Project Title: COMMERCIALIZATION OF SINGLE STAGE FINE COAL DEWATERING AND BRIQUETTING PROCESS

ICCI Project Number: 96-1/1.1B-2
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ABSTRACT

This research was an integral part of the ongoing ICCI series of coal preparation research projects. An important goal of these ICCI projects is to reduce the ash and sulfur content in coal by using fine grinding and other coal cleaning processes. The ultra-fine coal resulting from the grinding and cleaning operations is not only high in moisture content, but also creates problems in its storage, handling and transportation.

The objective of this research project was to combine the dewatering and briquetting process of fine coal preparation into a single-stage operation, thereby enhancing the viability of utilizing fine-coal. A bitumen-based emulsion, Orimulsion, proved to be an effective hydrophobic binder. It helps not only with the briquetting process but also in expelling water from the coal and preventing re-saturation.

Research this past year was done in the laboratory and with a pilot-scale (commercial) briquetting machine (Komarek B-220A). In using the pilot-scale machine initially, certain shortcomings were noticed concerning the briquetting of wet material. These problems were rectified early in the year by incorporating selected modifications to the machine, which enhanced dewatering of the feed material just before briquette formation.

Briquettes were produced with Illinois No. 5 coal feed material of different moisture contents, different levels of binder and solvent, and at various settings of machine parameters. Due to the fineness of certain samples (90% -400 mesh), solvents were used to dilute the binder so that a better binder distribution was achieved. The best results from testing, using –100 mesh material (with 37% -400 mesh content), required no solvent and consistently achieved low cured-moisture content (about 8%) and low deterioration (approximately 4% weight loss) of briquettes. These figures indicate quite robust products for ultimate handling and transport.

A preliminary economic analysis of the dewatering and briquetting process indicated a cost range of $3.84 to $6.90 per ton, depending on pilot-scale operating levels, i.e., 1.71 to 0.79 tph, respectively. Commercial-scale implementation would undoubtedly give an “economies of scale” effect, resulting in a reduced total unit cost. At this point, the
process is ready for field testing but insufficient funds and time prevented implementation.

EXECUTIVE SUMMARY

The Illinois basin coal contains minerals that are finely disseminated in micron-size particles. The mineral matter, especially pyrite, can be liberated from the coal matrix by an ultra-fine grinding operation followed by a wet physical coal cleaning process such as column flotation. The fine-ground coal has a large surface area and therefore entraps substantial amounts of water during the column flotation process, making dewatering of the filter cake more difficult than for moderately-ground coal. Moreover, even if dry, this ultra-fine coal would create dust control problems during its transportation, handling and storage.

This project focused on overcoming the problems mentioned above by forming the fine coal into briquettes and, in the process, achieving additional dewatering. During experimentation using a commercially-available briquetting machine, water that existed between coal particles was expelled and coal was compacted to form briquettes. By adding Orimulsion, a hydrophobic emulsified bitumen, to enhance the formation and dewatering of briquettes, a robust product was consistently formed from -100 mesh coal samples (containing 37%-400 mesh material). These robust briquettes had a low cured-moisture content (approximately 8%) and low weight loss (approximately 4%). The single-stage system is intended to be located at the downstream end of the deep coal-cleaning process.

During previous research, problems encountered in using the Komarek B-220A briquetting machine were arching and caking of the feed material in the feed hopper and poor drainage of water at the rolls and inside the feed barrel. This year a number of design modifications were proposed to address these problems, and all of the problems were conceptually handled with various alternative solutions. Due to funding and time constraints, steps were taken to remedy the water-drainage problem first. Modifications of the machine included lengthening the feed screw to improve the primary dewatering, incorporating a special cage-type filter screen along the feed barrel, and providing a suction port in the feed barrel at the region of the filter screen so that the water squeezed-out could be removed by a vacuum pump. In addition, a filter-cloth mesh screen was used in place of the sliding cover at the bottom of the feed hopper. A vacuum port was provided to draw out water that collected in the screw feed. Following these changes, further tests were conducted for the remainder of the year.

During the year, Illinois No.5 coal samples, -100 mesh in size but with varying size consists, were used in different experiments. The coal used in the second and third quarters was predominantly -400 mesh in size (90%), which caused delays in progress and, consequently, later in the year a revised schedule of tasks was approved. Because of the extreme fineness of the coal, the binder had to be diluted to reduce its viscosity and thereby achieve effective distribution over all of the coal surface. This led to the issue of selecting a suitable solvent for the purpose. In the second quarter various solvents were
mixed with the binder in various proportions and tests were conducted in the lab. For this, an automatic hydraulic press, SPEX Model 3630 was used. This equipment produced small pellets, and the settings had to be adjusted so that the conditions of the roll briquetting machine were approximated. Based on the results from this set of experiments, it was decided to use hexane as a solvent to reduce the viscosity of the binder. The experiments carried out with the -400 mesh coal were significant since it offered the worst case scenario of the single stage fine coal dewatering and briquetting application. It is emphasized that later research showed that the use of a solvent is not required for coarser coal.

