LRC-XVIII-A

Activation Technologies
Grand Forks

Grand Forks Activation Technologies
120 North Washington Street
Grand Forks, ND 58203-3451
Phone/Fax (701) 772-1733

PROJECT TITLE:

PRODUCTION OF ENHANCED PHYSICALLY CLEANED LIGNITE
GFAT Proposal No. 94-1002

Submitted to:

Ms. Karlene Fine

North Dakota Industrial Commission
600 East Boulevard Avenue
State Capitol, Ground Floor
Bismarck, ND 58505-0001

Applicant:
Grand Forks Activation Technologies
120 North Washington Street
Grand Forks, ND 58203-3451

Principal Investigator: Curtis L. Knudson, Ph.D

Date of Application: 10-1-94

Amount of Request: $85,000

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PRODUCTION OF ENHANCED PHYSICALLY CLEANED LIGNITE

1.0 TECHNICAL ABSTRACT

Objective: The objective of this work is to demonstrate that an ultra-clean lignite coal can be produced. The ultra-clean coal would have emissions below 0.5 lbs SO_2/MMBtu if utilized in a fluid bed combustor and below 1 lb SO_2/MMBtu if utilized in a PC-fired or spreader stoker combustor. In addition, the fuel would have less ash fouling tendencies and the ash would be usable as a cement additive.

Expected Results: It is expected that calcium will be ion exchanged into the lignite structure replacing sodium during the physical cleaning process. During combustion of the ultra-clean lignite the molecularly dispersed calcium would more effectively trap sulfur emissions in the ash. Emissions would be reduced from 1 lb SO_2/MMBtu for physically cleaned lignite to an even lower value. Fluid bed combustion tests conducted in a 2-lb/hour unit by the Energy an Environmental Research Center would verify the actual reduction in emissions. Other expected results are that the reduction of sodium in the ultra-clean lignite will minimize ash fouling tendencies during combustion and that with less sodium and more calcium in the ash, it will be more suitable as a cement additive. Tests will be performed to determine possible value-added end uses of the ash. The inexpensive production of a higher quality fuel during the physical cleaning process would make the ultra-clean lignite a more valuable product.

Duration: The duration of the project will be from January 1, 1995 to August 31, 1995.

Total Project Cost: The amount requested from the North Dakota Industrial Commission is $85,000 which is matched by industrial funds for a total of $170,000.

Source	Phase 1	Phase 1a
Knife River Coal Mining Company		$15,000
Grand Forks Activation Tech.	$70,000	
North Dakota Industrial Commission		85,000
Phase 1 and 1a total	$170,000	

Participants: The industrial participants will be the Knife River Coal Mining Company and Grand Forks Activation Technologies. Knife River Coal Mining Company funding is contingent on the North Dakota Industrial Commission's approval of this proposal.

KNIFE RIVER
COAL MINING COMPANY
A Subsidiary of MDU Resources Group, Inc.

1915 North Kavaney Drive
Bismarck, ND 58501-1698
(701) 223-1771
(701) 255-0560 (FAX)

Mine Locations
Beulah, N D
Gascoyne, N D
Savage, MT

September 28, 1994

Mr. Curtis L. Knudson
Grand Forks Activation Technologies
120 North Washington Street
Grand Forks, ND 58203-3451

Dear Mr. Knudson:

Re: Industrial sponsorship for beneficiated coal

Thank you for your interest in Knife River Coal Mining Company relative to your proposal for continuation of research and the development of an enhanced lignite product. Your proposal sets forth various phases in which we have a definite interest. We therefore will initially commit the amount of $15,000.00 for partial funding of Phase 1a of your proposal.

We have reviewed the proposal and are very interested in Phase 1a related to the addition of calcium during a physical cleaning process which would be a follow up of previous efforts in which preliminary results showed that a compliant fuel could be produced in a briquette form.

The $15,000.00 commitment is contingent upon approval of the project by the North Dakota Industrial Commission and securing the additional funding necessary to proceed with the project.

We will issue the funds upon your advising us that the project has secured the necessary funding from NDIC. Please keep us advised on this matter.

