2011

Mr. John A. Harju
Associate Director for Research
Energy & Environmental Research Center
15 North 23rd Street, Stop 9018
Grand Forks, ND 58202-9018

Dear John:

Continental Resources is pleased to provide this letter enumerating its support for the Energy & Environmental Research Center's (EERC's) proposed effort to utilize economically challenged natural gas resources within the state of North Dakota. Continental has a substantial presence in North Dakota, with 22 rigs currently operating. The company continues to implement the ECO-Pad® drilling concept in North Dakota, with several projects already completed and a significant number planned over the next 2 years. The concept provides for the efficient, economical, and environmentally sustainable development of the Bakken and Three Forks Formations by drilling multiple wells from a single location. Continuing in the spirit of the ECO-Pad® concept, Continental Resources is excited about the potential to work with the North Dakota Industrial Commission through the Oil and Gas Research Council (OGRC), the EERC, the U.S. Department of Energy (DOE), and Bakken Express to investigate gas-fired drilling operations. Continental, as part of the project team, will provide the investment in the associated hardware to complete a demonstration project that will enable the delivery of compressed natural gas to the location and attendant gas supply hardware. The expected value of the cost share to be provided to the project by Continental is $750,000 and will likely entail engine modifications to allow for dual-fuel (diesel–natural gas) usage, installation of necessary gas supply equipment, and the purchase of compressed natural gas.

Continental Resources will provide site access to research personnel for data collection and project monitoring. Coordination will be provided with the drilling operations to accommodate engine modification and allow access to operations data. The expectation is to first demonstrate diesel fuel replacement with "lean" natural gas over the course of one drilling project cycle and, subsequently, demonstrate "rich" Bakken associated gas utilization over the course of a second drilling project to clearly demonstrate the characteristics, economics, and performance of dual-fuel (gas–diesel)-fired drilling operations.

Continental Resources' commitment is, of course, contingent on the EERC's attainment of the necessary funding from OGRC, DOE and the negotiation of attendant agreements that are acceptable to all key parties. Please don't hesitate to contact me if you need further clarification or would like to discuss this effort further.

Sincerely,

Richard E. Muncrief
Senior Vice President, Operations
Continental Resources, Inc.

cc: Glenn Cox, Ryan Nelson, Shawn Svob

P.O. Box 1032 • 302 N. Independence • Enid, OK 73702
Voice (580) 233-8955 • Fax (580) 548-5232

Bakken Express, LLC
1521 Green Oak Place, Suite 197
Kingwood, TX 77339

June 1, 2011

Mr. Darren D. Schmidt, P.E., Senior Research Advisor
Energy & Environmental Research Center
University of North Dakota
15 North 23rd Street, Stop 9018
Grand Forks, ND 58202-9018

Dear Mr. Schmidt:

Bakken Express wishes to express support for the project titled "Demonstration of Gas Powered Drilling Operations for Economically Challenged Wellhead Gas and Evaluation of Complementary Platforms".

This project will provide valuable information with regards to the utilization of associated gas for wells that are not immediately connected to gas gathering. It will also demonstrate cost reductions in drilling operations of significant magnitude to warrant near term practice.

Bakken Express will actively participate in the project as a supplier of CNG and intends to seek similar opportunities in the Williston Basin.

Yours very truly,

James R. Paul

JRP/jh

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Web Site: www.undeerc.org

June 1, 2011

Ms. Karlene Fine
North Dakota Industrial Commission
State Capitol – Fourteenth Floor
600 East Boulevard Avenue, Dept. 405
Bismarck, ND 58505-0840

Dear Ms. Fine:

Subject: Cost Share for EERC Proposal No 2010-0253, Entitled "Demonstration of Gas-Powered Drilling Operations for Economically Challenged Wellhead Gas and Evaluation of Complementary Platforms"

The Energy & Environmental Research Center (EERC) is conducting complementary research and development efforts under a multimillion-dollar 5-year Cooperative Agreement with the U.S. Department of Energy (DOE) entitled "Joint Program on Research and Development for Fossil Energy-Related Resources." Through this joint program, nonfederal entities can team with the EERC and DOE in projects that address the goals and objectives of DOE's Office of Fossil Energy.

The proposed project to the North Dakota Industrial Commission Oil and Gas Research Council entitled "Demonstration of Gas-Powered Drilling Operations for Economically Challenged Wellhead Gas and Evaluation of Complementary Platforms" is a viable candidate for funding under this program. Therefore, the EERC intends to secure $400,000 of cash cost share for the proposed project through its Cooperative Agreement with DOE providing that NDIC commits $750,000 of cash cost share and Continental Resources provides $750,000 of in-kind contribution.

Once the EERC has commitment from all nonfederal partners to the project, the EERC will submit a proposal to DOE for its concurrence. 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 you have any questions, please contact me by phone at (701) 777-5153 or by e-mail at terickson@undeerc.org.

Sincerely,

Thomas A. Erickson
Associate Director for Business
and Operations

TAE/hmv

May 31, 2011

Mr. Darren D. Schmidt, P.E
Senior Research Advisor
University of North Dakota
15 North 23rd Street, Stop 9018
Grand Forks, ND 58202- 9018

RE: Research on Bi-Fuel Technology

Dear Mr. Schmidt:

Altronic-GTI is confident in the ability of our GTI Bi-fuel® products to provide economic and environmental benefits to the oil and gas industry in North Dakota. With over 2,200 bi-fuel systems sold worldwide, including approximately 100 bi-fuel systems sold to date for drillrig and hydraulic fracing applications in the United States, Canada, and China, Altronic-GTI already has a successful proven track record of the economical and environmental benefits of this technology in the oil and gas industry.

Through the proposed project with the Energy & Environmental Research Center, Altronic-GTI is pleased to collaborate and encourage technology for utilization of associated gas. The company's test facility in Girard, Ohio, equipped with a bi-fueled 500kW Caterpillar generator, has been used to prove our bi-fuel technology and is well suited to provide a platform in which to pilot-test gases rich in hydrocarbons as found in the Bakken formation. However, we are willing to work with EERC at the test site of your choice.

Sincerely,

Steven W. Roix
Sales Manager – GTI Bi-Fuel
steven.roix@hoerbiger.com

575 Mountain Ave.
Murray Hill, NJ 07974
908-464-8100
908-771-4803 (fax)
www.linde.com

May 27, 2011

Mr. Christopher N. Damiani
Research Engineer
Energy & Environmental Research Center
PO Box 9018
Grand Forks, ND 58202-9018

Subject: Project entitled "Demonstration of Gas-Fired Drilling Operations for Economically Challenged Wellhead Gas and Evaluation of Complementary Platforms"

Dear Chris:

This letter is in response to your prospectus and request for participation in the Energy & Environmental Research Center (EERC) demonstration and study entitled "Demonstration of Gas-Fired Drilling Operations for Economically Challenged Wellhead Gas and Evaluation of Complementary Platforms". Linde believes that this is an excellent program that will benefit the oil and gas industry in North Dakota as well as the technology and infrastructure providers. The study will generate critical information useful to equipment and technology providers by establishing operating and market conditions required to make distributed end use technologies for nontraditional natural gas commercially viable. This is certainly an area of interest to us and this program has many synergies with our interests in associated and nontraditional gas. We would, therefore, like to participate in the study in order to identify potential business opportunities for Linde.

Linde has strong technical and engineering capabilities in gas processing (separation, purification, compression, liquefaction and transport) and applications such as dispensing CNG or LNG for vehicle fueling. Linde recently built the largest landfill gas to LNG plant to supply LNG for Waste Management truck fleets, and we are working on additional similar projects. Linde also has relevant capabilities and interests in aspects of GTL and power generation using non-traditional sources of natural gas.