In the fourth quarter, coal of a coarser size fraction (37% -400 mesh) was used, with the good results mentioned earlier, i.e., the consistent formation of robust (4% weight loss) and low moisture content (8%) briquettes. This time it was possible to achieve good distribution of the binder on the coal without the use of a solvent. A total of six laboratory (using SPEX 3630 machine) and two pilot-scale (using the modified B-220QC) experiments were performed.

Having overcome the dewatering problems through machine modifications and having achieved the formation of robust briquettes, the process is now ready for testing in actual conditions at a coal preparation plant. Further problems that might occur can be addressed on site.

A preliminary economic evaluation of the dewatering and briquetting process, based on the pilot-scale machine and done with Komarek’s assistance, indicated a total cost for installation and operation of $3.84 to $6.90 per ton for production rates of 1.71 and 0.79 tph, respectively (using a 5-roll machine). Although not done yet, a commercial-scale implementation would reduce this cost, but until field testing is done at Kerr McGee’s plant, a better estimate cannot be made.
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OBJECTIVE

The objective of this research is to combine the dewatering and briquetting processes of fine coal preparation into a single stage operation, thereby enhancing the economic viability of utilizing fine coal. The operation involves the use of a hydrophobic binder as the dewatering and briquetting agent, and a commercially available compaction device.

INTRODUCTION AND BACKGROUND

The primary goal of the ongoing ICCI coal preparation research projects is to reduce the ash and sulfur content in Illinois coal by fine grinding and other deep coal cleaning processes. During fine coal cleaning processes, such as column flotation, fine coal particles are produced in the pulverization operation. These products possess large surface areas and conventional dewatering techniques cannot be effectively applied, thus creating transportation, storage and handling problems at utility plants. Therefore, a new fine coal dewatering technique is needed in order to take full advantage of the deep coal cleaning processes.

To utilize these cleaning technologies fully, dewatering and briquetting procedures should be developed at the downstream end of the deep cleaning process. In this research, Orimulsion, a hydrophobic bitumen-based emulsion, has proven to be an effective binder which not only helps with the briquetting process but also in the expulsion of water from the coal. Using a commercially available compaction device such as a briquetting machine, water that exists between the coal particles is expelled and the coal particles are compacted to form strong and robust coal briquettes. Research conducted in this year has focused on the commercialization of this single stage dewatering and briquetting process.

EXPERIMENTAL PROCEDURES

I. Sample Preparation

A. Coal sample

Illinois No. 5 Coal, -100 mesh in size with but three different size consists, was used in all of the experiments for this year. In the second quarter, 60% of the sample was -400 mesh with an average moisture content of 42%, while for the third quarter the -400 mesh fraction increased to more than 90% (38% moisture content). In the fourth quarter, a coarser size fraction of sample (37% -400 mesh) was used for all the experiments.

B. Coal-binder mixture preparation

Orimulsion was the binding agent used for this dewatering and briquetting process throughout this year. The preparation of the coal-binder mixture varied depending
II. Briquetting Machinery

Three types of compaction devices were used for this project during this year. In the laboratory experiments, a manual and an automatic hydraulic press in conjunction with steel dies were used to manufacture coal pellets. The steel die for the manually operated hydraulic press produced pellets measuring 1.7 inches in diameter and approximately 1 inch in length. For the automatic hydraulic press, an SPEX Model 3630 Automated X-Press, a stainless steel die with a diameter of 1.2 inches was used. The Model 3630 X-Press is a programmable hydraulic press with a 35-ton capacity which is intended for repetitive pressing of samples.

Pilot-scale briquetting experiments for this study were conducted at the research facility of K. R. Komarek Briquetting Research Inc. at Anniston, Alabama. The pilot-scale K. R. Komarek briquetting machine, Model B-220QC, was used for all the pilot-scale experiments. The coal-binder mixture was fed into the roll press by a horizontal screw. The coal sample was then compacted between the two rolls within the confines of the pockets. Each roll contains 24 pockets and each pocket produces a coal briquette that measures 2.5 inches long, 1.5 inches wide and 1 inch thick.

III. Dewatering Mechanism

During the briquetting process, coal-binder mixtures undergo two stages of dewatering. In the feeding process, the horizontal screw feeder pushes the feed material into the roll press. Because of the feed-screw extrusion effect, water is expelled from the coal-binder mixture at the pre-densification zone prior to the compaction stage. At the second stage of dewatering, the coal-binder mixture is compacted between the two rolls that rotate against each other under high pressure. Most of the remaining water is then squeezed out of the mixture as the briquettes are formed; this is the roll compacting and briquetting effect.

