Energy &
Environmental
Research
Center

UNIVERSITY OF NORTH DAKOTA
15 North 23rd Street — P.O. Box 9018 / Grand Forks, ND 58202-9018 / Phone: (701) 777-5000 Fax: 777-5181

PROJECT TITLE:

PHYSICAL CLEANING OF LIGNITE

EERC Proposal No. 94-6114
RFP No. 1993-2

Submitted to:

Ms. Karlene Fine

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

Applicant:

Energy & Environmental Research Center
University of North Dakota
P.O. Box 9018
Grand Forks, ND 58202-9018

Principal Investigator: Curtis L. Knudson, Ph.D

Date of Application: 9-29-93

Amount of Request: $80,000

TABLE OF CONTENTS

Page

PHYSICAL CLEANING OF LIGNITE

1.0 TECHNICAL ABSTRACT

Objective: The goal of this effort is to produce 100-pound samples of coal products with reduced sulfur, moisture, and sodium oxide contents with improved handling using the cheapest available processes. The effort will entail crushing and sizing lignite two methods. The various fractions obtained will be analyzed and processing of suitable fractions using washability, dense media, magnetic separation, and ion exchange will be done to produce an upgraded product. The most inexpensive reagents or methods (e.g., water, air, carbon dioxide, heat) will be used in the processing. The objective of the Phase 1 work is to determine if one lignite is worthwhile to process 100-pound lots. Other sponsors will be sought for additional lignite samples.

Expected Results: This work should determine whether selected North Dakota lignites can be fractionated and physically cleaned and treated to produce a product meeting the specifications given in the RFP. Sodium oxide and moisture levels are expected to be readily attained, but skepticism exists as to the attainability of low enough sulfur contents using only physical methods. While the final proposed process may not prove to be economically accomplished for under $0.50 per MMBtu, without this work, the economic feasibility will remain unknown for this coal. Optimistically, the Phase 1 effort will produce a scheme with which to successfully upgrade select North Dakota lignites.

Duration: The duration of the project will be from January 1, 1994 to September 1, 1994.

Total Project Cost:

This would be a jointly funded project with no funds committed until all of the parties are in agreement. The amount requested from the North Dakota Industrial Commission is $80,000 subject to the locating of matching funds.

Source	Total	Phase 1
Industrial	$80,000	$15,000
North Dakota	$80,000	$15,000
DOE	$160,000	$30,000
Total	$320,000	$60,000

Participants: The initial participants are expected to be the Knife River Coal Mining Company and the Department of Energy (DOE). Knife River has verbally committed to Phase 1 of the project subject to their final approval of the proposed work. Matching DOE funds will be requested for all industrial and North Dakota State Industrial Commission funds as they are secured.

2.0 PROJECT SUMMARY

The ultimate goal of this effort is to produce 100-pound samples of specification coal product using the least-expensive available processes. There are multiple objectives to be reached to achieve the goal. They include crushing, grinding, and splitting the initial coal sample into various particle sizes and subjecting the different splits to analysis and the appropriate laboratory coal-cleaning feasibility tests. It is desirable that one sizable split is found that is lower in sulfur content or amenable to processing to reduce sulfur content using known technologies. Testing will include the agglomeration of fines from wash water using an EERC-patented process and briquetting feasibility tests to improve handling by reducing fines and depressing spontaneous combustion.

From the above results a methodology will be developed (Phase 1 work) and a 100-pound sample will be processed (follow-on Phase 2 work) to demonstrate the methodology. A preliminary economic evaluation based on raw-material costs and published material will be made and data prepared for use in making an economic evaluation. A product evaluation will be made concerning the final end use of the coal product.

3.0 PROJECT DESCRIPTION

3.1 Coal Preparation and Characterization

3.1.1 Coal Preparation

The lignite(s) in this study will be crushed and classified, according to Scheme 1, to size ranges considered appropriate for conventional bench-scale characterization. Initial crushing of the run-of-mine (ROM) coal will be performed in a once-through, roll-crushing process and subsequent size reductions will be performed via hammer-mill crushing. Through the process of stage crushing (screening and crushing only the oversize), fines production will be reduced. Riffling, either automated or manual, will be used to maintain relative consistency in coal properties during subsequent splitting.

The coal fractions to be produced by splitting and stage crushing the head fraction (1.5" x 0") are 0.375" x 0" and 14-mesh x 0"; an optional fraction for study includes 100-mesh x 0". The fractions will be dry classified, as shown in Scheme 1, prior to washability analysis. These size fractions are preferred for two major reasons: 1) to assure proper separation during washability testing, and 2) to closely represent the size ranges treatable by conventional full-scale physical cleaning methods. For example, 0.375" x 14-mesh coal is a suitable feed for heavy-media cycloning while 14-mesh x 100-mesh is a suitable feed for heavy-media spiral separation.

Analysis on the head fraction (1.5" x 0"), stream 2, will include proximate, ultimate, heating value, ash XRFA, and sulfur forms. The crushed and classified fractions, streams 3 and 7 (10 optional), will be subjected to dry and wet sieve. Short-proximate analyses (moisture, ash, heating value, and total sulfur) will also be performed on these fractions to observe any deviation in fuel properties related to sample splitting. The dry-classified fractions (e.g. 0.375" x 14-mesh) will be subjected to proximate and ultimate, heating value, ash XRFA, dry and wet sieve, and sulfur forms analysis. These data will give an indication of the effect of grinding and classification on the liberation of inorganics and pyrites.