We understand that the EERC is pursuing funding for this project through the North Dakota Industrial Commission (NDIC) Oil & Gas Research Council and the U.S. Department of Energy. Linde LLC would be happy to support the proposed project by providing necessary technical and marketing input based on our expertise in this area. Linde LLC participation in the proposed study in the form of man-hours will be structured on a stage gate basis. As the opportunities and business cases are firmed up, we can consider proportionately increasing our contribution.

We look forward to the opportunity to participate in this program and to work with other partners who bring complementary skills to make this a successful venture. We wish you success in obtaining the necessary funding. Any questions regarding Linde LLC's involvement in the project may be directed to Dr. Satish Tamhankar.

Sincerely,

Dr. Krish Krishnamurthy
Head of Clean Energy
Technology Development
North America & CCS

APPENDIX C

DETAILED WORK PLAN

DETAILED WORK PLAN

Activity 1 – Lean-Gas Demonstration

Activity 1 includes the procurement of equipment, installation, and demonstration of compressed natural gas (CNG) delivery to a drilling location and the firing of pipeline-quality natural gas in a bi-fuel system used to power the drilling rig. The coordinating partners are Continental Resources, Bakken Express, and the Energy & Environmental Research Center (EERC). Continental Resources, as enumerated in the attached cost-share letter, will provide attendant equipment for the demonstration project in coordination with Bakken Express and the EERC. Equipment purchased for the "lean"-gas demonstration will also be used for the subsequent "rich"-gas demonstration outlined in Activity 3. Procurement for the natural gas supply requires the acquisition of a capture skid, three CNG tube trailers, and a pressure letdown skid. The skids and tube trailers have delivery times of 3 and 4 months, respectively (logistics provided in Appendix D). A GTI-Altronic Bi-Fuel® System is the intended equipment to enable dual fueling of the diesel engines. Equipment procurement will be arranged by Bakken Express (attached letter of support) and Continental Resources. An appropriate drill rig and site will be selected by Continental Resources, and the project will be conducted over one drilling cycle to occur over a maximum of 1 month. During this time, all performance data will be collected and documented, which includes tracking the fuel deliveries, fuel usage, engine emissions (emissions detail in Appendix F), and engine performance. The EERC will procure data acquisition hardware and instrumentation, and utilize experienced personnel (including engineering consultants) to oversee field operations.

Activity 2 – Bakken Gas Research

The work proposed for Activity 2 uses a test engine to experiment with bi-fuel operations with a representative Bakken Formation gas. The work will be coordinated between the EERC and GTI to utilize a 3412 Caterpillar test engine (typical size in drilling applications) at the GTI factory in Ohio. Tests will be performed using a gas prepared to match the analysis provided from Continental Resources for likely

associated gas from the Bakken Formation. Testing will identify the limits of performance using Bakken Formation gas in a bi-fuel system, including firing characteristics such as % diesel fuel replacement and engine load that contribute to knocking conditions. Experiments will be designed to overcome knock by adjusting injection rate of diesel or limiting injection of gaseous fuel. Emissions will be measured during testing to relate emission performance to diesel fuel replacement and load. The completed work will be summarized in a topical report or journal publication. Preparation for testing will occur over a 3-month time period in order to execute a 2-week test program and allow time for contingency given the test outcome.

Activity 3 – Rich-Gas Demonstration

The work conducted in Activities 1 and 2 will be used to achieve successful demonstration during Activity 3. Activity 3 will be conducted over an entire drilling cycle (spud to completion), obtaining data comparable to that of Activity 1. Methods and procedures will be similar. Bakken Express is already under contract to compress and transport Bakken gas in the Williston Basin and will have established operations by July of 2011. These operations will be applied in similar fashion to drilling operations conducted by Continental Resources.

Activity 4 – End-Use Technology Study

In North Dakota, more than three-quarters of natural gas production is from gas associated with oil production (Hvinden, 2009). There are some misconceptions surrounding the practice of flaring as it appears gas is burned for no use. In practice, gas is only flared at a well site where gas-gathering systems have not yet been installed. Furthermore, the practice is regulated under Section 38-08-04 of the North Dakota Century Code to conserve gas resources by limiting the amount of oil that can be produced from a well in which gas is flared. Associated gas from the Bakken Formation is a valued resource and, in particular, contains natural gas liquids (NGLs) that are highly valued by the petrochemical industry. This is demonstrated by the expanding pipeline infrastructure in North Dakota:

- Currently operational with a capacity of 100 MMcfd, EOG Resources Pecan Pipeline is transporting 40 MMcfd of NGLs to Alliance Pipeline and Aux Sable's Illinois refining facility.
- Proposed for 2012 – Vantage Pipeline will carry 100% of the produced ethane (capacity 60,000 bbl/d) from Hess Corporation's Tioga Gas Plant to Nova Chemical in Alberta, Canada.
- Proposed for 2013 – Oneok Pipeline is to initially transport 60,000 bbl/d of NGL to the Overland Pass Pipeline which connects Cheyenne, Wyoming, to Conway, Kansas.
- Announced for 2011 – CHS Inc. will market 40 million gallons/yr of NGLs (propane and butane) produced from the Robinson Lake fractionation plant owned by Whiting Oil and Gas Corporation.

This study is designed to work within the context of the natural gas and NGL market, seeking complementary utilization of associated gas, while recognizing the rapidly developing infrastructure for gas transportation and the evolution of flaring practices from wells. Challenges have been outlined by Alliance Pipeline (Monsour, 2010) for Bakken gas, including a limited infrastructure (although new pipelines projects are changing this), limited gas-processing capacity, geographic separation, and long distances to markets. Specific industry activities that may present economic opportunities for improved gas utilization include electric power generation, transportation fuels, and natural gas intermediates. The research study will be coordinated with commercial partners Linde and Bakken Express and will seek the guidance of key producers within the Williston Basin.

Assuming an average addition of 533 wells per year, power needs were projected by Pace Global Energy Services, to increase by 200 MW over a 5-year period in the Williston Basin (Raatz and Marthaller, 2007). The study was completed for Basin Electric Power Cooperative with support from the North Dakota Oil and Gas Research Council in 2007. Given the forecast for increased demand, the project team will work with local electric cooperatives to identify power supply opportunities. The study

will provide an overview of areas where gas-gathering infrastructure is limited and identify where CNG can be delivered to locations of power demand.

While the viability of CNG (or liquefied natural gas [LNG]) from pipeline natural gas for use as a transportation fuel has been well established, the use of associated gas for oil-field fleet vehicles presents a number of challenges and opportunities that will be explored in this study. The study will investigate and identify if vehicle fleets that utilize CNG are commercially attractive to the industry, where opportunities exist for utilization of wellhead gas, and if a dedicated CNG fleet adds value to gas-utilization strategies for gas-processing facilities.

Intermediate products from natural gas will be considered relative to current commercial demands for transportation of NGLs to refining facilities. The intermediate products include gas-to-liquids, high-value products, and ammonia-based fertilizer. The approach is to identify specific markets either within the region or high-value markets that suffer from lack of supply in order to enumerate an opportunity for products from associated gas. Consideration will be given to the existing chemical industry and how the feedstock from North Dakota can meet the industry's needs. New technologies that provide cost-efficient small-scale production may provide solutions for geographically constrained resources that are far from commodity markets in North Dakota.

References

Hvinden, D., 2009, So why are all these gas flares burning in the oil fields? North Dakota Department of Mineral Resources Newsletter; v. 36, no. 1, January 2009.

Monsour, G., 2010, Bakken gas challenges and opportunities: Presentation at the Williston Basin Petroleum Conference, May 2010.

