PROJECT TITLE

INVESTIGATION OF TECHNIQUES FOR OBTAINING NO_x REDUCTIONS BY MODIFYING THE COMBUSTION INSIDE A CYCLONE BARREL BURNING LIGNITE

ORGANIZATION

NORTH DAKOTA LIGNITE CYCLONE USERS GROUP
COYOTE GENERATING STATION
LELAND OLDS GENERATING STATION
MILTON R. YOUNG GENERATING STATION

INVESTIGATORS

CURT MELLAND, RESULTS ENGINEER,
BASIN ELECTRIC POWER COOPERATIVE

ELECTRIC POWER RESEARCH INSTITUTE (EPRI)

DATE OF APPLICATION

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ELECTRIC POWER RESEARCH INSTITUTE (EPRI)

DATE OF APPLICATION

JANUARY 1, 1996

AMOUNT OF REQUEST

$88,938

BASIN ELECTRIC
POWER COOPERATIVE
1717 EAST INTERSTATE AVENUE
BISMARCK, NORTH DAKOTA 58501-0564
PHONE: 701/223-0441

December 12, 1995

Lignite Research Council
State of North Dakota
Office of the Industrial Commission
State Capitol
Bismarck, ND 58505

Dear Gentlemen:

Enclosed is the application of the North Dakota Lignite Cyclone Users Group for a grant from the North Dakota Lignite Research Fund. By this application, the North Dakota Lignite Cyclone Users Group hereby commits itself to complete the project as described in the application should the Industrial Commission of North Dakota make the grant requested by the application.

The applicant certifies that it has read and understands the statutes and administrative rules governing grants from the Lignite Research Fund and agrees to all conditions and terms set forth therein. The applicant also certifies that all information contained in the application is true to the best of the applicant's knowledge and acknowledges the right of the North Dakota Industrial Commission to modify or terminate any subsequent agreements with applicant if the Commission becomes aware of any material misrepresentation contained in this application.

Sincerely,

Richard B. Fockler

Richard B. Fockler
Assistant General Manager
Basin Electric Power Cooperative

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1.0 ABSTRACT

Reburning, selective catalytic reduction, and non-catalytic reduction techniques have demonstrated some potential for NO_x reduction in cyclone boilers. All of these techniques either require high cost equipment retrofits, produce high operating costs, cause restrictions in operation capability or flexibility, or a combination of these effects. The objective of this investigation is to determine if NO_x reductions can be produced by modifying the cyclone combustion within the cyclone barrel without significantly impacting the operation, maintenance, reliability, or capacity of the cyclone.

Three North Dakota lignite cyclone-fired plants (**Coyote Generating Station** owned by Northern Municipal Power Agency, Montana-Dakota Utilities Co., Northwestern Public Service Co., and Otter Tail Power Co.; **Leland Olds Generating Station** owned by Basin Electric Power Cooperative; and **Milton R. Young Generating Station** owned by Minnkota Power Cooperative) have joined together to form the **North Dakota Lignite Cyclone Users Group**. The **North Dakota Lignite Cyclone Users Group** submits this proposal determining if cyclone combustion modification techniques can be effective in obtaining NO_x emission reductions.

The North Dakota Lignite Cyclone Users Group will contract Electric Power Research Institute (EPRI) to conduct the studies. The project will cost $177,876 and last six months. The North Dakota Lignite Cyclone Users Group is requesting the North Dakota Industrial Commission to issue a grant for the sum of $88,938, which is 50 percent of the funds needed to complete the project.

2.0 PROJECT SUMMARY

Objectives

The objective of this study is to show that NO_x reductions can be obtained by modifying the combustion in a cyclone burning lignite without significantly impacting the operation, maintenance, reliability, or capacity of the cyclone.

Introduction & Background

There are presently 105 operating, cyclone-equipped utility boilers representing approximately 14 percent of pre-New Source Performance Standards (NSPS) coal-fired generating capacity (over 26,000 MW). However, these units contribute approximately 21 percent of the NO_x emitted since their inherently turbulent, high-temperature combustion process is conducive to NO_x formation. Although the majority of cyclone units are 20 - 30 years old, utilities plan to operate many of these units for at least an additional 10 - 20 years. These units (located primarily in the Midwest) have been targeted for the second phase of the Federal acid rain legislation. The cyclone boilers that use lignite located in the Dakotas represent 2,000 MW generating capacity.