IV. Evaluation of Fine Coal Dewatering and Briquetting Efficiencies

A. Moisture content, curing and absorption tests

In order to determine the moisture content of the coal pellets and briquettes that were produced, the products were weighed and then placed in an oven at 100°C for at least 24 hours. The pellets/briquettes were next re-weighed periodically until the weight was constant. The following equation was used to evaluate the moisture content:

\[
% \text{Moisture} = \left( \frac{W_i - W_d}{W_i} \right) \times 100\%
\]

(1)
where $W_i$ is the initial weight of a pellet and $W_d$ is the dried weight of the pellet.

The curing test was used to determine the time effects on the products’ moisture content. Curing periods for the pellets in this study were typically 0, 8, 16 and 24 hours after the pellets were manufactured, except in the fourth quarter. For briquettes that were produced in the fourth quarter at Anniston, Alabama, different curing periods were chosen based on the time of production. To determine the amount of weight loss during the curing period, the weights of the pellets were recorded before and after placing them in the drying oven for 24 hours.

The water absorption test was used to study the effect of curing time on water resistance of the coal briquettes. The water absorption test was performed exclusively on the coal briquettes. To conduct the absorption test, briquettes were placed under water for 24 hours after being exposed to the atmosphere for a predetermined period. The percentage weight gained by the briquettes after 24 hours of soaking in water was used to measure the water resistance of the briquettes. In all pilot-scale experiments this year, the absorption test was further extended to determine whether the hydrophobicity of the briquette was still effective after allowing water to evaporate, even after 24 hours of soaking. After the first round of curing and soaking, the briquettes were again cured in the atmosphere for another 24 hours. The weight of the briquettes was recorded before and after placing them in the oven for 24 hours.

B. Drop and shatter tests:

The drop and shatter test was used to evaluate the strength and friability of the coal pellets. The coal pellets were released from a height of one meter, and allowed to free fall and impact on a concrete floor after a pre-determined curing period. The coal pieces of +6 mesh were then recovered and the weight loss (6 mesh x 0) was determined.

C. Compression tests:

The crushing test was used to determine the ultimate compressive load which the briquettes could withstand before failure. A manual press with a load gauge was used to determine the ultimate load needed to crush the briquettes. Due to the non-uniform contact area between the press and the briquette, only the peak compressive load was recorded.
D. Evaluation of water quality

Water was extracted and analyzed for both sets of pilot-scale experiments that were conducted at Anniston, Alabama. The analyses included pH, conductivity, temperature, and settleability.

i. pH

The measurement of pH allows for the determination of the alkalinity or acidity of the water extracted.

A pH of 7.0 is considered neutral, although in water chemistry there are three ranges of pH which are important to evaluate:

- Phenolphthalein alkalinity (P alkalinity)  $\text{pH} > 8.2$
- Methyl orange alkalinity (M alkalinity)  $4.2 < \text{pH} < 8.2$
- Acidity  $\text{pH} < 4.2$

A Cole-Parmer Model 59002 pH/mV/Temperature Meter was used to determine pH measurements of water extracted from the vacuum ports of the briquetting machine for each experiment. This model performs temperature correction and reports the values in standard $25^\circ\text{C}$ notation to +/- 0.01 pH units.

ii. Oxidation-Reduction Potential (ORP)

Oxidation-reduction measurement is used to determine the oxidizing or reducing properties of solutions, to monitor chemical reactions, and to make quantitative determinations of ionic concentrations. ORP measurements are measured in mV, with a metallic indicating electrode and a standard reference electrode.

A Cole-Parmer Model 59002 pH/mV/Temperature Meter was used to make ORP measurements of water extracted for each experiment. This model reports the values in standard $25^\circ\text{C}$ notation to +/- 0.01 mV.

iii. Temperature

Temperature measurements are routinely collected with pH and conductivity measurements so that equivalent conductance and pH can be calculated to the $25^\circ\text{C}$ standard.

A Cole-Parmer Model 59002 pH/mV/Temperature Meter was used to collect temperature measurements of water extracted for each experiment. This model measures temperature to +/- 0.01°C.
iv. Settleability

A modified cylinder test was performed to provide information on how fast the suspended solids will settle from the water extracted. Due to a lack of adequate samples, only the first three experiments were analyzed.

v. Total Suspended Solids

Total suspended solids were approximated using a modified version of Standard Method 2540 D.