3.1.2 Washability Analysis

Washability (float–sink) testing will be performed on surface-dry samples of the crushed and classified lignite(s) fractions, i.e. streams 4, 5, 6, 8 and 9 (10 optional). True specific gravity solutions will be used to perform separations at relative densities of 1.3, 1.4, and 1.6. Static separation (G = 1) will be used on samples coarser than 14-mesh, centrifugal separation (G = +500) will be used on samples finer than 14-mesh.

Analysis for the 3-float/1-sink fraction for each coal-size range (e.g. 0.375" x 14-mesh) will include ash and total sulfur; select float and sink samples will be analyzed for forms of sulfur and ASTM ash composition. The data from float–sink washability tests will indicate the liberation and reduction of coal inorganics and sulfur (pyrites) as a function of Btu recovery under ideal (near 100% separation efficiency) conditions of gravity-based physical cleaning. The results will be used to predict actual separations using conventional, full-scale, non-ideal (less than 100% separation efficiency) physical cleaning methods.

3.2 Coal Preparation and Water Separation

3.2.1 Coal Preparation

The lignite(s) in this study will be reduced to a nominal top size of 1.5" via once-through roll crushing and then will be stage crushed to a 0.25"-top size via hammer-mill crushing. Again automated or manual riffling will be used to maintain relative consistency in coal properties during splitting.

3.2.2 Water Separation

Water separation (wet classification) will be performed via the methodology depicted in Scheme 2. This classification technique will suppress hazardous air-born dust, which is typically generated during low-rank coal handling. Previous experience has also indicated that this safe, yet simple, technique can achieve sharp coal-size separations.

The crushed and 0.25" x 0"-classified lignite(s) will be slurried and charged to the classifying vessel shown in Scheme 2. Water will be circulated at a predetermined rate, based on the vessel geometry, to facilitate elutriation of the desired size fraction of coal. The coarse (unelutriated) coal fraction will remain in the classifying vessel; the circulating water containing elutriated fines will discharge to a clarifier to facilitate gravity separation. The clarifier water will be decanted to recover the settled fines. Ultrafines suspended in the clarifier water will be recovered by mechanical or coagulation (agglomeration) techniques.

Analysis on the head fraction (stream 1), coarse coal (stream 2), settled fines (stream 3), and ultrafines (stream 4) will include short proximate, wet sieve, and sulfur forms.

The coarse and settled coal fractions produced from water separation (classification) will be air dried, in a vitiated air atmosphere, to reduce surface-moisture content. Each fraction will be subjected to bench-scale float–sink testing using static separation on the coarse coal and centrifugal separation on the settled coal. Separations will be performed at relative densities of 1.3, 1.4 and 1.6; each float and sink fraction will be analyzed for ash and total sulfur, and select samples will be analyzed for forms of sulfur and ash XRFA. The data from float–sink washability will indicate the liberation and reduction of coal inorganics and sulfur (pyrites) as a function of Btu recovery under ideal conditions of gravity-based physical cleaning. The results will be used to predict actual separations using conventional full-scale non-ideal physical cleaning methods.

3.3 Ion Exchange for Sodium and Ash Reduction

3.3.1 Carbonic Acid Treatment

Carbonic acid (CO_2 dissolved in water) will be investigated as an agent for reducing the sodium content of the coal (or ash) to specified levels; concurrently, the coal-ash content will be proportionally reduced. Previous experiments have indicated that carbonic acid is selective toward the reduction of sodium over other inorganic species such as calcium. Ion exchange with carbonic acid will be performed on up to six selected samples, including float fractions from streams 4, 5, and 8 (Scheme 1) and one or more of the fractions from streams 1, 2, and 3 (Scheme 2) of the water-washing tests.

Carbonic acid treatment will be accomplished via one of two methods. In the first method, a sample will be slurried in deionized water and charged to an appropriate vessel into which CO_2 will be bubbled to produce carbonic acid and achieve sodium reduction. In the second method, the slurry will be charged to a pressure vessel into which CO_2 will be charged at elevated pressures, causing CO_2 to dissolve in the slurry. Coals will be subjected to additional size reduction prior to carbonic acid treatment.

Provisions can also be made to achieve sodium reduction concurrent to the water washing of the coal by bubbling CO_2 into the clarifier or decantate vessel.

Reduction of coal sodium will be determined via flame photometric analysis of the ion-exchange process water; select coal samples will be ashed and analyzed via XRFA. Reduction of coal-ash content will be determined by ASTM methods.

3.3.2 Alternative Ion Exchange Agents

Two additional ion exchange agents may be evaluated for reduction of coal sodium, mine-site processing water and dilute nitric acid. A coal sample will be mixed in the proper ratio with the processing water or dilute nitric acid and the slurry will be mixed in an open vessel at atmospheric pressure.

Reduction of coal sodium will be determined via flame photometric analysis of the ion-exchange process water; select coal samples will ashed and analyzed via XRFA. The consumption of acid (hydrogen ions) will be determined by titration of the mine-site processing water or dilute nitric acid before and after coal treatment. Reduction of coal-ash content will be determined by ASTM methods.