Raatz, D.; Marthaller, D., 2007, Energy transmission needs study on North Dakota oil development: Presentation to North Dakota Oil and Gas Research Council; www.nd.gov/ndic/ogrp/info/g-012-023-sumpres.pdf (accessed May 2011).

APPENDIX D

PROJECT LOGISTICS

PROJECT LOGISTICS

The following illustrates the requirements for supplying Bakken Formation wellhead gas to a drilling location.

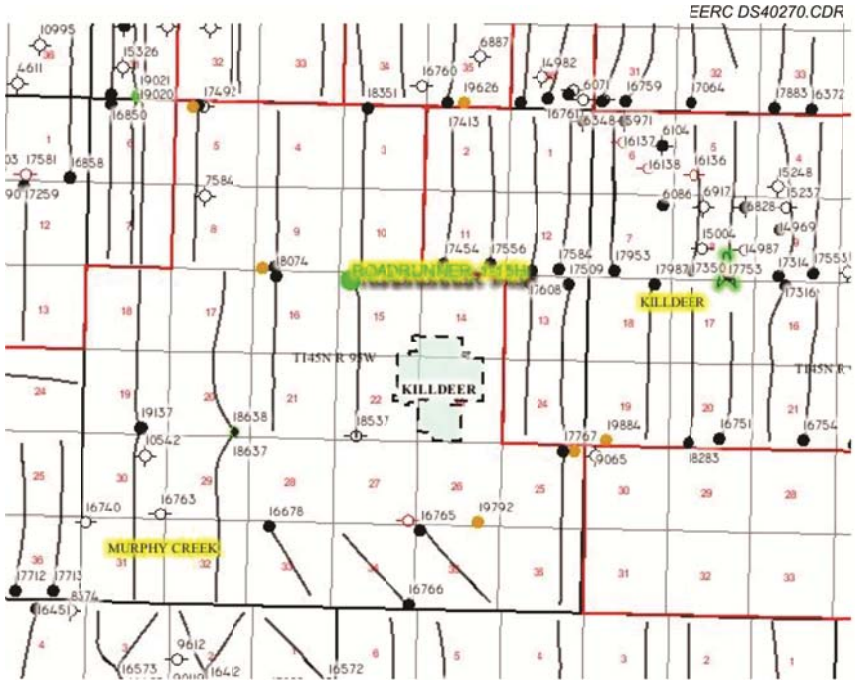

Figure D-1. Well location of example well: NDIC 18769, Roadrunner 1-15H, Spud 6/20/2010, IP 761 Bpd.

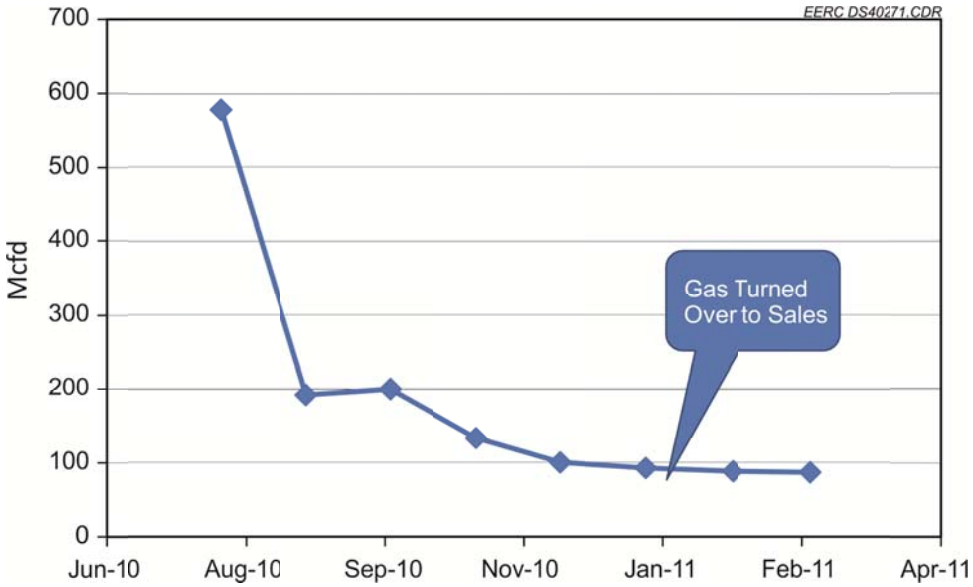

Figure D-2. Associated gas production from Roadrunner 1-15H Murphy Creek Field (total gas flared 31,854 Mcf).

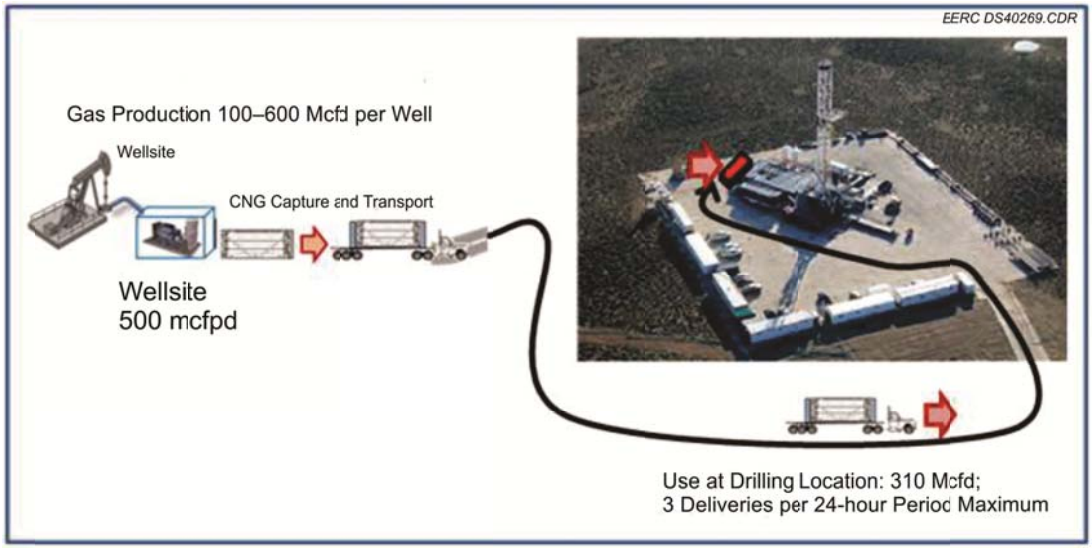

Figure D-3. Gas capture process from wellsite and transport to drilling rig.

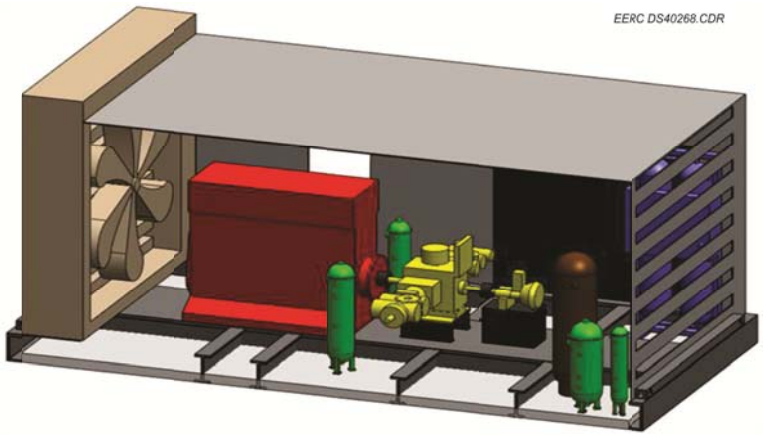

Figure D-4. Gas compressor skid to perform gas conditioning, dehydration, and compression.