Sincerely,

Curtis L. Blohm

Curtis L. Blohm
Vice President
Engineering & Environment

ie

2.0 PROJECT SUMMARY

Knife River Coal Company and Grand Forks Activation Technologies (GFAT) propose to demonstrate an inexpensive, novel beneficiation process for production of a sulfur dioxide emission-compliant, low ash-fouling fuel from Beulah lignite. The proposed work is an extension of work performed by the University of North Dakota Energy & Environmental Research Center (EERC) for the project entitled "Physical Cleaning of Lignite," SFY94-XV-53, and work being performed by GFAT on production of a fluid-bed combustion compliance coal by stock-pile calcium ion-exchange using waste calcium carbonate. Run-of-mine Beulah lignite will be crushed, classified, and processed to investigate the effectiveness of innovative water-based beneficiation techniques in yielding low sulfur, low fouling fuel for fluid-bed or stoker combustion applications. Beneficiation processes to be investigated include dense media separation (DMS) and DMS combined with calcium ion-exchange techniques, and water classification and water classification combined with calcium ion-exchange techniques. The DMS processes will be performed using -1/4-inch by +16-mesh material and the water classification processes will be performed using -16-mesh material. Processed fuels will be evaluated in combustion tests using a 2-pound/hour fluid-bed reactor (FBR) equipped for monitoring SO_2 and other flue gas component concentrations. Samples of combustion test ashes recovered from the FBR cyclone (post-combustion solids separator) will be evaluated based on their suitability as cement additives and for other commercial applications.

3.0 PROJECT DESCRIPTION

3.1 Project Need and Anticipated Results

The need for, and value of the proposed project is based on its potential to sustain and expand commercial demand for Beulah lignite through its use as a feedstock for production of an SO_2 emission-compliant, low ash-fouling fuel. A major need in this effort is to obtain the analytical and performance data required for beneficiation process development and optimization. Commercial combustion equipment vendors contacted by GFAT have requested this information prior to approving performance of demonstration combustion tests.

Anticipated results of the project are the demonstration that the combination of physical cleaning and calcium ion-exchange produces very low sulfur emissions in a fluid bed combustor (FBC), and that the combustion ash has a premium value as a cement additive.

3.2 Objectives and Methodologies

The goal of the proposed work is to develop an economically viable coal beneficiation process that will enable commercial utilization of Beulah lignite for production of a sulfur dioxide (SO_2) emission-compliant, low ash-fouling fuel. This work will demonstrate the technology and provide information required for pilot-plant testing and, ultimately, commercial-scale-up. Explanations of the tasks to be performed follow.

Task 1a Dense Media Separation

Run-of-mine (ROM) Beulah lignite will be crushed and classified to yield coarse and fine coal fractions. Three samples of the coarse coal fraction will undergo three different beneficiation processes: physical cleaning via dense media separation (DMS), DMS combined with calcium ion-exchange (using waste calcium carbonate from the Bismarck water treatment plant), and DMS combined with carbonic acid-enhanced ion-exchange. Task 1 will be subcontracted for performance by the University of North Dakota Energy & Environmental Research Center (EERC), using the EERC pulverized magnetite-water slurry DMS system employed in previous research funded by the North Dakota Lignite Research, Development and Marketing Program.

Task 1b Coal Fines Cleaning

Three samples of the fine coal fraction yielded by Task 1b will undergo three different beneficiation processes: physical cleaning via water classification, water classification combined with calcium ion-exchange (using waste calcium carbonate from the Bismarck water treatment plant), and water classification combined with carbonic acid-enhanced ion-exchange. Task 1b will include design, construction, and optimization of a research-scale water classification system. In addition to resulting in reduced SO_2 emissions, the ion-exchange processes to be studied in Tasks 1a and 1b should also result in a significant level of calcium-for-sodium substitution, thereby reducing the propensity for bed agglomeration, grate slagging, and ash-fouling during fluid-bed or stoker firing.

Task 2. Combustion Testing

The combustion characteristics of beneficiated coal samples will be evaluated in tests using the EERC research-scale (2-pound/hour) fluid bed reactor (FBR) equipped for on-line analysis (using a computer-automated data acquisition system) of flue gas for SO_2, NO_x, CO, CO_2, and O_2 contents. The SO_2 emissions from each beneficiated coal will be compared to emissions from its parent material and emissions from the other beneficiated coals to determine the effect(s) of different processing conditions. NO_x emissions will also be compared to investigate any process-related effects.