3.4 Oil Agglomeration

3.4.1 Selective Agglomeration

Selective agglomeration will be evaluated as a method of separating liberated inorganics and pyrites from fine coals. Selective agglomeration will be performed on 100-mesh x 0" fractions (streams 4 and 9 in Scheme 1) and the settled fines (stream 2 in Scheme

2). The preferred oils will be crude phenol, tar oil, or fractions of these streams, all obtained from the Dakota Gasification Company's (DGC) Great Plains Synfuels Plant. The oil-to-coal ratio will be varied to observe the effect on coal recovery.

The effectiveness of selective agglomeration will be determined from ash and total-sulfur determinations on the agglomerates. Supplemental analysis will include determination of agglomerate-oil content via Soxhlet extraction or other suitable means.

3.4.2 Oil Agglomeration for Fine-Coal Recovery and Water Cleanup

Oil agglomeration will be investigated as a substitute method for recovering the ultrafine coal that will remain suspended in the decantate water (Scheme 2 above) during water washing. The previously tested DGC oils or a bitumen will be added in varying quantities to the ultrafine-coal-slurry suspension, and mixing will be employed to cause coagulation of the particles. The recovered agglomerates will be analyzed for ash, total sulfur, and oil content; the process water will be analyzed for total suspended solids (TSS) before and after testing to determine the effectiveness of recovery by oil agglomeration.

3.4.3 Briquetting

The physically and/or carbonic acid-cleaned coals produced in previous tests will be aggregated in a lump fuel via bench-scale tableting. A manually operated press with a maximum compressive force of five tons will be used to make tablets 1.25" in diameter, 0.75" thick and up to 20 grams in mass. The tablets will be air dried at prevailing atmospheric conditions or will be thermally dried at 200°F in a furnace purged with vitiated air. Tablets will be subjected to friability and dustiness evaluation via drop/shatter, tumble, and compressive testing. The moisture stability of the tablets will be evaluated by soaking the tablets in water and then subjecting them to compressive testing.

The primary binders of interest will be the DGC coal-derived oils. Agglomerates produced with these oils will be admixed with coarser coal fractions produced during float–sink or water wash testing. Subject to the results of friability, dustiness, and moisture stability testing, supplemental binders may be used to improve these specific criteria.

3.5 Work Statement

1. Four drums of coal will be obtained from each participating coal company.

2. Each will be crushed and sized as follows:
   a) sieved to give fractions indicated in Scheme 1
   b) water washed to produce fractions indicated in Scheme 2

3. Proximate, ultimate, heating value, ash-analysis (performed by XRFA), and sulfur-forms data will be obtained on fractions 2, 4, 5, 6, 8, and 9 (optional on 10). Short-proximate analyses will be performed on fractions 3 and 7. Float–sink tests will be performed at densities of 1.3, 1.4, and 1.6 on fractions 4, 5, 6, 8, and 9 (optional on 10). Short-proximate, ash-analysis (XRFA), and sulfur-forms data will be obtained on the float and sink fractions. Sulfur and inorganic (ash) reductions will be assessed as a function of coal and Btu recovery.

4. Ion exchange tests, to modify sodium content and to give a small ash reduction, will be performed on up to six selected samples each from Schemes 1 and 2. The preferred agent will be carbonated water (carbonic acid), however, a strong acid may be required, depending on the sodium content of the parent coal. Mine-site processing water will be collected and analyzed to determine its suitability for ion exchange.

5. Sulfur reduction tests will be performed using magnetic methods on up to six selected samples chosen from fractions 4, 5, 6, 8 and 9 (optional on 10). The selection of samples will depend on previously determined analytical and float–sink data. Analyses to be performed include short-proximate analyses and sulfur forms.

6. It was initially desired to include up to six small-scale tests using elevated temperatures and partial oxidation or pyrolysis to reduce pyritic and organic sulfur content. However, this task is not possible based on the proposed funding level.

7. Oil agglomeration will be investigated for two purposes: 1) to affect selective rejection of ash and pyrite from ion-exchanged coal fines, and 2) to simultaneously recover ultrafines and clean process water that may be produced during water washing as shown in Scheme 2. The analyses to be performed on the agglomerates include short-proximate analyses and sulfur forms. The agglomeration oil used would be obtained from the Dakota Gasification Company, and the methods used are covered in an EERC-held patent concerning oil agglomeration of low-rank coals.

8. As necessary, samples will be dried prior to further testing. The amount of water removed and potential, commercially available, methods will be determined.