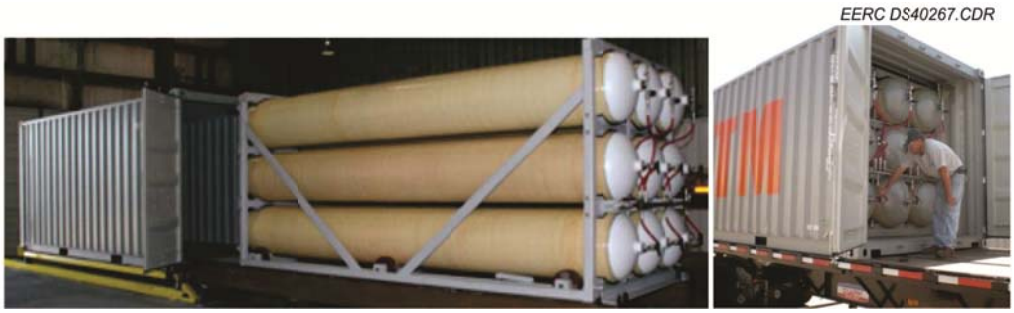

Figure D-5. Commercial tube container (125 Mscf at 3250 psig) and loading operation.

APPENDIX E

ISSUES RELATIVE TO KNOCK

ISSUES RELATIVE TO KNOCK

The vast majority of bi-fuel systems operate using pipeline natural gas; consequently, more data and experience are available for fuels with greater methane purity. Bakken Formation gas is rich in natural gas liquids (NGLs) including ethane–heptane, and accounts for over 50% of the gas produced in North Dakota (North Dakota Department of Mineral Resources, 2011). Comparatively, associated gas from the Madison Formation accounts for over 10% of gas production in North Dakota and is characterized by methane composition of greater than 70% and lower NGL concentrations that are within requirements for bi-fuel systems. Engine systems are designed based on internal combustion properties of the fuel. Table E-1 provides gas characteristics and the relative fuel properties of the pure gas components. Notice that the NGLs of higher carbon numbers are lower octane, which means they have less knock resistance and, therefore, a lower critical compression ratio relative to autoignition. Mixing NGLs with methane lowers the fuel's resistance to knock and, therefore, requires greater understanding to better tune an engine for Bakken Formation gas applications in bi-fuel systems.

Table E-1. Characteristics of NGL Components and Compositions in Various Gases (Caterpillar, 1997; Energy Conversion Systems, 2011; Ferguson, 1986; Hess, 2011)

	Dry Pipeline Gas	Bi-Fuel System Recommended Gas Quality	Example Bakken Gas (Hess, 2011)	Critical Compression Ratio	Octane Number (Motor)
Methane, CH_4	92.2%	>92%	55%	12.6	120
Ethane, C_2H_6	5.5%	<8%	22%	12.4	99
Propane, C_3H_8	0.3%	<8%	13%	12.2	97
Butane, C_4H_{10}		<2% combined total butane – heptane	5%	5.5	90
Pentane, C_5H_{12}			1%	4.0	63
Hexane, C_6H_{14}			0.25%	3.3	26
Heptane, C_7H_{16}			0.1%	3.0	0
Nitrogen, N_2	1.6%		3%		
Carbon Dioxide, CO_2	0.4%		0.5%		
HHV,[1] Btu/scf	1041				
LHV,[2] Btu/scf	937				
Methane Number	82.8				

[1] Higher heating value.
[2] Lower heating value.

Engine knock is the noise generated from autoignition of the fuel in the engine cylinder, where the fuel burns quickly and will rattle the engine parts. This form of combustion within the cylinder is referred to as detonation and is a phenomenon where combustion inside the engine cylinder proceeds uncontrolled. During audible knock, the pressure produced inside the cylinder is erratic and creates forces that lead to catastrophic engine damage such as piston pitting and physical cylinder head failure. Normal fuel combustion produces a pressure rise inside the engine cylinder at a predictable rate and peak. The combustion in a diesel engine is controlled by the injection rate of diesel fuel into the cylinder. Critical to diesel engine design is the compression ratio and the appropriate ignition delay period for the fuel. Ignition delay is the period between the start of injection and autoignition of the fuel. A designer strives for the appropriate ignition delay, for once the mixture of fuel and air autoignites, all of the fuel already injected burns very quickly. Too much fuel charge or too high of a compression ratio can result in intolerable knocking in a diesel engine. In a dual-fuel engine, autoignition of the injected gas is unlikely to result from piston compression. Natural gas ignites at a much higher temperature (1150°–1200°F) compared to diesel fuel (500°–750°F) (Generac, 2003); however, a significantly larger amount of fuel is precharged in the cylinder prior to injection of diesel. The injection of diesel is the source for ignition of the gaseous fuel; therefore, careful consideration is required to assure the fuel charge does not burn uncontrollably upon ignition.

REFERENCES

Caterpillar, 1997, Gas engines applications and installation guide—dry pipeline gas composition: G3600-G3300; LEKQ7256, October 1997.

Energy Conversions Inc. Recommended tolerances for natural gas fired with diesel in a 970-hp Caterpillar D398 engine generator: www.energyconversions.com/catspec.htm#CAT399 specs (accessed May 2011).

Ferguson, C.R., 1986, Internal combustion engines applied thermosciences: ISBN 0-471-88129-5.

Generac Power Systems, Inc, 2003, Bi-fuel engine generators—white paper: Bulletin 0169400SBY.

Hess, 2011, Personal communication with Hess Corporation Tioga Gas Plant: May 2011.

North Dakota Department of Mineral Resources, 2010, North Dakota gas production by formation: www.dmr.nd.gov/oilgas/stats/2010gasprod.pdf (accessed May 2011).

APPENDIX F

EMISSIONS

EMISSIONS

Beginning January 1, 2011, engines typically used in drilling applications (less than 10 liters per cylinder and greater than 175 hp) will be required to meet Tier 4 Interim emission regulations. Tier 4 Interim regulations call for 50%–90% reductions in particulate matter (PM) emissions and up to 90% reduction in emissions of oxides of nitrogen (NO_x), depending on the kilowatt rating of the engine/ generator set. This is the fourth phase of the nonroad U.S. Environmental Protection Agency (EPA) air quality regulations since 1996 and will be followed by regulations known as Tier 4 Final. Figure F-1 provides a summary of the regulations and relevant schedule.