Cyclone equipped boilers have a unique configuration which prevents application of standard low-NO_x burner technology. The use of selected catalytic reduction or selected non-catalytic reduction (SCR/SNCR) and reburning technologies offer promise of controlling NO_x emissions from cyclone boilers, but at high capital and/or operating costs. Previous short-term cyclone combustion modification tests done at the M.R. Young Station, Center, North Dakota and Kaw

Generating Station, Kansas City, Kansas, have shown that NO_x emissions could be reduced. The tests were terminated because of concerns for cyclone corrosion and slagging.

Ten organizations which operate cyclone boilers have formed a Cyclone NO_x Controls Interest Group (CNCIG) with EPRI. Through Basin Electric, the North Dakota Lignite Cyclone Users Group (NDLCUG) gains representation with CNCIG. Part of the mission of CNCIG is to explore, evaluate, and demonstrate potential alternatives for cyclone NO_x control. One task authorized by CNCIG is to utilize a calculated fluid dynamics program to study the physics of the cyclone combustion process. Once the formation of NO_x in the cyclone barrel is modeled, then combustion modifications will be modeled to find a technique that will reduce NO_x emissions while minimizing cyclone slagging and corrosion concerns. The CNCIG model simulation will be based upon bituminous and sub-bituminous coal. This project would modify the fluid dynamics model developed by CNCIG to represent North Dakota lignite cyclones. The project will use the results of the CNCIG model to guide the lignite model simulation studies. Working the two projects together provides a large cost savings for this project.

The Need For This Study

The EPA will be making rules affecting cyclone boilers by 1997. The North Dakota Lignite Cyclone Users Group will need to find a cost-effective method for meeting the requirements of the new emission limits. This study will ascertain whether combustion modification techniques offer enough promise for future development work.

Statement of Work

The study consists of the following tasks:

- Task 1 - Prepare geometry of computational fluid dynamic (CFD) model.

- Task 2 - Collect gas and temperature data from utility lignite cyclone
- Task 3 - Validate base case results from CFD model.
- Task 4 - Predict effects of different combustion modification techniques and fuel composition
- Task 5 - Prepare reports summarizing the results of the study.

The project will start in December 1995 and be completed by the end of June 1996.

Value to North Dakota

To-date, SCR, SNCR and reburning technologies are being promoted for NO_x control on cyclone boilers. These technologies are expensive and reduce the flexibility and capability of cyclone boilers. The increased costs associated with these technologies would decrease the lignite unit's ability to compete in the surplus energy market and could increase consumers rates. Both of these affects tend to decrease the amount of electricity generated and lignite fuel burned further decreasing North Dakota lignite consumption.

3.0 PROJECT DESCRIPTION

Introduction & Objectives

The North Dakota Lignite Cyclone Users Group in conjunction with Babcock and Wilcox Company (B&W) and the Lignite Energy Council have completed studies evaluating the application of the reburning technology for NO_x control on lignite-fired cyclone boilers. The results of the studies have shown that the reburning technology has potential for significant NO_x reductions. However, the cost and complexibility of the reburn system raises concerns about the viability of using reburning for NO_x control on North Dakota lignite cyclone boilers.

Other organizations throughout the United States which operate cyclone boilers have similar concerns about using reburning and other technologies promoted for cyclone NO_x control. Through EPRI, these organizations have formed a Cyclone NO_x Controls Interest Group (CNCIG). Through Basin Electric, the North Dakota Lignite Cyclone Users Group gains representation with CNCIG. Part of the mission of CNCIG is to explore, evaluate and demonstrate potential alternatives for cyclone NO_x control. One project authorized by CNCIG will utilize a calculated fluid dynamics program to study the physics of the cyclone combustion process. The combustion in a cyclone barrel will be modeled to better understand the combustion processes and NO_x formation mechanisms that occur inside the cyclone barrel. Combustion modification methods will be modeled and analyzed to evaluate the amount of NO_x formed and the possible operation and maintenance constraints of each combustion modification method. Although the CNCIG work will model cyclones burning bituminous and sub-bituminous coal, the North Dakota Lignite Cyclone Users Group will be able to use large portions of the CNCIG work in the lignite cyclone model simulations providing a cost savings for this project.