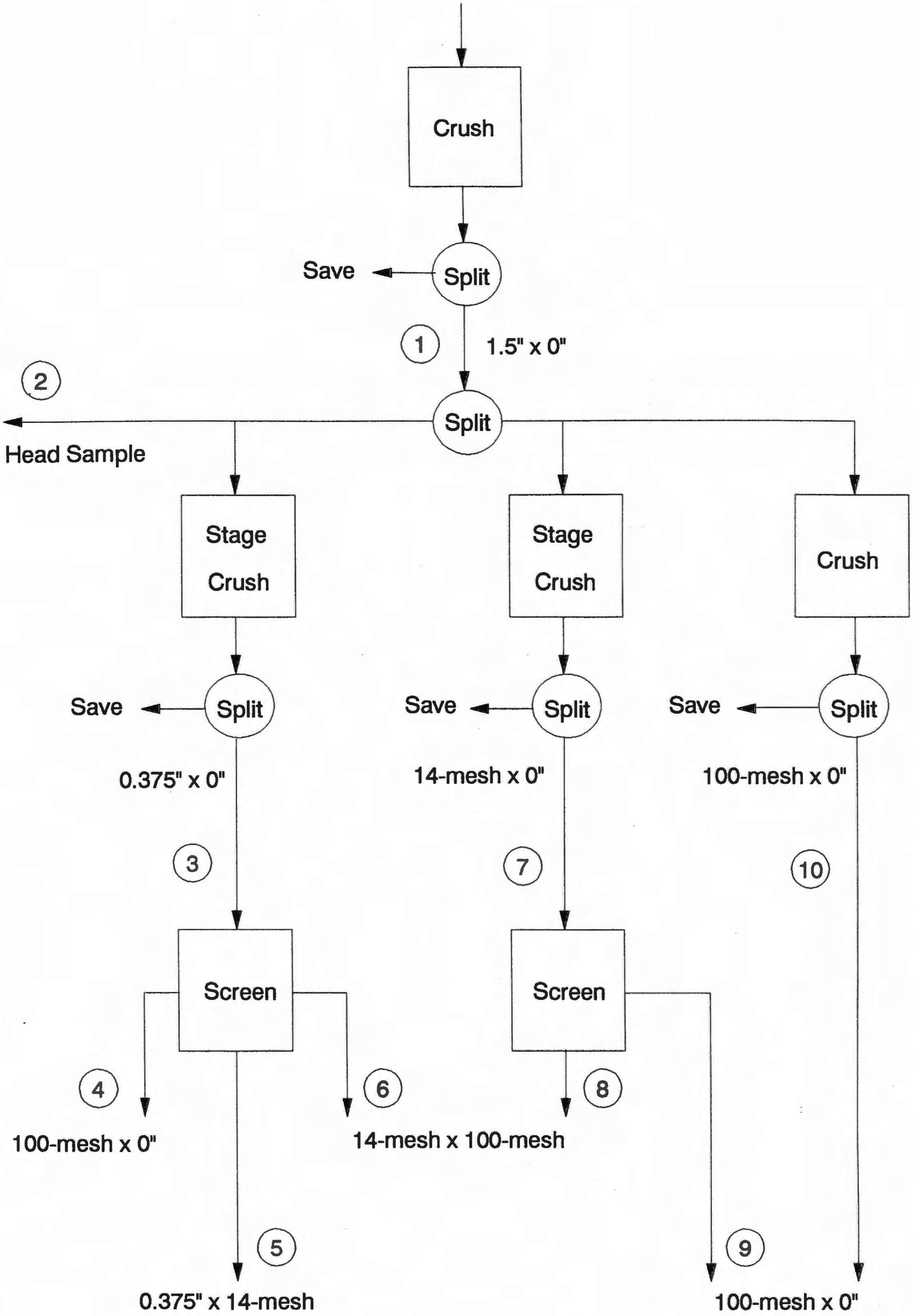
9. Briquetting qualities will be evaluated by making cylindrical pellets using oil agglomerates or another appropriate binder as necessary.

10. An interim and final report will be prepared, including a recommendation as to the methodology for preparing 100-pound samples of specification-grade coal products.