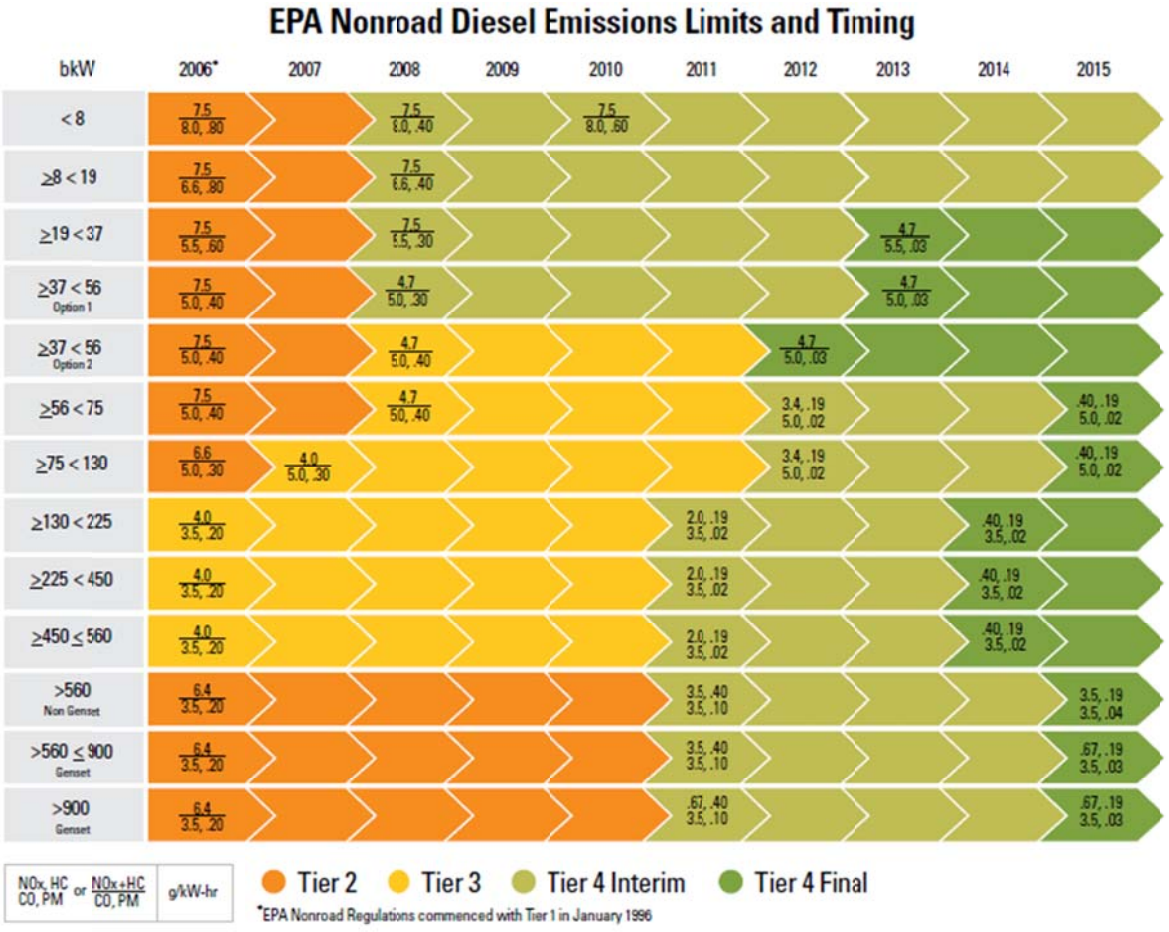

Figure F-1. Schedule for EPA emission limits.

Previously manufactured engines are not affected by Tier 4 regulations; however, as provided in Table F-1, it is important to understand the impact of dual-fuel operations on new and used engines. Firing natural gas in diesel engines generally provides a decrease in NO_x and PM and an increase in hydrocarbons (HC) and CO. Exhaust aftertreatment such as combustion catalysts are important to maintain low emissions. Systems in the future that are likely to include urea injection for NO_x control may require investigation relative to the impact of the aftertreatment system.

Table F-1. Emissions in g/kWh

					CAT 3512 Tested by (Hill and others, 2011)		
Emission	Tier 1 (2000)	Interim Tier 4 (2011)	Final Tier 4	CAT 3512 OEM Specifications	CAT 3512 Tier 0	CAT 3512 Tier 1 + Exhaust Catalyst	CAT 3512 Bi-Fuel
NO_x	9.2	0.67	0.67	12.5	13.6	7.1	12.0
CO	11.4	3.5	3.5	1.3	1.1	0.8	6.8
HC	1.3	0.4	0.19	0.4	0.3	0.1	1.1
PM	0.54	0.1	0.03	0.2	0.1	0.1	0.1

REFERENCE

Hill, D., Johnson, J., Bell, J., Mayer, N., Giberson, H., Hessler, R., Matthews, W., 2011, Natural gas as a fuel in drilling operations analysis, testing and implementation: SPE/IADC SPE-140357-PP.

APPENDIX G

RESUMES OF KEY PERSONNEL

DARREN D. SCHMIDT
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) 777-5120, Fax: (701) 777-5181, E-Mail: dschmidt@undeerc.org

Principal Areas of Expertise

Mr. Schmidt's principal areas of interest and expertise include geologic CO_2 storage, enhanced gas production from coal, CO_2 enhanced oil production, associated gas utilization, distributed power systems, biomass gasification, combustion, microturbines, gas to liquids, hydrogen, emission control, fuel cells, energy efficiency, and Bakken Shale research.

Qualifications

B.S., Mechanical Engineering, West Virginia University, 1994
Registered Professional Engineer
Certified Energy Manager
Certified Green Building Engineer

Professional Experience

2008–Present: Senior Research Advisor, EERC, UND. Mr. Schmidt provides engineering, project management, and field services for oil- and gas-related projects at the EERC, which include CO_2 pilot injection and geologic storage research, enhanced gas production from coal, and Bakken Shale research. Additionally, Mr. Schmidt contributes to the organization's revenue through research proposals, publications, and intellectual property.

1998–2008: Research Manager, EERC, UND. Mr. Schmidt's responsibilities include securing research contracts, managing projects, and performing engineering tasks in the areas of cofiring and biomass power systems, including combustion, fluidized-bed, gasification, microturbine, and internal combustion engine generators; energy efficiency; ground-source heat pumps; hydrogen production from biomass; and researching the behavior of biomass in combustion systems relative to ash fouling and trace elements.

1994–1998: Mechanical Engineer III, Research Triangle Institute (RTI), Research Triangle Park, North Carolina. Mr. Schmidt's responsibilities included serving as project leader for a $3M Cooperative Agreement with the U.S. Environmental Protection Agency (EPA) to demonstrate electricity production using a 1-MW wood gasification technology. The project involved engineering design, specification, purchase, fabrication, installation, and testing for a wood chip feed system; obtaining a North Carolina air quality permit; development of a computer program to interactively solve thermodynamics for drying; interaction with the EPA client, project subcontractors, and RTI project team; budget tracking and projecting; operation and testing of the power plant facility; preparing an 1-MW Waukesha engine generator set to burn low-Btu wood gas; and completion of technical reports for the EPA project monitor and for RTI

management. Other activities at RTI included support of marketing activities and coauthoring publications.

Summer 1993: Internship, EERC, UND. Mr. Schmidt's responsibilities included operation of a pressurized drop-tube furnace to analyze coal ash deposition in large-scale utility boilers. Ash samples were scanned by an electron microscope, and data analysis techniques were used to characterize the coal ash. Other activities involved design and testing of an experimental coal slurry feed system for the drop-tube furnace and compiling reports on testing procedures and test results.

Summer 1992: Internship, Foster Wheeler Development Corporation, Livingston, New Jersey. Mr. Schmidt's responsibilities included a research project involving testing the first stage of a fluidized-bed coal gasification combined-cycle process. Duties included collecting and logging all process samples during a 2-week test run; analyzing data collected for all previous test runs to establish relationships between the data and the plant-operating conditions; and submitting internal reports to the supervising research professor to state conclusions.

Publications and Presentations
Has authored or coauthored numerous publications.

CHAD A. WOCKEN
Senior 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) 777-5273, Fax: (701) 777-5181, E-Mail: cwocken@undeerc.org

Principal Areas of Expertise

Mr. Wocken's principal areas of interest and expertise include the development of alternative energy technologies and renewable fuels. He is also involved in projects researching liquid reforming for hydrogen production, hydrogen utilization, systems engineering, and energy efficiency. He is currently involved in the development of liquid fuels and chemicals from renewable resources, hydrogen production and purification technologies, energy conversion and technology integration, and hydrogen education and outreach activities.

Qualifications

B.S., Chemical Engineering, University of North Dakota, 1994.
Certifications: E.I.T. Chemical Engineering, U.S. Army Corps of Engineers Construction Quality Management; 40-hour OSHA Health and Safety; 8-hour HAZWOPER Supervisor; and 10-hour Construction Safety and Health.