Objectives

The objective of this study is to find a combustion modification technique that could be used as an alternative to SCR, SNCR and reburning for cyclone NO_x control. A successful combustion modification technique would produce significant cyclone NO_x emission reductions while minimizing the impact to the operation, maintenance, reliability, or capacity of the cyclone.

Project Methodology

The premise of this work is that computational fluid dynamics (CFD) modeling has progressed to a point where meaningful analysis can be used as a screening tool for indicating whether or not a concept has merit. In this study the effort is to assess the NO_x reduction potential and operational consequences of using selective air staging, flue gas recirculation, or steam injection within a lignite-fired scroll burner cyclone. This study will be conducted as a parametric variation to the sub-bituminous/bituminous radial burner cyclone study being conducted for CNCIG.

Task 1 is to select and prepare the burner and cyclone geometry for the CFD model. Geometries from the NDLCUG participants are compared and the most common geometry selected for the model. Operational practices and operational data are compared to select the base case characteristics of the CFD model.

Task 2 is to collect actual excess oxygen, carbon dioxide, carbon monoxide, NO_x, hydrogen sulfide concentrations, and gas temperature profiles along the centerline of an operating cyclone. The data will be collected using a water cooled high velocity thermocouple and gas sampling device with a 15 foot working length. Data will be collected from the burner to the

cyclone re-entrant throat. Cyclone coal data will gathered during the cyclone testing. The cyclone and coal data will be used to benchmark the CFD model.

Task 3 is to develop a CFD model that produces the same results as the data collected in task 2. The simulations will be conducted using Reaction Engineering International reacting two-phase computational fluid dynamics code, "GLACIER," to examine the physical and chemical processes controlling coal combustion, pollutant formation and surface (slagging) characteristics in the cyclone barrel. Simulations will incorporate chemical and physical models developed for the CNCIG radial burner case which include:

- Turbulent dispersion and deposition of large coal particles,
- Heat release from large coal particles burning in suspension and in the slag layer,
- Slag layer properties (e.g. temperature and viscosity),
- NO_x formation from large particles.

Simulation results will include flow patterns, gas temperatures, equilibrium species concentrations (CO_2, O_2, H_2S, etc.), finite-rate-chemistry-based NO_x concentrations, surface heat transfer, slag layer surface temperatures, particle cloud trajectories and deposition rates, and particle cloud time-temperature and time-reaction histories.

Task 4 is to predict the effects on NO_x production, potential for surface corrosion and difficulties in slag tapping of different combustion modification techniques, and fuel composition. Fuel composition variations found at the area mines will be modeled. Air biasing inside the cyclone barrel, steam injection, flue gas injection, and fuel staging will be modeled.

Task 5 is to prepare reports as required by the requirements of the grant.

Anticipated Results

We expect the results of this study will show that NO_x reductions can be made utilizing combustion modification techniques when burning a low sulfur, low iron content fuel such as North Dakota lignite. We expect that cyclone maintenance requirements may increase slightly, but do not expect any significant change in cyclone capacity or long-term reliability. We expect the combustion modification techniques will offer a very cost-effective alternative to present cyclone NO_x reduction techniques. We expect the results to be favorable enough to warrant a full-scale demonstration of the combustion modification techniques.

The Need For This Project

The EPA will be making rules affecting cyclone boilers by January 1, 1997. The North Dakota Lignite Cyclone Users Group will need to have a cost-effective method of meeting the requirements of the new emission limits. This study will ascertain the viability of a full-scale retrofit using combustion modification techniques on North Dakota Lignite Cyclone Boilers.

Environment & Economic Impact

This study has no environmental impact while it is under way. While the economic impact of a full-scale retrofit may be significant, this study would have a minimal effect.

4.0 STANDARDS OF SUCCESS

- Numerical CFD model results compare favorably to cyclone test data.
- Significant NO_x reduction is obtained through combustion modification techniques.
- Combustion modification techniques have minimal effects on cyclone capacity and reliability.