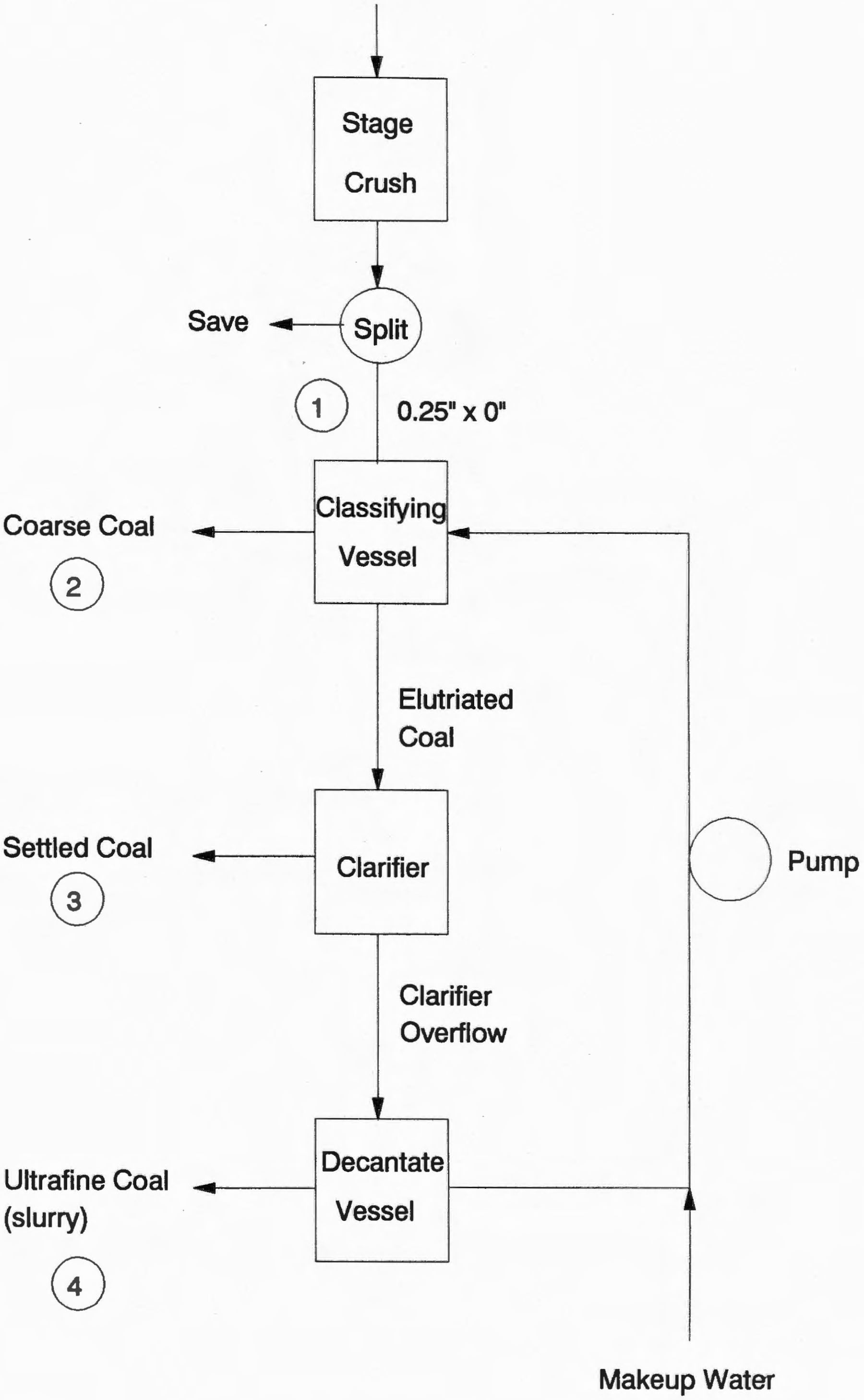
4.0 STANDARDS OF SUCCESS

There are three primary standards of success associated with this work on one lignite mine sample. One standard is if the sulfur content is decreased to or below the desired value. Another is whether or not the industrial sponsor will support further work. Since the third standard is the building of a coal physical-cleaning plant in North Dakota, the degree of success of this project by this standard would not be known for years. This effort will determine the validity of processing steps used for this type of lignite.

SCHEME 1


Crush
Save
Split
①
1.5" x 0"
②
Split
Head Sample
Stage Crush
Stage Crush
Crush
Save
Split
Save
Split
Save
Split
0.375" x 0"
14-mesh x 0"
100-mesh x 0"
③
⑦
⑩
Screen
Screen
④
⑥
⑧
100-mesh x 0"
14-mesh x 100-mesh
⑤
⑨
0.375" x 14-mesh
100-mesh x 0"

SCHEME 2


Stage
Crush
Split
Save
1
0.25" x 0"
Classifying
Vessel
Coarse Coal
2
Elutriated
Coal
Clarifier
Settled Coal
3
Pump
Clarifier
Overflow
Decantate
Vessel
Ultrafine Coal
(slurry)
4
Makeup Water

5.0 BACKGROUND

North Dakota lignites are uniquely different from most other coals except Saskatchewan lignites. Fresh from the mine they contain at least 40% moisture; during air-blown hammer milling this is reduced to about 30%. Further air drying reduces the moisture to 15%–20%. However, lignite becomes more pyrophoric as the water content decreases. Mineral matter is very finely dispersed or present as ion-exchangeable cations associated with organic matter. However, bands of pyrite can collect along seam fractures in the mine. Methods for reducing ash and sulfur need to be supplemented (at times) with a method to reduce sodium content since excess sodium increases ash fouling during combustion. Conventional processes are generally not known to be successful when applied to lignites, whether from physical cleaning or coal liquefaction. Lignites are unique.

Typically no process has been found to economically clean a total run-of-mine stream of coal. In this work, the concept of inexpensive, single-pass grinding followed by splitting the coal into separate size fractions will be studied. Hopefully, a specification-grade product can be produced by drying a selected fraction or by drying and briquetting or pelletizing. In the worst case, it would require the addition of dense-media separation or magnetic separation to remove sulfur-containing pyrites. Each added step reduces the market, since preparation costs would increase. Blending differently processed streams is also a possibility, such as using a lower-sulfur, oil-agglomerated, side stream as a binder in briquetting a slightly higher-sulfur fraction. Any over-specification fractions would become feed to a power plant fitted with a scrubber. The following discusses some areas in more detail.

5.1 Float-Sink Testing

Assessment of the possible separation of mineral matter and pyrites from coal by gravity methods is provided by static and centrifugal float–sink methods. This bench-scale technique is not applicable to assessment of coal cleanability via surface-based methods, e.g. froth flotation or agglomeration. Float–sink testing is designed to separate a coal sample into fractions within narrow specific gravity ranges. This allows determination of the optimum specific gravity for treatment of a specific coal size to maximize coal recovery and ash and pyrite reduction.

The EERC has performed float–sink testing on a range of U.S. low-rank coals and has determined that the effect cannot be predicted accurately except for low-rank coals which have ash characteristics similar to bituminous coals (e.g., Texas lignite [1]). Significant ash reduction can, however, be achieved by size reduction to 0.25-mm top size as was indicated in previous experiments with two western subbituminous coals (2).