Task 3. Ash Evaluation

Comprehensive characterization of one or two of the FBR combustion residues (cyclone ashes) and their hydration products will be performed to investigate their commercial utilization options and potential environmental impacts. Options to be evaluated include utilization in flowable/control density fill, cement additives, brick, soil stabilization, structural fill, production of expansive cement and other specialty cements, waste stabilization, concrete mineral admixture, and "no-cement" concrete.

Additional details on methodology are described in the attached EERC subcontract.

3.3 Environmental and Economic Impacts

Because the project is a lab-scale effort requiring only beneficiation processing and testing of nominally 30- to 50-pound samples, environmental and economic impacts of the project while it is being conducted should be minimal. Disposal of wastes will be handled in accordance with the EERC waste disposal program, which is fully compliant with all relevant state and federal regulations. Assuming that the proposed process is commercially viable, the project could economically impact North Dakota and environmentally impact North Dakota and the United States by expanding commercial demand for Beulah lignite through its utilization in production of a low SO_2-emitting combustor fuel.

3.4 Facilities and Availability

GFAT conducts business from its Washington Street location in Grand Forks. A 1000 sq ft office is dedicated to daily operations and a conference/meeting area. Office equipment includes a Panasonic facsimile/telephone machine, Canon PC-25 photocopier, Magnavox television/VCR, and a full inventory of office supplies. In addition, GFAT is outfitted with two personal computers, one Packard Bell 486DX - 60 Mhz and one MicroSys 486DX - 60 Mhz. These are complemented with both IBM dot matrix and Epson Action Laser printers, and graphics, word processing, and spreadsheet software.

GFAT's laboratory facilities are located in a 375 sq ft area adjacent to its office space. Future plans are to increase this area to approximately 550 sq ft. Laboratory equipment includes a dedicated data acquisition computer, Fluke data logger, Cole-Parmer laboratory oven, ThermoLyne 1300 furnace, and a full stock of laboratory equipment and glassware. Process monitoring-type analyses will be conducted at the GFAT laboratory. These include ion concentration, water, lignite moisture, and lignite ash analyses.

Additional analyses will be conducted through subcontracts to other laboratories such as the EERC in Grand Forks and/or the Minnesota Valley Testing Laboratory (MVTL) in Bismarck. These are both well established analytical and physical-testing laboratories. Coal analyses may be performed by the EERC Coal Laboratory, and x-ray fluorescence analyses can be done by the EERC Inorganic Laboratory using established ASTM procedures. Capabilities exist at both the EERC and MTVL to determine sodium and calcium contents, etc., as needed in the project. Coal-drying equipment is also available to extend the work to the small pilot-plant stage if this study is successful. The dense media processing, combustion tests, and ash evaluation tasks will be completed through subcontract at the EERC.

The Energy & Environmental Research Center (EERC) has well established analytical and physical-testing laboratories necessary to support this work. Coal analyses will be performed by the Coal Laboratory, and x-ray fluorescence analyses will be done by the Inorganic Laboratory using established ASTM procedures. Capabilities exist to determine sodium and calcium contents, etc., as needed in the project. Coal-drying and -briquetting equipment is available to extend the work to the small pilot-plant stage if this study is successful.

The facilities and equipment necessary for this project will be made available by GFAT and EERC as required to complete the proposed work.

4.0 SUCCESS MEASUREMENT STANDARDS

Success of the project will be measured by 1) the level of SO_2 reduction achieved as determined by comparison of processed coal SO_2 emissions to emissions from the unprocessed parent coal, 2) the effectiveness of the calcium ion-exchange technique in incorporating calcium into the coal structure, as determined by the level of calcium-for-sodium substitution achieved (which should impact ash-fouling tendency), and 3) the estimated value of the combustion ash yielded from the calcium-enriched, low-sodium beneficiated fuel, as determined by the ash utilization evaluation.

5.0 BACKGROUND

Recent work performed at the EERC demonstrated that pyrite could be effectively removed from Beulah lignite by relatively inexpensive physical cleaning. However, the sodium oxide content in the ash was essentially the same (1). Sodium in the ash has been found to cause ash fouling during combustion and more recently has been reported to cause bed material in fluid bed combustion units to agglomerate (2).

The sodium is not originally in the ash but is highly dispersed as individual ions throughout lignite as salts. Lignites contain quantities of organic acids and salts:

$Coal\text{-}CO_3^-\ H^+$ $\quad$ $Coal\text{-}CO_3^-\ Na^+$ $\quad$ $Coal\text{-}(CO_3^-)_2\ Ca^{++}$

These are typically called weak carboxylic acids or salts of carboxylic acids.