Professional Experience

2009–Present: Senior Research Manager, EERC, UND. Mr. Wocken is involved in several program areas focusing on renewable energy development, technology development for renewable liquid fuels, systems integration of alternative energy technology, and hydrogen production from both renewable and fossil-based feedstock. Currently, he is managing projects focused on distillate fuel and chemical production from crop oil and other renewable oil feedstock as well as projects investigating alternative energy conversion technology. Specific responsibilities include preparing proposals, managing projects and researchers, preparing and reviewing research reports, presenting research information, compiling and reviewing research data, and managing EERC research in laboratory and pilot-scale reactor systems.

2005–2009: Research Manager, EERC, UND. Mr. Wocken's responsibilities included managing tasks and serving as principal investigator in a variety of renewable energy program areas including renewable fuel development and hydrogen production and use. Specific responsibilities included preparing proposals, interacting with industry and government organizations, researching the literature, designing and conducting effective experiments as a principal investigator, performing calculations and interpreting data, writing technical reports and papers, and presenting research results.

2001–2005: Research Engineer, Environmental Technologies, EERC, UND. Mr. Wocken's responsibilities included environmental control research focused on energy systems, mercury measurement and control, and fine particulate measurement and control, including the development of methods to determine the fate and transport of trace elements associated with

coal combustion processes. Specific responsibilities included preparing proposals, interacting with industry and government organizations, researching the literature, designing and conducting effective experiments as a principal investigator, performing calculations and interpreting data, writing technical reports and papers, and presenting research results.

1995–2001: Project Engineer, URS/Radian International, Salt Lake City, Utah (1997–2001), and Milwaukee, Wisconsin (1995–1997). Mr. Wocken's responsibilities included the following:

- Designed groundwater remediation systems to remove BTEX compounds and chlorinated solvents from groundwater. The projects consisted of site evaluation, technology selection, and design of several groundwater circulation wells and air sparge/soil vapor extraction treatment systems, and groundwater extraction with air stripper treatment technology. Design aspects included mass balance calculations, equipment design (pumps, pipe sizing, blowers, filters, etc.), equipment selection and specification, bid/construction specifications, and design drawing development.
- Performed start-up and long-term operations for a variety of groundwater remediation systems. Responsibilities included troubleshooting equipment/system malfunctions, process optimization, development of operations and maintenance manuals, establishment of performance verification criteria, operational cost evaluation, developing routine maintenance schedules, and directing technicians' work activities.
- Conducted detailed reviews of industrial wastewater treatment systems to identify alternative treatment technologies, process optimizations, cost-saving measures, water reuse/zero discharge alternatives, and review regulatory considerations.
- Provided on-site quality control oversight for several construction projects consisting of mechanical equipment installation, instrumentation and process control, facility and road construction, excavation, and underground utility installation. Daily responsibilities included evaluating work for conformance with construction drawings and specifications, conducting progress meetings, coordinating subcontractor work activities, and facilitating communication between the design firm, client, and subcontractors.
- Served as project manager for several large projects which were completed successfully. Activities included developing cost proposals, managing budget and schedule, equipment and subcontractor acquisition, and maintaining effective communication with the client.

1994–1995: Process Engineer, Archer Daniels Midland, Clinton, Iowa. Mr. Wocken's responsibilities included supervising operations and personnel at a wet corn mill and corn oil extraction and refining plant. Tasks consisted of prioritizing work activities, scheduling maintenance and repairing process equipment, reviewing quality control, and extensive system troubleshooting and failure analysis.

Publications and Presentations

Has authored or coauthored numerous publications.

CHRISTOPHER N. DAMIANI
Research Engineer
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) 777-5035, Fax: (701) 777-5181, E-Mail: cdamiani@undeerc.org

Principal Areas of Expertise

Mr. Damiani's principal areas of interest and expertise include the design of compressed natural gas (CNG) and hydrogen refueling systems, the development of high-pressure gaseous fuel infrastructure, reciprocating-compressor packaging, transportation alternative fuels, and commercialization of environmental technologies.

Qualifications

M.B.A., Finance, University of Manitoba, 2004.
B.S., Mechanical Engineering, University of Manitoba, 1995.

Professional Experience

2010–Present: Research Engineer, EERC, UND. Mr. Damiani's work focuses on projects related to the development of renewable fuels, alternative energy, hydrogen production, and energy systems integration. Specific responsibilities include pressure piping and system design, writing and presenting research reports, and interacting with industry and government organizations to develop new business and research opportunities for the EERC.

2009–2010: Vice President of New Business Development, Kraus Global, Inc., Winnipeg, Manitoba. Mr. Damiani was responsible for generating new business opportunities in new markets or by using new technologies, leveraging federal and provincial grants to fund Kraus research and development, and mechanical design on strategic H_2 and CNG projects.

2007–2009: Vice President of Product Development, Kraus Global, Inc., Winnipeg, Manitoba. Mr. Damiani was responsible for Kraus Engineering and its hydrogen and liquefied natural gas (LNG) businesses and field service operations; developing strategic direction for the company, which included long-term product development plans and budgets; implementing the use of a CRM software solution; and negotiating intellectual property rights for an innovative hydrogen production technology. Mr. Damiani also set up new management structure in Product Development.

2005–2007: Business and Product Development Manager, Kraus Global, Inc., Winnipeg, Manitoba. Mr. Damiani was responsible for Kraus Engineering and Kraus's emerging hydrogen business, developed an "industrial style" hydrogen dispenser for the quickly emerging fuel cell utility vehicle market, performed technical and business analyses to facilitate long-term agreements, and initiated and led a successful proposal for a hydrogen refueling station.

2004–2005: Technical Sales, Kraus Global, Inc., Winnipeg, Manitoba. Mr. Damiani's work focused on developing quotes and determining pricing policy, overseeing the North American CNG and hydrogen dispenser and valve markets, and development of new product design.

2003–2004: Mechanical Engineering Leader, Kraus Global, Inc., Winnipeg, Manitoba. Mr. Damiani managed a team of design engineers, quote developers, and technical writers; led project teams in the design of CNG compressor packages in many international locations; developed both overall and project-specific cash flow reports determining risk and recommendations; and implemented a restructuring of organizational structure.

2001–2003: Mechanical Designer, Kraus Global, Inc., Winnipeg, Manitoba. Mr. Damiani's primary responsibility was to design CNG compressor packages and associated equipment utilizing SolidWorks CAD software. He also designed air intake and exhaust systems for a Caterpillar 3306 natural gas engine and developed an effective engine-driven hydraulics system.

1997–2001: Process Engineer, Phillips and Temro Industries, Winnipeg, Manitoba. Mr. Damiani supervised a staff of three mechanics and developed a preventive maintenance program; was a member of a Lean Manufacturing team; supported Development Engineering in new product design and in developing PPAP and FMEA testing and documentation; developed an automated drill and tap machine and an automated pressure decay tester; and solved weld quality issues.

1995–1997: Manufacturing Engineer, Unisys Canada Inc., Winnipeg, Manitoba. Mr. Damiani provided technical support on tooling, material, and crimp quality issues; was in charge of cable and harness department and ASR9000 disk subsystem product line; and developed innovative work assembly line using individual work cells.

Professional Memberships
Member, Manitoba Hydrogen Steering Committee, 2005–2010
Executive Committee Member, Canadian Natural Gas Vehicle Alliance, 2008–2009
Chair of the Red River Valley Clean Cities Coalition, 2006–2009
Registered Professional Engineer – Manitoba No. 20706

Publications and Presentations
Has coauthored several technical publications.