5.2 Oil Agglomeration

Agglomeration relies on preferred attachment of a compatible oil to the coal carbonaceous matter to affect a separation from liberated minerals and pyrites. Mixing causes the oil-cleaned coal to agglomerate into larger particles which can then be separated from the reject material via simple mechanical means.

The EERC has successfully demonstrated the application of oil agglomeration with polar coal-derived oils principally as an aggregation method for coals which have been treated via ion exchange (3, 4). The process has been effective with all coals tested including lignites from North Dakota, Texas, and the Czech Republic; subbituminous coals from Wyoming, Montana, and Alaska; and brown coals from Australia. Agglomeration can achieve significant heating-value recovery (+90%), and the products exhibit tendencies of reduced moisture reabsorption and dusting. Recent tests have shown that appropriate agglomeration conditions can achieve significant mineral reduction at high coal yields (2).

5.3 Ion Exchange

The association of inorganics in low-rank coals includes both discrete minerals which are heterogeneously dispersed within the coal and organically associated elements such as sodium and calcium, which are chemically attached to the coal matrix. Separation of organically associated elements from low-rank coals can not be accomplished via gravity or surface-based (froth flotation, agglomeration) methods. Consequently, these ionically bound elements can only be removed via exchange with another cation such as H^+ (from an acid) or Ca^{+2} (from a salt).

The EERC has demonstrated that low-ash, low-sodium fuels can be produced by chemical cleaning of fine coal (1, 5–7). 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 (4). 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 (2).

5.4 Rare Earth Magnetic Separation

The dry-beneficiation process of rare earth magnetic separation (REMS) offers significant advantages for low-rank coals. It eliminates dewatering and waste streams as well as minimizes the thermal energy subsequently required to reduce moisture content. The capital and operating costs of REMS can be lower than the costs of selective agglomeration.

The REMS technology is typically applied to −6 + 0.5-mm coal, but finer sizes can be accommodated. The process involves removing magnetic mineral matter, such as pyrite and pyrrhotite. It is envisaged that an ERIEZ magnetic separation unit would be employed. ERIEZ is a world leader in REMS technology.

Judicious selection of sample sizes will be necessary for the removal of magnetic mineral matter in lignites as the pyrite could be finely dispersed. Where prior wet processing occurs, some preliminary drying will be necessary before applying REMS.

5.5 Pyrolytic Removal of Sulfur

Reduction of sulfur in coal can be achieved by pyrolysis. However, effective reduction depends on the coals, its reactivity, sulfur forms and amount as well as pyrolysis conditions. Sulfur removal of over 50 wt% has been reported for the low-temperature pyrolysis of Spanish low-rank coals (8). Both inorganic- and organic-sulfur forms are removed. The efficiency of desulfurization is decreased for weathered coals (9).

The temperature range, atmosphere (oxidizing or reducing), residence time, and additives are key factors in the removal of sulfur (10, 11). Typically, the quantity of sulfur removed from coal increases with temperature but within certain ranges, limited removal may occur (10). The effectiveness of some additives, e.g., dolomite [$CaMg(CO_3)_2$] is also dependent on the temperature regime. For example, under reducing conditions around 800°C, dolomite transforms into a half-calcined state (CaO.MgO), which is stable and hence its adsorption potential is optimized (12). The addition of dolomite will reduce the conversion of inorganic sulfur into organic sulfur form. Previous pyrolysis experience for sulfur removal from low- and high-rank coals at EERC (11) will assist with sulfur-removal procedures for North Dakota lignite.

5.6 Briquetting and Pelleting

The primary objective of briquetting or pelleting is to enhance the handling and utilization performance of the product. Problems of dust and spontaneous ignition can be greatly reduced, and the properties of the solid product can be tailored to specifications applied to a wide range of markets. Coal as a low-cost raw material can thereby be utilized in applications where it was formerly unusable (13).

Briquetting involves the compaction of fine material at moderate to high pressures and at temperatures of 70° to 500°C with or without a binder. Various coals as well as chars and other materials have been briquetted or pelleted (e.g., anthracite, bituminous, subbituminous, lignite, and brown). The briquetting or pelleting process relies on the cohesive forces between solids, the adhesion of binders, and the rheology of particles and lump materials.

The development of strong and cohesive briquettes or pellets is a function of the properties of the coal (including size, ash level, hardness, and surface and chemical characteristics), the nature of the binder, the mixing technique, and briquette- and pellet-processing conditions. The selection of coal, binder, and processing conditions will largely depend on the ultimate utilization and potential value of the briquetted or pelleted product.

The particle size of coal for briquetting or pelleting is generally less than 6 mm (0.25 inches), but larger-size coal (e.g., 10 to 15 mm [0.4 to 0.6 inches]) can be briquetted. However, stable and effective briquettes also require an appropriate size distribution of particles. Briquetted fine coal (−4 mm) would typically contain 30%–60% fines less than 1 mm (0.04 inches).

Tableting and stamping machines, sear pelleters, as well as extruding and double-roll-press machines, have been used for making briquettes and pellets. In recent years, the double-roll press has often been preferred as it offers significant advantages, including high throughput, relatively low energy usage and maintenance, insensitivity to material variability, and a variety of compact shapes and sizes.

Whatever the briquette or pellet application, it will be necessary for the coal briquettes or pellets to meet specific mechanical-strength and moisture-durability criteria. The required minimum strength and moisture resistance will depend on the desired use, as well as on the type of binder and the extent of the processing conditions.