The EERC has demonstrated that low-ash, low-sodium fuels can be produced by chemical cleaning (treating the coal with an acid to ion-exchange out sodium ions) of fine coal (3–6). The near-complete removal of sodium and potassium and over-50% removal of calcium and magnesium can be achieved using dilute (<3 wt%) solutions of nitric, hydrochloric or sulfuric acid (7). Recent testing has also demonstrated that modest ash reductions (~ 15%) and significant sodium reductions (up to 75%) can be achieved using CO_2 dissolved in a slurry of pulverized coal and water (8). However, beneficial calcium can also be removed.

Calcium carbonate has a low solubility in water (4.7×10^{-4} Molar at 25°C and atmospheric carbon dioxide) and causes the pH of the solution to increase to 8. Carbon dioxide is about 0.03% of the atmosphere, which is similar to its partial pressure in air. This creates a carbon dioxide solubility in water as carbonic acid of only 10^{-5} Molar, which though low, has a significant effect on the geological weathering of calcite formations (9). Increasing the partial pressure of carbon dioxide to 1 atmosphere increases the amount of carbonic acid in water to 0.031 Molar. This can greatly influence the solubility of calcium carbonate since carbonic acid can interact with calcium carbonate:

$$CaCO_3 + H_2CO_3 <=====> 2HCO_3^- + Ca^{2+}$$

The solubility of calcium carbonate can be increased significantly to 0.1 to 0.2 Molar.

Carboxylic acid groups in the coal can also interact with solid calcium carbonate outside the coal structure, increasing the amount of calcium ions in solution. Hydrogen

ions are easily transferred throughout water by simple shifts in hydrogen bonding (they do not have to physically move).

$$CaCO_3 + Coal\text{-}HCO_3 <=====> Coal\text{-}CO_3^- + Ca^{2+} + HCO_3^-$$

If the calcium ions are in solution while the negatively charged carboxyl group is in the coal structure, the calcium ion will be forced to migrate into the lignite to obtain a charge balance. This will cause dispersion of single calcium ions throughout the lignite.

The sodium ions can be ion-exchanged with calcium ions resulting in the removal of sodium from the lignite while adding calcium to the lignite. Since calcium ions have a plus two charge while hydrogen and sodium ions have a plus one charge, calcium is preferred over hydrogen or sodium by a factor of 10. For instance, a solution of 0.1 Molar acid (singly charged hydrogen ions) will effectively remove singly charged sodium from lignite; however, it requires a 1 Molar acid solution to remove doubly charged calcium ions. Calcium in solution will, in reverse, effectively replace either sodium or hydrogen ions in lignite.

In this work it will be determined whether or not sodium can be effectively removed and replaced by calcium while also removing high sulfur pyrite to produce an enhanced physically cleaned lignite product. The effectiveness of the added calcium to reduce sulfur emissions during combustion will be determined, as will the suitability of this modified ash to have an end-use as a cement replacement.

6.0 QUALIFICATIONS

GFAT presently consists of the owner, Dr. Curt Knudson, a research associate, Tim Gerlach, and a student employee. Plans are being made to hire a laboratory assistant. In addition, two full time EERC employees assist on a part time, as needed, basis.

Under subcontract, Ted Aulich, Mark Musich, Mike Swanson, and Debbie Hassett will participate in this work; their resumes are part of the attached EERC subcontract. Dr. Knudson's resume follows:

Dr. Curtis L. Knudson
Professional Background

Dr. Curtis L. Knudson will be the Principal Investigator of this effort. He is the Business Manager of GFAT, which is a sole proprietorship. He is part owner and bookkeeper of Art and Learn (a retail store) that recently opened a branch store in Nehalem, Oregon, the sole proprietor of Research-Computer Services (a consulting firm formed five years ago), and is employed (since 1975) as a contract researcher at EERC. He has had consulting contracts with the Alberta Research Council, Amoco Research, Knife River Coal Mining Company, and the Korean Institute of Energy Research. EERC is a nonprofit, contract research organization that was formerly part of the U.S. Department of Energy. Present contracts through the EERC cover 49% of his time while 51%+ is devoted to the development of Grand Forks Activation Technologies. He has also acted as an architect/contractor/laborer in the development of 3 houses and 2 business establishments, for a total value of over $500,000.