DR. STEVEN M. SCHLASNER
Research Engineer
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) 777-5479, Fax: (701) 777-5181, E-Mail: sschlasner@undeerc.org

Principal Areas of Expertise

Dr. Schlasner's principal areas of interest and expertise include hydrogen, CO_2 capture, petroleum-refining and microbial bioprocess technologies, and advanced process control.

Qualifications

Ph.D., Chemical Engineering, Ohio State University, 1987
M.S., Chemical Engineering, Ohio State University, 1983
M.B.A., University of South Dakota, 1977
B.S., Chemical Engineering, South Dakota School of Mines & Technology, 1980
B.A., Chemistry and Mathematics, St. Olaf College, 1974
Diploma, Air War College, 1997
Diploma, Air Command and Staff College, 1993
Air University by correspondence
Professional Engineer, Ohio and Oklahoma
U.S. Department of Defense Acquisition Professional in Systems Planning, Research, Development, and Engineering, certified Level II (1995), trained Level III (2000)
Master of Process Technology, certified (1997); one of the first 18 engineers certified by Phillips
Top Secret/SBI Security Clearance, updated 2004

Professional Experience

2010–Present: Research Engineer, EERC, UND, Grand Forks, North Dakota. Dr. Schlasner works on projects related to hydrogen production technology, petroleum refinery emission control, and hot-gas filtration.

1987–2009: ConocoPhillips Company (formerly Phillips Petroleum Company), Bartlesville Technology Center, Oklahoma.

2001–2009: R&D Team Lead and Chief Engineer, CO_2 Capture/H_2 Production Team, R&D Senior Engineer, Long-Range Technology.

1992–2001: Refinery Senior Engineer, Advanced Process Control, Sweeny Petrochemical Complex, Texas.

1991–1992: Refinery Engineer, Process/Operations, Bartlesville Corporate Engineering, Oklahoma.

1987–1991: Process Engineer, Plastics, Bartlesville Research Center, Oklahoma.
Process Automation Engineer, Advanced Composites
R&D Engineer, Advanced Composites
R&D Engineer, Biotechnology Division

1980–2004: Colonel, Directorate Senior Reservist, U.S. Air Force Reserve, Air Force Research Laboratory (AFRL), Ohio.
Lieutenant Colonel, Division Senior Reservist
First Lieutenant – Major:

- Biotechnology Project Engineer
- Nonmetallic Materials Project Engineer
- Chemical Research Officer

1974–1978: Second Lieutenant – First Lieutenant, U.S. Air Force Active Duty, 44th Strategic Missile Wing (SAC), South Dakota.

- Wing Operations Staff Officer
- Missile Combat Crew Commander
- Deputy Missile Combat Crew Commander

Professional Memberships
National Hydrogen Association, Director (2006–2007)
American Chemical Society
American Society for Microbiology
Tau Beta Pi
Beta Gamma Sigma

APPENDIX H

DETAILED BUDGET AND BUDGET NOTES

DEMONSTRATION OF GAS-POWERED DRILLING OPERATIONS FOR ECONOMICALLY CHALLENGED WELLHEAD GAS AND EVALUATION OF COMPLEMENTARY PLATFORMS
NDIC
PROPOSED PROJECT START DATE: 8/1/11
EERC PROPOSAL #2011-0253

BUDGET SUMMARY

CATEGORY			PROJECT TOTAL		NDIC COST SHARE		CONTINENTAL NON-CASH SHARE		FEDERAL SHARE	
LABOR		Rate	Hrs	$ Cost	Hrs	$ Cost	Hrs	$ Cost	Hrs	$ Cost
Schmidt, D.	Project Manager	$ 55.11	1,500	$ 82,665	960	$ 52,906	-	$ -	540	$ 29,759
Wocken, C.	Principal Investigator	$ 54.51	240	$ 13,082	200	$ 10,902	-	$ -	40	$ 2,180
Damiani, C.	Principal Investigator	$ 45.43	360	$ 16,355	257	$ 11,676	-	$ -	103	$ 4,679
Schlasner, S.	Research Scientist/Engineer	$ 48.06	480	$ 23,069	250	$ 12,015	-	$ -	230	$ 11,054
----------	Senior Management	$ 74.19	285	$ 21,144	28	$ 2,077	-	$ -	257	$ 19,067
----------	Research Scientists/Engineers	$ 39.47	3,330	$ 131,435	3,330	$ 131,435	-	$ -	-	$ -
----------	Research Technicians	$ 25.94	581	$ 15,071	70	$ 1,816	-	$ -	511	$ 13,255
----------	Technology Dev. Mechanics	$ 30.94	700	$ 21,658	700	$ 21,658	-	$ -	-	$ -
----------	Undergrad-Res.	$ 10.61	900	$ 9,549	900	$ 9,549	-	$ -	-	$ -
----------	Technical Support Services	$ 21.50	110	$ 2,365	35	$ 754	-	$ -	75	$ 1,611
				$ 336,393		$ 254,788		$ -		$ 81,605
Escalation Above Base			5%	$ 16,820		$ 12,739		$ -		$ 4,081
TOTAL DIRECT HRS/SALARIES			8,486	$ 353,213	6,730	$ 267,527	-	$ -	1,756	$ 85,686
Fringe Benefits - % of Direct Labor - Staff		55%		$ 188,753		$ 141,625		$ -		$ 47,128
Fringe Benefits - % of Direct Labor - Undergrad. Research		1%		$ 99		$ 99		$ -		$ -
TOTAL FRINGE BENEFITS				$ 188,852		$ 141,724		$ -		$ 47,128
TOTAL LABOR				$ 542,065		$ 409,251		$ -		$ 132,814
TRAVEL				$ 49,215		$ 17,650		$ -		$ 31,565
EQUIPMENT > $5000				$ 70,000		$ -		$ -		$ 70,000
SUPPLIES				$ 17,504		$ 4,094		$ -		$ 13,410
PROFESSIONAL FEES AND SVCS (ENGINEERING CONSULTANT)				$ 55,000		$ 20,000		$ -		$ 35,000
COMMUNICATION - LONG DISTANCE & POSTAGE				$ 450		$ 50		$ -		$ 400
PRINTING & DUPLICATING				$ 225		$ 30		$ -		$ 195
FOOD				$ 550		$ 550		$ -		$ -
OPERATING FEES & SVCS										
Graphics Support				$ 6,615		$ -		$ -		$ 6,615
Shop & Operations Support				$ 1,146		$ 1,146		$ -		$ -
Research Information Systems				$ 15,977		$ 15,977		$ -		$ -
TOTAL DIRECT COST				$ 758,747		$ 468,748		$ -		$ 289,999
FACILITIES & ADMIN. RATE - % OF MTDC			VAR	$ 391,253	60%	$ 281,252	60%	$ -	50%	$ 110,001
TOTAL PROJECT COST - US DOLLARS				$ 1,900,000		$ 750,000		$ 750,000		$ 400,000

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.