Combustion reactivity and emission tests are performed when the briquettes or pellets are to be used as a fuel.

6.0 QUALIFICATIONS

6.1 Key Personnel

Dr. Curtis L. Knudson will act as the Principal Investigator for this effort. He has been involved with low-rank coal research for over 15 years at the Energy & Environmental Research Center. He holds two patents on upgrading low-rank coals. Dr. Brian Young will act as the Coprincipal Investigator. He has been extensively involved in low-rank coal research. See Appendix A for resumes.

6.2 Proposer Capabilities

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.

7.0 VALUE TO NORTH DAKOTA

The private sector will benefit most from this project, since a coal company will provide the samples and funding. However, the public sector is also well-served. The results will indicate the viability of processing one company's coal while the public sector will know if similar coals can be processed. Since any processing plant would need to be large to be economical, the successful completion and implementation of the information obtained in this research effort would create construction and plant-operating jobs in North Dakota as well as increase coal production on the order of one million tons per year.

8.0 MANAGEMENT

All efforts on this work will be monitored by Dr. Knudson as to the completion of the tasks. Internal review will be provided by Dr. Michael L. Jones. Accounting will oversee the expenditures.

9.0 TIMETABLE

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

	Completion Date
Contract Award	1-1-94
Task 1. Coal Procurement	1-31-94
Task 2. Coal Crushing, Dry and Wet Classifying	2-28-94
Task 3. Coal Analysis, Float–Sink Testing	4-15-94
First Progress Report	4-15-94
Task 4. Ion Exchange Testing	5-31-94
Task 5. Magnetic Separation Testing	5-31-94
Task 6. Partial Oxidation Testing (not funded)	6-30-94
Task 7. Oil Agglomeration Testing	6-30-94
Task 8. Drying (as needed)	
Task 9. Briquetting (tableting)	7-15-94
Second Progress Report	7-15-94
Task 10. Final Report	9-1-94

10.0 BUDGET

The estimated budget for the proposed Phase 1 work described in this proposal is attached.

11.0 MATCHING FUNDS

The initial participants are expected to be the Knife River Coal Mining Company and the Department of Energy (DOE). Knife River has verbally committed to Phase 1 of the project subject to their final approval of the proposed work. If the Phase 1 work for the one lignite is successful, it would require an additional request to produce 100-pound samples. We do request a six-month time period to secure additional industrial funds.

We will be soliciting other North Dakota industries to process an additional North Dakota lignite sample using this same methodology. However, it is expected that no more than one coal could be fully studied with the existing funding if 100-pound samples were produced.

Matching DOE funds will be requested as base funds are allocated. There is no guarantee that DOE will provide matching funds for this effort. However, this effort does fit DOE research goals and objective and we would expect a favorable response to a funding request from DOE.

12.0 TAX LIABILITY

The EERC is an organized research center within the University of North Dakota. The University of North Dakota is an institution of higher education within the State of North Dakota and is not a taxable entity.

13.0 REFERENCES

1. Brown, D.J. et al. "Washability Data Base of Very Fine Western Coals," Presented at Society of Mining Engineers AIME Annual Meeting, DE-FC21-83FE60181, New York, Feb. 1986.

2. Musich, M.A.; Anderson, C.M.; Young, B.C.; Timpe, R.C.; Olson, E.S., Sharma, R.K. "Task 4.0 Advanced Fuel Forms and Co-Products," semiannual report; DE-FC21-93MC30097, EERC publication, July 1993b, pp 18–34.

3. Musich, M.A.; Dewall, R.A., Timpe, R.C. "Oil Agglomeration of Low-Rank Coals," *In* Proceedings of the Eighth Annual Coal Preparation, Utilization, and Environmental Control Contractors Conference; July 1992b, pp 454–461.

4. Musich, M.A.; DeWall, R.A.; Timpe, R.C. "Oil Agglomeration of Low-Rank Coals," *In* Proceedings of the Ninth Annual International Pittsburgh Coal Conference; Oct. 12–16, 1992a, pp 62–67.

5. Malterer, T.J. et al. "Screening of Low-Rank Coals for Low-Ash Fuel Preparation," *In* Proceedings of the Thirteenth International Conference on Coal and Slurry Technology, Denver, CO, April 1988, pp 443-457.

6. Potas, T.A.; Baker, G.G.; Maas, D.J. "Pilot-Scale Preparation of Low-Rank Coal–Water Fuels (LRCWFs)," *J. Coal Qual.* **1987**, *6* (2), 53–57.

7. Smit, F.J.; Maas, D.J. "Preparation and Analyses of Low-Rank Coals for Combustion Applications," final report DE-AC18-84FC10623; U.S. Department of Energy, Morgantown Energy Technology Center, Morgantown, WV, Oct. 1986.

8. Ibarra, J.V.; Miranda, J.L.; Moliner, R. In *Coal Science and Technology*, Moulijn, J.A., Mater, K.A., Chermin, H.A., Eds.; Series Vol. II; Elsevier: Amsterdam, 1987, p 633–637.