Dr. Knudson has been a Project Manager (responsible for the administration of $1,200,000 per year in research funding and a staff of 12 research professionals) and has been responsible for his own research group. He has successfully prepared and submitted proposals and been the Principal Investigator on numerous projects at the EERC, and is presently the Principal Investigator of the National Alternative Fuels Laboratory. Previous recent contracts have been industry-sponsored joint-venture projects with government agencies. He holds 5 patents in the areas of lignite conversion and lignite beneficiation and was the scientist (in each patent) that worked with the patent attorneys. Dr. Knudson initiated the research and is the inventor (or one of the inventors) for patents in low-rank coal-oil agglomeration and the use of leonardite to produce char, which are presently being studied (through DOE funding) under EERC's Cooperative Agreement. He remains an advisor in these projects.

More recently, Dr. Knudson's attention is being focused on the research and development of commercial products. His involvement as the Principal Investigator in a recent project entitled "Multiple-Use Marketing of Lignite" (sponsored by the J.R. Simplot Company, Knife River Coal Mining Company, the North Dakota Industrial Commission, and the U.S. Department of Energy), and past research on coal properties (including low-rank coal structure, ion exchange and sulfur retention in ash studies), have led him to believe that using waste calcium materials to chemically modify coal could produce an FBC fuel that would yield less waste solids while trapping sulfur. This concept was recently funded by the Department of Energy's Small Business Innovative Research Program to Grand Forks Activation Technologies. However, this work is aimed at the addition of calcium at the mine stock pile to add just enough calcium to make a lignite barely compliant if utilized in an FBC.

Dr. Knudson was the proposer and Principal Investigator on the recent Physical Cleaning of Lignite project that demonstrated that a compliant lignite could be produced (results of the project were verified in the follow-up project where over a ton of clean lignite was produced and delivered for combustion testing). A water carrier was used in the physical cleaning process. The incorporation of calcium into the coal structure while simultaneously decreasing the sodium content during the physical cleaning of lignite could result in creating an ultra-clean lignite (emissions of 0.2 to 0.5 lbs SO_2/MMBtu in an FBC and under 1 in PC-fired or spreader-stoker units) with much less ash fouling tendencies and perhaps producing an ash usable as a cement additive. This proposal has been submitted to demonstrate the technical validity of this concept by physically cleaning lignite, performing fluid bed combustion studies, and performing an ash evaluation as a cement additive.

Active Contracts

National Alternative Fuels Laboratory: $224,000; U.S. Department of Agriculture, Principal Investigator.

Physical Cleaning of Lignite: $60,000; Knife River Coal Mining Company, North Dakota Industrial Commission, and U.S. DOE; Principal Investigator (completed September, 1994)

Education and Military Experience

Ph.D., Analytical Chemistry, University of North Dakota, 1975.
M.S., Analytical Chemistry, University of North Dakota, 1972.
B.A., ACS accredited, Augsburg College, Minneapolis, Minnesota, 1969.
U.S. Army, August 1964-July 1967.
Bemidji State College, Bemidji, Minnesota, 1964.
St. Olaf College, Northfield, Minnesota, 1962-1964.

Professional Memberships

American Chemical Society
Sigma Xi
North Dakota Academy of Science

Patents

Knudson, Curtis L., Warrack G. Willson, Gene G. Baker, Everett A. Sondreal, and Sylvia A. Farnum, "Continuous Process for Conversion of Coal," U.S. Patent 4,337,142, June 29, 1982.

Knudson, Curtis L., John R. Rindt, and Sylvia A. Farnum, "Ionic Liquefaction Process," U.S. Patent 4,846,963, July 11, 1989.

Knudson, Curtis L., Ronald C. Timpe, "Low-Rank Coal Oil Agglomeration," U.S. Patent 5,032,146, July 16, 1991.

Knudson, Curtis L., Ronald C. Timpe, "Low-Rank Coal Oil Agglomeration Product and Process," U.S. Patent 5,162,050, November 10, 1992.

Knudson, Curtis L., "Leonardite Char Adsorbents," U.S. Patent No. 5,254,521, October 19, 1993.

Publications and Presentations

- Aulich, T.R.; He, X.; Knudson, C.L. "Gasoline Sampling Technique Crucial to Ensuring RVP Compliance," *Oil & Gas Journal*, Oct. 4, 1993, p. 80.