5.0 BACKGROUND

No cyclone combustion modification process has been commercially demonstrated in the United States. However, past tests by B&W in utility boilers achieved 15-30 percent reduction in NO_x emissions. Cyclone tube corrosion concerns due to the reducing conditions in the cyclone barrel were not fully addressed because of the short duration of these tests. Further investigation of staging for cyclone NO_x control was halted due to concerns of incurring cyclone corrosion damage.

Cyclone operation at low cyclone barrel stoichiometric ratios was achieved at the Leland Olds Station in late 1977 and early 1978. The operation resulted from secondary air staging in the cyclone to increase cyclone barrel temperatures. The higher cyclone barrel temperatures were needed to improve cyclone performance when burning higher than normal ash, lower than normal Btu lignite coal. During a portion of the testing one-half of the secondary air inlet duct into each cyclone was blanked off. Until methods were found to increase the air flow into the cyclones, the unit was operated with low cyclone stoichiometric ratios. The cyclone barrels did experience higher wear rates. The higher wear rates were thought to be caused by erosion rather than corrosion. With the higher operating temperatures inside the cyclone barrel, the protective ash coating normally protecting the tubes did not exist. Changes in maintenance

practices reduced cyclone maintenance to reasonable levels. No NO_x measurements were taken during the low stoichiometric ratio cyclone operation.

In Europe, the U.S. style B&W cyclones were used to burn German coals. These cyclones did not perform satisfactorily. After years of experimentation, a new cyclone design which stages air and fuel evolved. The "Secant" fired cyclone was successful burning the German coals. As a side benefit, the cyclone NO_x emissions were reduced from 30 to 40 percent. The key to the NO_x reduction was the careful control of the fuel air ratios throughout the cyclone barrel. The combustion air was controlled so that 80 percent of the combustion was completed inside the cyclone barrel. Additional air was added in the fire box so that the combustion was completed in the boiler lower furnace area. Maintenance requirements of the cyclone barrels have been reasonable. This technology has not been demonstrated in the United States.

Foster Wheeler has begun to develop a cyclone burner which provides regions of sub-stoichiometry within the cyclone barrel. A stream of pulverized coal is fed through the center of the cyclone. Crushed coal is also fed radially similar to the normal cyclone burners. The combination of crushed and pulverized coal fed into the cyclone barrel is controlled to keep the gas in the center of the cyclone sub-stoichiometric while the gas near the cyclone barrel tubes is at or above a stoichiometric ratio of 1.0. The air required for complete combustion is added in the fire box much like the Riley Deutsche Babcock "Secant" cyclone low NO_x design. Foster Wheeler has not done the engineering on this concept that is needed for a full-scale installation, but is seeking a utility and funds for a demonstration project.

It is particularly interesting that little work has been done to understand the combustion process inside the cyclone barrel. It is generally agreed that an oxygen rich core exists in the center of the cyclone barrel during the normal combustion process. It is thought this oxygen rich core increases the cyclone NO_x production. Both the Riley and Foster Wheeler designs seek to reduce or eliminate the rich oxygen core. The CFD model work in this proposal should go a long way in helping us understand the cyclone combustion process. With the better understanding, CFD model results may allow us to find a way to eliminate the oxygen rich core and reduce the cyclone NO_x production without the use of extensive modifications required by the Riley and Foster Wheeler designs.

6.0 QUALIFICATIONS

Project Organization

Mr. Curt Melland will coordinate the efforts of EPRI in accordance with the wishes of the North Dakota Lignite Cyclone Users Group. **Mr. Gerald Gress** will be the spokesman for the Coyote generating station, **Mr. Merrill Lewis** will be the spokesman for the Milton R. Young generating station, and Mr. Curt Melland will be the spokesman for the Leland Olds generating station.

Mr. Tony Facchiano, Environmental Controls Business Unit NO_x Emissions Control Manager, from EPRI will be the Project Manager and Contract Manager. Mr. Facchiano will direct the sub-contractors in the completion of the project's tasks. Although Mr. Facchiano will be the prime contact between EPRI and the North Dakota Lignite Cyclone Users Group, direct contact between sub-contractor personnel and Mr. Melland will be used for technical project matters (Figure 1).