DEMONSTRATION OF GAS-POWERED DRILLING OPERATIONS FOR ECONOMICALLY CHALLENGED WELLHEAD GAS AND EVALUATION OF COMPLEMENTARY PLATFORMS
EERC PROPOSAL #2011-0253

DETAILED BUDGET - TRAVEL

RATES USED TO CALCULATE ESTIMATED TRAVEL EXPENSES

DESTINATION	AIRFARE	PER MILE	LODGING	MEALS	CAR RENTAL	REGIST.
Unspecified Destination (USA)	$ 900	$ -	$ 200	$ 71	$ 85	$ 575
Western North Dakota	$ -	$ 0.33	$ 75	$ 25	$ -	$ -
Girard, OH (One night)	$ 1,000	$ -	$ 100	$ 51	$ 60	$ -
Girard, OH (Two weeks)	$ 750	$ -	$ 100	$ 51	$ 60	$ -
Pittsburgh, PA	$ 900	$ -	$ 225	$ 71	$ 75	$ -

PURPOSE/DESTINATION	NUMBER OF TRIPS	PEOPLE	MILES	DAYS	AIRFARE	MILEAGE	LODGING	MEALS	CAR RENTAL	MISC.	REGIST.	TOTAL
Conference/Unspecified Dest. (USA)	4	2	-	4	$ 7,200	$ -	$ 4,800	$ 2,272	$ 1,360	$ 640	$ 4,600	$ 20,872
Site Visits/Western North Dakota	7	1	500	2	$ -	$ 1,155	$ 525	$ 350	$ -	$ 140	$ -	$ 2,170
Sampling/Western North Dakota	14	2	500	3	$ -	$ 2,310	$ 4,200	$ 2,100	$ -	$ 840	$ -	$ 9,450
Monthly Meetings/Western North Dakota	12	1	500	2	$ -	$ 1,980	$ 900	$ 600	$ -	$ 240	$ -	$ 3,720
Site Visit/Girard, OH	1	2	-	2	$ 2,000	$ -	$ 200	$ 204	$ 120	$ 80	$ -	$ 2,604
Sampling/Girard, OH	1	2	-	14	$ 1,500	$ -	$ 2,600	$ 1,428	$ 840	$ 560	$ -	$ 6,928
DOE Review Meeting/Pittsburgh, PA	1	2	-	3	$ 1,800	$ -	$ 900	$ 426	$ 225	$ 120	$ -	$ 3,471
TOTAL ESTIMATED TRAVEL												$ 49,215

DEMONSTRATION OF GAS-POWERED DRILLING OPERATIONS FOR ECONOMICALLY CHALLENGED WELLHEAD GAS AND EVALUATION OF COMPLEMENTARY PLATFORMS
EERC PROPOSAL #2011-0253

DETAILED BUDGET - EQUIPMENT

Fabricated Equipment	$ COST
Industrial Engine Data Acquisition System	$ 25,000
Industrial Engine Field Instrumentation Package	$ 45,000
Total Estimated Cost:	$ 70,000

DEMONSTRATION OF GAS-POWERED DRILLING OPERATIONS FOR ECONOMICALLY CHALLENGED WELLHEAD GAS AND EVALUATION OF COMPLEMENTARY PLATFORMS
EERC PROPOSAL #2011-0253

DETAILED BUDGET - EERC RECHARGE CENTERS

			TOTAL
Graphics Support	Rate	#	$ Cost
Graphics (hourly)	$ 63	100	$ 6,300
Subtotal			$ 6,300
Escalation		5%	$ 315
Total Graphics Support			$ 6,615
Shop & Operations Support	Rate	#	$ Cost
Technical Development Hours	$ 1.56	700	$ 1,092
Subtotal			$ 1,092
Escalation		5%	$ 54
Total Shop & Operations Support			$ 1,146
Research Information Systems	Rate	#	$ Cost
Research Information Systems (Hourly)	$ 48	317	$ 15,216
Subtotal			$ 15,216
Escalation		5%	$ 761
Total Research Information Systems			$ 15,977

BUDGET NOTES

ENERGY & ENVIRONMENTAL RESEARCH CENTER (EERC)

BACKGROUND

The EERC is an independently organized multidisciplinary research center within the University of North Dakota (UND). The EERC receives no appropriated funding from the state of North Dakota and 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

If federal funding is proposed as part of this project, the applicable federal intellectual property (IP) regulations may govern any resulting research agreement. In addition, in the event that IP with the potential to generate revenue to which the EERC is entitled is developed under this agreement, 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.) is for planning purposes only. The project manager may, as dictated by the needs of the work, incur costs in accordance with Office of Management and Budget (OMB) Circular A-21 found at www.whitehouse.gov/omb/circulars. If the Scope of Work (by task, if applicable) encompasses research activities which may be funded by one or more sponsors, then allowable project costs may be allocated at the Scope of Work or task level, as appropriate, to any or all of the funding sources. Financial reporting will be at the total-agreement level.

Escalation of labor and EERC recharge center rates is incorporated into the budget when a project's duration extends beyond the current fiscal year. 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: The EERC employs administrative staff to provide required services for various direct and indirect support functions. 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 current average rate of a personnel group with a similar job description. Salary costs incurred are based on direct hourly effort on the project. Faculty who work on this project will be paid an amount over their normal base salary, creating an overload which is subject to limitation in accordance with university policy. Costs for general support services such as contracts and intellectual property, accounting, human resources, purchasing, shipping/receiving, and clerical support of these functions are included in the EERC facilities and administrative cost rate.

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 is estimated on the basis of UND travel policies which can be found at www.und.edu/dept/accounts/policiesandprocedures.html. Estimates include General Services Administration

(GSA) daily meal rates. Travel may include site visits, field work, meetings, and conference participation as indicated by the scope of work and/or budget.

Equipment: Equipment, as specified in the budget, includes fabrication of the data acquisition system and instrumentation hardware comprising signal processing, computer hardware, data storage, communications interface, temperature sensors, pressure sensors, flow sensors, level indication, and emission sensors. The equipment will be used to acquire engine performance and emission data during field demonstration and pilot testing.

Supplies – Professional, Information Technology, and Miscellaneous: Supply and material estimates are based on prior experience and may include chemicals, gases, glassware, nuts, bolts, and piping. Computer supplies may include data storage, paper, memory, software, and toner cartridges. Maps, sample containers, minor equipment (value less than $5000), signage, and safety supplies may be necessary as well as other organizational materials such as subscriptions, books, and reference materials. General purpose office supplies (pencils, pens, paper clips, staples, Post-it notes, etc.) are included in the facilities and administrative cost.

Subcontracts/Subrecipients: Not applicable.

Professional Fees/Services (consultants): Numerous professional engineering consultants will be utilized during the proposed scope of work. Consultants are required to provide relevant and current industry practices that affect equipment hardware installation and market trends specific to gas utilization.

Other Direct Costs

Communications and Postage: Telephone, cell phone, and fax line charges are generally included in the facilities and administrative cost. Direct project costs may include line charges at remote locations, long-distance telephone, postage, and other data or document transportation costs.

Printing and Duplicating: Photocopy estimates are based on prior experience with similar projects. Page rates for various photocopiers are established annually by the university's duplicating center.

Food: Food expenditures for project meetings, workshops, and conferences where the primary purpose is dissemination of technical information may include costs of food, some of which may exceed the institutional limit.

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 development and execution of the project by the research team.

Fees and Services – EERC Recharge Centers, Outside Labs, Freight: EERC recharge center rates for laboratory, analytical, graphics, and shop/operation fees are established and approved at the beginning of the university's fiscal year.

Laboratory and analytical fees are charged on a per sample, hourly, or daily rate, depending on the analytical services performed. Additionally, laboratory analyses may be performed outside the university when necessary.

Graphics fees are based on an established per hour rate for production of such items as report figures, posters, and/or PowerPoint images for presentations, maps, schematics, Web site design, professional brochures, and photographs.

Shop and operation fees are for expenses directly associated with the operation of the pilot plant facility. These fees cover such items as training, personal safety (protective eyeglasses, boots, gloves), and physicals for pilot plant and shop personnel.

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

Facilities and Administrative Cost: Facilities and administrative (F&A) cost is calculated on 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 one year, as well as subawards in excess of the first $25,000 for each award. The F&A rate for nonfederal sponsors is 60%. This rate is based on costs that are not included in the federally approved rate, such as administrative costs that exceed the 26% federal cap and depreciation/use allowance on buildings and equipment purchased with federal dollars.