- Knudson, C.L.; Kruse, C.W.; Assanis, D.N.; Feizoulof, C.; Ehrlinger, H.P.; Rostam-Abadi, M. "Lignin-Augmented Bituminous Coal Depolymerization: A Route to Clean Coal," final report to U.S. DOE/PETC DE-FC21-86MC10637, EERC publication, Sept. 17, 1991.

- Knudson, C.L.; Rindt, D.K.; Ruud, A.L. "Chemical Relationship in Ethanol and Nonethanol Fuels," *Prepr. Pap.—Am. Chem Soc., Div. Fuel Chem.* **1990**, *35* (1), 285-291.

- Knudson, C.L.; Aulich, T.R. "Desulfurization Using CO/Ethanol II," final technical progress report to USDOE/METC for the period of July 1, 1989 - June 30, 1990; EERC publication, Sept 1990.

- Potas, T.A.; Anderson, C.M.; Musich, M.A.; DeWall, R.A.; Knudson, C.L.; Gunderson, J.R.; Swanson, M.L.; Stepan, D.J.; Rezania, L.W.; Stevens, B.L. "Preparation and Combustion of Loy Yang Coal/Water Fuel," final report to State Electric Commission of Victoria, Australia; EERC publication, Sept. 1990.

- Knudson, C.L. "Production of Jet Fuels from Coal-Derived Liquids: Vol XIV - Oxygenates Content of Coal-Derived Jet Fuels," interim report for the period Nov. 26, 1986 - Jul. 31, 1989, Aero Propulsion and Power Laboratory, Department of the Air Force; Wright-Patterson Air Force Base, OH, June 1990.

- Timpe, R.C.; Knudson, C.L. "Evaluation of Formed Coke Products," final report to the North Dakota Industrial Commission, EERC publication, Sept. 1989.

- Aulich, T.R.; Knudson, C.L.; Hawthorne, S.B. "Coal Liquefaction Using Deuterium-Labeled Anthracene Oil Solvent," *Prepr. Pap.—Am. Chem. Soc., Div. of Fuel Chem.* **1988**, *33* (2), 368-379.

- Knudson, C.L.; Willson, W.G.; Miller, D.J.; Ness, R.O.; Ruud, A. "Composition of Jet Fuels from Tar Oil," *Prepr. Pap.—Am. Chem. Soc., Div. Petroleum Chem.* **1987**, *32* (2), 591.

- Knudson, C.L.; Rindt, J.R.; Willson, W.G. "Low-Severity Coal Processing: The ChemCoal Process," *In* Proceedings of the Fourth Korea-U.S. Joint Workshop on Coal Utilization Technology; Seoul, South Korea, Oct. 1987.

- Knudson, C.L. "Wyodak Coal: Composition, Reactions, and Products," EPRI AP-4536, Project 2655-3, Final Report, May 1986.

- Holm, P.L.; Knudson, C.L. "Coal Mineral Matter and its Effects on Low-Rank Coal Liquefaction," Topical Report No. V, DOE/FC/10120, Aug. 1985.

- Knudson, C.L.; Baltisberger, R.J.; Woolsey, N.F.; Willson, W.G. "Changes in Asphaltenes and Preasphaltenes with Reaction Conditions and Effects on Coal Structure," *Prepr. Pap.—Am. Chem. Soc., Div. Fuel Chem.* **1984**, *29* (5), 31-42.

- Knudson, C.L.; du Plessis, M.P. "Coal Hydrogen Effects on Pyrolysis and Liquefaction Conversion," *In* CANMET, Proceedings of the Coal Conversion Contractors' Review Meeting; Calgary, Canada, Nov. 1984, p 146.

- Knudson, C.L.; Willson, W.G.; Baker, G.G. "Hydrogen-Carbon Monoxide Reactions in Low-Rank Coal Liquefaction," *Prepr. Pap.—Am. Chem. Soc., Div. Fuel Chem.* **1981**, March.

- Willson, W.G.; Knudson, C.L.; Baker, G.G.; Owens, T.C.; Severson, D.E. "Application of Liquefaction Process to Low-Rank Coals," *In* Proceedings of the 1979 Lignite Symposium; Grand Forks, ND, May 30-31, 1979; DOE GFETC/IC-79/1, pp 170-206; and "I&EC Product R&D," No. 18, Dec. 1979, p 14.