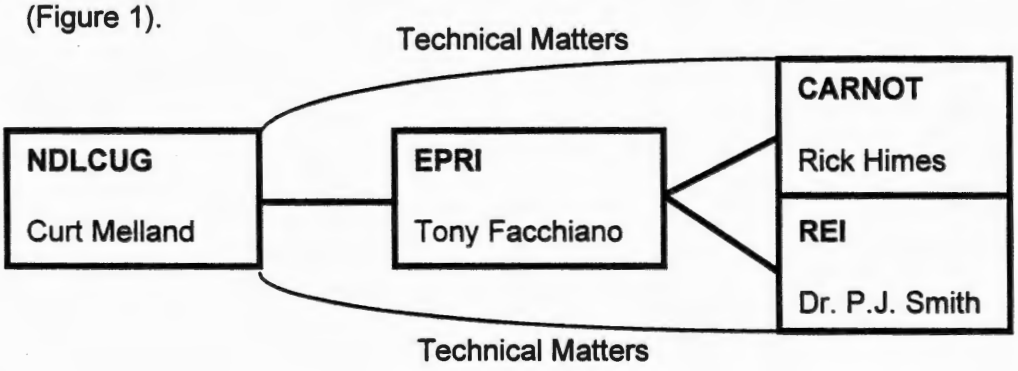


Figure 1

Mr. Tony Facchiano from EPRI will have the prime responsibility for all contractual matters between EPRI, North Dakota Lignite Cyclone Users Group, and sub-contractors. He will

monitor adherence to the schedule, budgets, sub-contractor reporting requirements, and contract terms.

Mr. Rick Himes, Director of Engineering from Carnot, will provide the technical expertise needed to properly measure the gas temperature and gas constituents in an existing cyclone during normal operation.

Dr. Philip J. Smith, Vice President at Reaction Engineering International and Professor of Chemical Engineering at the University of Utah, will be responsible for the CFD model work. Dr. Smith will be supported by Drs. Bradley Adams and Michael Bockelie. Dr. Adams will work with Dr. Smith on the model results and Dr. Bockelie will provide support with mesh generation.

Related Experience

The **Electric Power Research Institute (EPRI),** founded in 1972, conducts a far-reaching collaborative research and development program on behalf of the nation's electric power industry. EPRI has more than 700 utilities among its members, representing approximately 70 percent of all electricity generated in the United States From EPRI headquarters in Palo Alto, California, 325 engineers and scientists manage nearly 2,600 on-going projects carried out by equipment suppliers, government and private laboratories, universities, and independent contractors around the world. Below is a partial list of EPRI contracts pertaining to cyclones and low NO_x combustion:

EPRI Contract	**Title**
RP 2154-9	NO_x Control Options for Coal-Fired Cyclone Utility Boilers
RP 2154-11	Pilot Scale Evaluation of Reburning for Cyclone Boiler NO_x Control

RP 2916-6	Ohio Edison Gas Reburning of a Cyclone Boiler at Niles
RP 2916-15	Wisconsin P&L Coal Reburning of a Cyclone Boiler at Dewey
RP 2916-23	PSCCo Reburning of a Wall-Fired Boiler at Cherokee
RP 2916-16	New England Electric Low NO_x Burner Test
RP 3069-2	TransAlta LNS for Utility Cyclone Boilers
RP 2916-17	Low NO_x Cell Burner Demo @ Dayton P&L
RP 3069-17	TRW Combustor
RP 296-14	Four Corners Emission Testing
RP 9066-1,2	Low NO_x Study @ Aem
RP 9086-1	Roof-Fired Low NO_x Retrofit @ AEP Tanners Creek
RP 9060-1,2,3	Low NO_x Cell Burner Retrofit and Corrosion Study @ Hatfield Station
RP 3958	Gas Co-Firing Retrofit at NEP Brayton Point
RP 3524	Furnace Modeling @ SCS Lancing Smith
RP 4100-1,2	Ultra Low NO_x Burner Demo @ Con Edison

Carnot is a specialty air quality and engineering services firm with a focus on engineering design and implementation of combustion improvements and air pollution control technologies on combustion systems; emissions measurement; and continuous emissions monitoring. Carnot has 60 full-time employees and has working relationships with a number of specialty consultants and associates. The corporate headquarters are in Tustin, California. Carnot has offices in Cheshire, Connecticut; Boulder, Colorado; Seattle, Washington; and Concord, California.