9. Ibarra, J.V.; Palacios, J.M.; Gracia, M.; Gancedo, J.R., **1989** *Fuel Processing Technology*, *21*, 63–73.

10. Grygalewicz, G.; Jasineko, S., **1992** *Fuel*, *71*, 1225–1229.

11. Runge, B.D.; Ness, R.O.; Sharp, L.L. "Characterization of the Products of Mild Gasification at the University of North Dakota Energy and Environmental Research Center," Presented at the 205th American Chemical Society Meeting, Denver, CO, March 22–26, 1993, 8 p.

12. Liliedahl, T.; Sjostrom, K.; Wiktorsson, L-P. "A Thermodynamic Study of Dolomite as Hydrogen Sulfide Adsorbent when Pyrolysing or Partially Gasifying Coal," *Fuel* **1992**, *71*, 797–803.

13. Young, B.C. "Meeting the Value-Added Challenge with Coal Briquetting and Pelleting," Presented at the Tenth Annual International Pittsburgh Coal Conference, September 1993, pp 402–407.

PHYSICAL CLEANING OF LIGNITE
29–Sep–93 EERC PROPOSAL #94–6114

		HOURLY	NDIC		COMMERCIAL		DOE		TOTAL	
LABOR	LABOR CATEGORY	RATE	HOURS	$ COST	HOURS	$ COST	HOURS	$ COST	HOURS	$ COST
M. JONES	PRINCIPAL SCIENTIST	$41.35	3	$124	3	$124	6	$248	12	$496
B. YOUNG	PRINCIPAL SCIENTIST	$32.70	22	$719	22	$719	44	$1,439	88	$2,877
A. RUUD	RES. SCIENTIST II	$21.10	10	$211	10	$211	40	$844	60	$1,266
M. MUSICH	RES. SCIENTIST II	$20.72	20	$414	20	$414	80	$1,658	120	$2,486
C. KNUDSON	PRINCIPAL SCIENTIST	$30.72	20	$614	20	$614	56	$1,720	96	$2,948
R. DEWALL	CHEMIST III	$16.14	20	$323	20	$323	64	$1,033	104	$1,679
J. RICHTER	RES TECH II	$13.33	20	$267	20	$267	112	$1,493	152	$2,027
-----------	FACILITY MANAGER	$32.69	2	$65	2	$65	1	$33	5	$163
-----------	PILOT PLANT OP. IV	$17.07	3	$51	3	$51	4	$68	10	$170
-----------	PILOT PLANT OP. III	$13.67	21	$287	21	$287	30	$410	72	$984
-----------	OFFICE SERVICES	$9.36	12	$112	12	$112	24	$225	48	$449
			153	$3,187	153	$3,187	461	$9,171	767	$15,545
ESCALATION ABOVE CURRENT BASE			2%	$64	2%	$64	2%	$183	2%	$311
TOTAL DIRECT LABOR				$3,251		$3,251		$9,354		$15,856
FRINGE BENEFITS – % OF DIRECT LABOR		46%		$1,495		$1,495		$4,303		$7,293
TOTAL LABOR AND FRINGE BENEFITS				$4,746		$4,746		$13,657		$23,149
OTHER DIRECT COSTS										
TRAVEL				$0		$0		$600		$600
GENERAL SUPPLIES AND EQUIPMENT <$500				$177		$177		$533		$887
SUBCONTRACT				$250		$250		$500		$1,000
TOTAL SUBCONTRACT				$250		$250		$500		$1,000
OTHER										
COMMUNICATION – PHONES AND POSTAGE				$55		$55		$115		$225
OFFICE SUPPLIES, DUPLICATING				$0		$0		$0		$0
FEES										
LRCB @ $70/HR			14	$980	14	$980	10	$700		$2,660
COAL ANALYSIS LAB				$2,857		$2,857		$3,121		$8,835
INORGANIC ANALYSIS				$724		$724		$1,521		$2,969
PROCESS CHEMISTRY LAB				$47		$47		$94		$188
SHOP/OPERATIONS SUPPORT @$1.00/HR			24	$24	24	$24	34	$34	82	$82
PRO.F STAFF CLERICAL SUPPORT @$0.62/HR			120	$74	120	$74	407	$252	647	$400
TOTAL OTHER				$4,761		$4,761		$5,837		$15,359
TOTAL OTHER DIRECT COST				$5,188		$5,188		$7,470		$17,846
TOTAL DIRECT COST = LABOR BASED + TOTAL OTHER DIRECT				$9,934		$9,934		$21,127		$40,995
INDIRECT COST – % OF MTDC			51%	$5,066	51%	$5,066	42%	$8,873	VAR.	$19,005
TOTAL ESTIMATED COST				$15,000		$15,000		$30,000		$60,000

BUDGET NOTES - ENERGY & ENVIRONMENTAL RESEARCH CENTER

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.

FRINGE BENEFITS

Fringe benefits are estimated based on historical data. The fringe benefits which will actually be charged consist of two components. The first component covers average vacation, holiday, and sick leave for the EERC. This component will be charged as a percentage of direct labor. The second component covers actual expenses for items such as health and life insurance, social security, UND retirement, unemployment insurance, and worker's compensation.

INDIRECT COST

The indirect cost rate included in this proposal is the rate which became effective July 1, 1989. Indirect cost is calculated on Modified Total Direct Costs (MTDC). MTDC is defined as Total Direct Costs less individual items of equipment in excess of $500 and subcontracts/subgrants in excess of the first $25,000 for each award.