- Stenberg, V.I.; Baltisberger, R.J.; Knittel, D.; Wettlaufer, D.; Woolsey, N.F.; Knudson, C.L. "New Catalysts for Carbon Monoxide-Water Induced Liquefaction," *In*

Proceedings of the 14th Intersociety Energy Conversion Conference; Boston, MA, Aug. 5-10, 1979.

- Knudson, C.L.: Schiller, J.E.; Ruud, A.L. "Temperature Effects on Coal Liquefaction: Rates of Depolymerization and Product Quality as Determined by Gel Permeation Chromatography," *Prepr. Pap.—Am. Chem. Soc., Div. Fuel Chem.*, Chicago, IL, August 1977; *Organic Chemistry of Coal*, ACS Series 71; Larsen, J.W., Ed.; Washington, DC, 1978, p 15.

- Schiller, J.E.; Knudson, C.L. "Effect of Solvent Molecular Composition in Coal Liquefaction," *Fuel* **1978**, *57*, 36-40.

- Baltisberger, R.J.; Knudson, C.L. "Investigation of Isothiocyanatopentaaquochromium (III) as a Reagent for the Separation and Identification of Nanogram Quantities of Mercury (I), Mercury (II), and Methylmercury (II)," *Anal. Chem.* **1975**, *48*, 1402-1406.

7.0 VALUE TO NORTH DAKOTA

North Dakota's economy stands to gain the most from this undertaking. If successful, an efficient, ultra-clean fuel will be produced from North Dakota lignite. In addition:

Water treatment sludge, containing calcium, will be utilized, thereby reducing dependence on landfilling. With the advent of Subtitle D regulations and the closing of many small local landfills, larger regional landfills have taken on increasing volumes, and tipping fees have escalated. Although North Dakota's costs remain below the national average, future projections are that costs will continue to multiply into the 21st Century. Future utilization of water treatment sludge will reduce disposal costs, an added savings, to North Dakota municipalities.

North Dakota's quality of life would improve by way of an expanded economic base. A successful end result of this project could mean an increase in mining, processing, and steam/electrical generating capacity in North Dakota (and the increase in jobs that would accompany it). Also, an ultra-clean lignite fuel would be extremely attractive to markets outside North Dakota. North Dakota lignite would be better able to compete with cleaner, higher rank coals, oil, and gas. North Dakota lignite could assist with the reduction in our nation's dependence on foreign energy sources.

Our North Dakota quality of life could improve in other ways as well. The proposed work, an efficient, clean coal technology, will investigate the process of ion exchanging calcium in lignite. Calcium traps sulfur during combustion, thereby reducing air pollution (SO_2). Ion-exchanged calcium is hoped to be more efficient and better able to trap sulfur at lower Ca/S molar ratios. The goal of this work is to demonstrate that an ultra-clean lignite can be produced that during combustion creates less than 0.2 lbs SO_2/MMBtu of coal burned. North Dakota would continue to be known for its pristine air even while increasing its use of lignite.

What successful completion of this project could mean to North Dakota:

1. Increase North Dakota mining production (goal: 1 million tons per year)

2. Consume waste agricultural products (goal: 1 million bushels per year for binder material)

3. Consume waste calcium sludge from water treatment (all we can get!)

4. Increase local jobs in producing clean, inexpensive steam from North Dakota lignite

5. Produce a value-added ash product

6. Create an export market for this value-added lignite product

8.0 MANAGEMENT

The management of this work will be the responsibility of the Principal Investigator, Curtis L. Knudson of Grand Forks Activation Technologies. He will be responsible to maintain close contact with the co-industrial partner, Curtis Blohm of the Knife River Coal Mining Company, and Clifford Porter of the Lignite Research Council to inform them of research results and any changes in work that may be necessary. He will coordinate efforts between GFAT and the EERC through the EERC Principal Investigator, Ted Aulich. Ted Aulich will oversee the work performed by the EERC task leaders and be responsible for sample and data transfer between research groups as well as reporting results to GFAT. Periodic meetings will be held between Dr. Knudson and EERC personnel (more often during testing) to insure communication is maintained. Dr. Knudson will be responsible for the final report.