Carnot is actively involved in three areas- Engineering Services, Continuous Compliance/CEMS Engineering, and Emissions Measurement. The Engineering Services group works with its clients in combustion and air emission-related areas ranging from NO_x emission control to system performance optimization programs. The Emissions Measurement group provides a wide range of measurement services, including regulatory compliance tests, CEMs certification, and support of engineering projects directed toward minimizing NO_x emissions through optimized performance. The Continuous Compliance/CEMs Engineering group has seen rapid growth with the passage of the 1990 Clean Air Act Amendments. Carnot works with its clients to match the best available commercial system with site-specific operating conditions and constraints of a given facility. Carnot is a service- oriented business, representing and assisting its clients in achieving pollution control in the most cost-effective manner possible. Recently published Carnot papers on NO_x related topics are as follows:

- Selective Catalytic Reduction Performance Project at Public Service Electric and Gas Company's Mercer Generating Station No. 2
- Evaluation of Combine SNCR/SCR For NO_x Abatement On a Utility Boiler
- An Assessment of Boiler Impacts From Reduced Air Flow Operation
- NO_x Compliance Plan For Central Hudson Gas & Electric's Roseton and Danskammer Power Plants
- Demonstration of Fuel Injection Recirculation (FIR) For NO_x Emissions Control

Reaction Engineering International (REI) is an engineering consulting firm focused on solving the needs of industry by the application of advanced engineering and scientific technology. REI is comprised of 18 professional staff whose experience covers a broad range of combustion system design, development, analysis, and simulation in both industrial and academic fields.

REI principals have been performing combustion research and system development for more than 20 years.

REI provides a range of combustion-related products and services including:

- Computer models (detailed special purpose models of reacting systems, simplified PC models, coal quality impact models)
- Design and construction of special test equipment
- Fuels system testing (waste and fuels evaluations, bench-scale kiln firing, co-firing in stokers and PC units)
- NO_x control (burner design, reburning with coal and biofuels, SNCR)
- Model-based control systems
- Engineering analysis (waste firing in cement kilns, dioxin emissions, reburning with wood waste in cyclone fired boiler)

REI has performed work for clients in the energy, engineering, waste, and process industries. REI has also been involved with U.S. DOE Combustion 2000 LEBS and HIPPS programs related to the design, development, and modeling of new coal combustion systems.

Experience of Project Personnel

Gerald L. (Gary) Gress has worked in the electric utility industry for 22 years. He has been Plant Manager and Director of Power Production for Southern Indiana Gas and Electric Company. He joined Montana-Dakota Utilities in August, 1993, and presently serves as Power Production Manager. Mr. Gress has a B.S. degree in Electrical Engineering Technology from Purdue University and a M.B.A. from the University of Evansville in Indiana.

Merrill Lewis has worked in the lignite power generating industry for 30 years. He joined Minnkota Power Cooperative in 1985 and presently serves as Director of Power Production. Mr. Lewis was recently awarded the Nikola Telsa Award for his significant contributions to the power industry. Mr. Lewis has a B.S. and M.S. in Mechanical Engineering from North Dakota State University.

Curt Melland is the Results Engineer at Basin Electric's Leland Olds generating station. He has worked for Basin Electric as a mechanical engineer for 19 years. Mr. Melland has a B.S. and M.S. in Mechanical Engineering from North Dakota State University.

Tony Facchiano has worked for EPRI as the Environmental Controls Business Unit, NO_x Emissions Control Manager since 1993. Mr. Facchiano has worked for Bechtel Power Corp. and Coen Combustion Company on combustion systems related to utility boilers. Mr. Facchiano has a B.S. and a M.S. from Manhattan College and is a registered professional engineer in the State of California.