9.0 TIMETABLE

The timetable to complete the tasks and reports is listed as follows:

	Completion Date
Contract Award	1-1-95
Coal Procurement Coal Crushing and Classifying Coal Analysis, Float-Sink Testing	3-31-95
Progress Report	3-31-95
Task 1a Dense Media Separation	4-15-95
Task 1b Coal Fines Cleaning	5-31-95
Task 2 Combustion Tests	6-1-95
Task 3 Ash Evaluation	7-1-95
Draft of Final Report	8-1-95
Final Report	8-31-95

10.0 BUDGET

The estimated budget for the proposed Phase 1a work described in this proposal is as follows:

Budget for Phase 1a Work

A. PERSONNEL	$/hour	Hours	Wage	Fringe 16.20%	TOTALS
C.Knudson	$32.00	260	$8,320	$1,348	$9,668
T.Aulich	$23.50	100	2,350	381	2,731
A.Grisanti	$23.50	60	1,410	228	1,638
T.Gerlach	$17.00	720	12,240	1,983	14,223
Lab Tech.	$10.00	120	1,200	194	1,394
TOTAL	$20.25	1,260	25,520	4,134	29,654
					$29,654
B. CONSULTANTS					
Hauserman Assoc.	$40.00	48	1,920		1,920
C. LEASED EQUIPMENT	none				
D. PURCHASED EQUIPMENT	none				
TOTAL EQUIPMENT.....					0
E. TRAVEL					
Trip - 1				242	
Trip - 2				242	
TOTAL TRAVEL					484
F. OTHER DIRECT COSTS					
1. Materials and Supplies				4,800	
2. Publication Costs				800	
3. Testing Services				1,500	
4. Computer Services				0	
5. Subcontracts				49,061	
6. Other				1,493	
TOTAL OTHER DIRECT COSTS.....					57,654
G. TOTAL DIRECT COSTS					89,712
H. INDIRECT COSTS		15.67%			10,288
I. TOTAL COSTS					100,000
J. FEE OR PROFIT		5.00%			5,000
K. APPLICANTS COST SHARING - waiver of fee					
TOTAL APPL. COST SHARING.....					(5,000)
L. TOTAL AMOUNT OF THIS REQUEST (I. plus J. minus K.)					$100,000

Fringe Benefits include SS, etc., and 13 days VHS.
Indirect on first $25,000 of subcontract.

The proposed work will be done on a fixed-price basis. The distribution of costs between budget categories (labor, travel, supplies, equipment, subcontracts) is for planning purposes only. The principal investigator may, as dictated by the needs of the work, reallocate the budget among approved items or use the funds for other items directly related to the project, subject only to staying within the total dollars authorized for the overall program. Financial reporting will be at the total project level.

11.0 MATCHING FUNDS

The industrial participants in this program are Knife River Coal Mining Company and Grand Forks Activation Technologies (GFAT). GFAT is a recently established Research-Development-Marketing company with a direct goal of expanding the use of North Dakota lignite in North Dakota and as a value-added export product. The GFAT cost-share is already committed to demonstrate the ability to produce an enhanced lignite through the stockpile addition of calcium. This Phase 1 work will consist of producing test quantities of enhanced lignite and performing fluid bed combustion tests to determine the efficiency of ion-exchanged calcium at reducing sulfur emissions. Phase 1 work also involves locating mining companies and commercial FBC vendors who would participate in a Phase 2 pilot demonstration effort and, based on the success of the Phase 2 work, would participate in commercialization. Recent success at the EERC in physically cleaning lignite produced a lignite product with compliant sulfur levels, but still contained 4.5 wt% of sodium oxide in the ash. Introduction of calcium during the physical cleaning process (possibly with the addition of carbonic acid) would reduce (eliminate?) the sodium content resulting in an ash that should then have reduced fouling tendencies. With the added calcium, a further decrease in sulfur emissions would be achieved. This fuel would be an ultra-compliant FBC fuel and/or a compliant, non-fouling PC-fired or spreader stoker fuel, broadening the potential uses of lignite. GFAT obtained Phase 1 investment funding of $70,000 through the DOE-SBIR Program. Knife River Coal Mining has committed $15,000 to the program for Phase 1a work if the North Dakota Industrial Council agrees to invest $85,000. The use of waste calcium and relatively inexpensive physical cleaning technology could produce an enhanced, compliant lignite fuel.

12.0 TAX LIABILITY

Grand Forks Activation Technologies (GFAT), Dr. Curtis L. Knudson, and none of his activities/involvements have any outstanding tax liabilities owed to the city of Grand Forks, the states of North Dakota, Oregon, or other state governments, or the United States of America or any other entities.

13.0 REFERENCES

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