Richard Himes has worked in the utility related research field since 1984. He was worked as the director of Engineering for Carnot since 1992. He is responsible for a broad range of technical activities in the areas of applied combustion and emission control technologies. Mr. Himes has a B.S. in Biology, a B.S. in Chemistry, and a M.S. in Mechanical Engineering from the University of California, Irvine. Mr. Himes also has a M.B.A. from the University of Southern California.

Philip Smith is one of the founders of Reaction Engineering International. He has worked in the Los Alamos National Laboratory modeling reactive flows. He has worked as an Associate Professor at Brigham Young University and is presently a professor in the department of Chemical Engineering at the University of Utah. Dr. Smith has a B.S., M.S., and Ph.D. from Brigham Young University.

Michael Bockelie is a senior engineer for Reaction Engineering International. He has spent the last nine years working on the areas grid generation and Computational Fluid Dynamics. He has a B.S. in Mathematics and M.S. in Mechanical Engineering from the University of Utah. Dr. Bocklelie has a Ph.D. in Engineering Mechanics from Columbia University.

Bradley Adams is a senior engineer for Reaction Engineering International. He has worked since 1989 on combustion computations. He has performed R&D in the areas of heat transfer, fluid dynamics, and numerical simulations for the past 10 years.

Detailed resumes of the proposed project team are contained in Appendix A.

7.0 VALUE TO NORTH DAKOTA

To-date, SCR, SNCR and reburning technologies are being promoted for NO_x control on cyclone boilers. These technologies are expensive and reduce the flexibility and/or capability of cyclone boilers. The increased costs associated with these technologies would decrease the lignite unit's ability to compete in the surplus energy market and could increase consumers rates. Both of these effects tend to decrease the amount of electricity generated and lignite fuel burned further decreasing North Dakota lignite consumption. Without further development of NO_x reduction techniques for lignite-fired cyclone boilers, pending stricter emission control legislation, utilities may have to either phase out cyclone-fired boilers, convert them to gas/oil firing, or add expensive NO_x control systems.

Lignite tends to produce less NO_x than sub-bituminious and bituminous coals in a cyclone boiler. The lower NO_x levels from burning lignite combined with NO_x reductions from combustion modification techniques may limit the cost for lignite burning cyclones to comply with new NO_x regulations. The successful completion of this project will maintain the use of lignite in cyclone boilers and preserve existing jobs associated with mining, cleaning, and firing North Dakota lignite in cyclone boilers.

8.0 MANAGEMENT

Curt Melland, together with **Tony Facchiano** from EPRI, will supervise, direct, plan, manage, and analyze all the work assignments with the goal of accomplishing the project objectives in a timely and cost-effective manner. Project planning is initiated with the preparation of proposals and definitive work statements which include project organization, resource requirements, schedule, and costs. The project contracts will require monthly invoicing with justification which will be reviewed by EPRI. Project review meetings will be held as required to ensure the project is kept on track. Once developed, the project plan will only be changed under controlled conditions and only after all elements are appropriately justified and approved by Mr. Melland and Mr. Facchiano.

9.0 TIMETABLE

The period of performance is six months. A schedule reflecting the individual spans for each of the tasks is shown below:

	Months					
	1	2	3	4	5	6
Task 1 - Prepare Geometry	—	—				
Task 2 - Collect Cyclone Data	—					
Task 3 - Validate CFD Model		—	—			
Task 4 - Model Combustion Mod.			—	—		
Task 5 - Reporting			—		—	—

10.0 BUDGET

PROJECT COSTS

1995 EPRI BUSINESS UNIT FEE	$ 11,792
1995 EPRI CNCIG PROJECT FEE	10,000
1996 EPRI BUSINESS UNIT FEE	29,083
1996 EPRI CNCIG PROJECT FEE	10,000
PHASE I NUMERICAL ANALYSIS LIGNITE ANALYSIS	
CYCLONE TESTING	26,000
COAL/ASH TESTING	15,000
SCROLL BURNER GEOMETRY AND BASELINE CASE	13,000
AIR BIASING TEST RUN	3,300
AIR/FUEL STAGING TEST RUN	3,300
FLUE GAS INJECTION TEST RUN	3,300
STEAM INJECTION TEST RUN	3,300
FUEL COMPOSITION VARIATION TEST RUN	19,800
SUBTOTAL	**$147,875**
PROJECT ADMINISTRATION	$ 30,001
TOTAL COSTS	**$177,870**

PROJECT FUNDING

ND RESEARCH COUNCIL GRANT	$ 88,938
LELAND OLDS STATION	29,646
MILTON R. YOUNG STATION	29,646
COYOTE STATION	29,646
TOTAL	**$177,876**

11.0 AFFIDAVITS

AFFIDAVIT

This is to verify that Basin Electric Power Cooperative and its subsidiaries have no due but unpaid tax obligations payable to the State of North Dakota or any of its political subdivisions as of December 12, 1995.

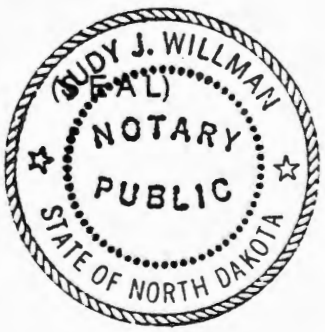
Rod J. Kuhn, CPA
Manager of Tax and Insurance
Basin Electric Power Cooperative

12/12/95
Date

STATE OF NORTH DAKOTA)
) ss.
COUNTY OF BURLEIGH)

Subscribed and sworn to before me this 12th day of December, 1995, by Rod J. Kuhn, known to me to be the Manager of Tax and Insurance of Basin Electric Power Cooperative.

Witness my hand and official seal.



Notary Public, County of Burleigh

JUDY J. WILLMAN
Notary Public, Burleigh Co., ND
My Commission Expires March 1, 1997

My Commission Expires:

MPC MINNKOTA POWER COOPERATIVE, INC. P.O. Box 13200, Grand Forks, ND 58208-3200 • Phone: (701) 795-4000

One of the Minnkota Power Systems

TAX LIABILITY AFFIDAVIT

STATE OF NORTH DAKOTA)
) ss
COUNTY OF GRAND FORKS)

I, Donald L. Zeman, hereby certify that I am the Director of Finance and Administration of Minnkota Power Cooperative, Inc., and that as such, I have personal knowledge of various aspects of its operations including the payment of taxes in North Dakota; that upon investigation, I have determined that all North Dakota taxes have been paid and that Minnkota is not presently in arrears for any such taxes.

Dated this 8th day of December, 1995.

Donald L. Zeman

Donald L. Zeman
Director of Finance and Administration

Subscribed and sworn to before me this 8th day of December, 1995.

Notary Public
My commission expires:

KATHERINE K. ANAGNOST
Notary Public, STATE OF NORTH DAKOTA
My Commission Expires JULY 27, 2000

(seal)

AFFIDAVIT

STATE OF NORTH DAKOTA)
COUNTY OF BURLEIGH)

Bruce T. Imsdahl, being first duly sworn on his oath, says and deposes:

1. That the Coyote Generating Station is a participant in and a member of the North Dakota Lignite Cyclone Users Group which has submitted a grant application and proposal to the Lignite Research Counsel.

2. That Montana-Dakota Utilities Co., a Division of MDU Resources Group, Inc., serves as Operating Agent for the Coyote Generating Station and, as such, determines and submits all taxes due the State and its political subdivisions on behalf of the Coyote Generating Station.

3. That pursuant to the application requirements of Section 43-03-04-01(15), N.D.A.C., Montana-Dakota Utilities Co., as Operating Agent, hereby states that the Coyote Generating Station does not have any outstanding tax liability owed to the State of North Dakota or any of its political subdivisions as of the date of this Affidavit.

Submitted and dated this 11th day of December, 1995.

MONTANA-DAKOTA UTILITIES CO.,
a Division of MDU Resources Group, Inc.
400 North Fourth Street
Bismarck, ND 58501

By: Bruce T. Imsdahl
Bruce T. Imsdahl
Vice President-Energy Supply

Subscribed and sworn to before me this 11th day of December, 1995, by the above-named Bruce T. Imsdahl, known by me to be the person named as the affiant in the above Affidavit.

Sharon L. Sabo, Notary Public
Burleigh County, North Dakota
My Commission Expires: 2/24/2000

(SEAL)