RESULTS AND DISCUSSIONS

I. Accomplishments in the First Quarter

Research conducted in the first quarter focused on the design of modifications necessary to improve the applicability of a commercial briquetting machine so as to enhance the dewatering and briquetting process. With the assistance of a selected manufacturer, areas that required modifications were identified and the changes were designed for improving the dewatering efficiency of coal fines through the currently available briquetting machine. Modifications to the feed system, drainage system and roll configuration, and preliminary design to each system, were considered. Details of each proposed modification can be found in the first quarterly report dated September 1, 1996 to November 30, 1996. The highlights of these modifications can be summarized as follows:

A. A vertical screw, in conjunction with a change in the feed hopper configuration, was proposed to solve the arching problem.

B. A new porous material placed at the bottom of the feed hopper, along with a vacuum attachment was proposed to the dewatering efficiency at the feeder.

C. The installation of an inclined trough or the use of grooved concentric rings at the bottom of the feed path were modifications proposed to solve back-drainage at the pre-densification zone.

D. A new pocket design for the rolls was proposed to eliminate unnecessary briquette handling during the briquetting process.

II. Accomplishments in the Second Quarter

A. Modifications to the Model B-220A briquetting machine
After many discussions and meetings with the briquetting machine manufacturer, K. R. Komarek, Inc., it was decided that in order to enhance the dewatering capability of the briquetting machine, both the feeder and the briquetting rolls required modifications. For the feeder, proposed modifications included a porous plate which would be located in the paddle feeder directly below the coal/binder feed. Also, holes would be drilled at the bottom of feeder base and provide vacuum-assisted drainage. Either grooves or grooved rings would be installed in the feeder base to allow water to flow away from the briquetting rolls. The screw feeder was also proposed to be lengthened to increase the pre-compaction time and create more surface area for removing the expelled water.

In terms of the briquetting rolls, the only modification would be in the form of installed slots along the side of the rolls to prevent the squeezed-out water from re-entering the roll pockets.

B. Study of the efficiency of a solvent/binder combination for reducing the viscosity of Orimulsion

The objective of this study was to determine the efficiency of the solvent/binder combination used for reducing the viscosity of Orimulsion, and the potential to produce low moisture and robust pellets, even with a high proportion of -400 mesh coal particles. Two groups of experiments were conducted including the use of four types of solvent. In the first group of experiment, chloroform was used but was eliminated from the second group due to its potential health hazard. In the second part of the study, an orthogonal fractional factorial design was used to design the experimental matrix. In this part, Dichloromethane, Toluene, and Hexane were used as solvents. The details of the experimental setup for this study was provided in the second quarterly report dated December 1, 1996 through February 28, 1997.

Experimental results from this study provided the following conclusions:

i. Results from the first group of experiments indicated that as the compaction pressure increased, the moisture content of the coal pellets decreased.

ii. Combining a solvent with the binder reduced the viscosity of Orimulsion, which in turn allowed a more efficient usage of the binder and a better coating of the ultra-fine coal particles.

iii. The reduction of moisture was sensitive to the types and amount of solvent. On the other hand, the strength of the pellets was insensitive to any of the operating variables, namely the amount of solvent, mixing time and binder concentration.

III. Accomplishments in the Third Quarter
The research in the third quarter focused on determining the dewatering efficiency of the modified pilot-scale briquetting machine on ultra-fine coal particles (-400 mesh). Modifications to the briquetting machine included the installation of a dewatering screen with additional vacuum ports along the feed barrel path in an attempt to eliminate the back drainage problem. Four experiments were conducted at different mixing and operating conditions. A commercial pilot-scale briquetting machine provided by K. R. Komarek Briquetting Inc. was used as the primary compacting device. Two concentrations of Orimulsion were used to determine the efficiency of the binder in ultra-fine coal dewatering.

It is important to note that in order to distribute the binder more evenly to the ultra-fine coal surfaces (> 90% -400 mesh), hexane was used as a solvent to reduce the viscosity of the binder. If a higher percentage of the +400 mesh coal had been present in the fine coal sample tested, it would not have been necessary to use a solvent to produce robust briquettes with low moisture content. Details of each experimental setup and results were provided in the previous report dated March 1, 1997 to May 30, 1997. The following conclusions were drawn from the experimental results obtained from the third quarter:

A. As the curing time of briquettes increased, the hydrophobic nature of the coal-binder mixture not only promoted the evaporation of water, it also prevented the re-entry of the moisture into the briquettes.

B. Curing time also affected the strength and friability of the briquettes. With the pilot scale briquetting machine, Komarek Model B-200QC, the weight loss of briquettes in the drop tests increased with curing time.

C. The weight loss in the drop tests increased at the lower binder concentrations. Conversely, the binder concentration did not have a significant effect on the moisture content.

D. Roll speed was important in terms of the strength and friability resistance of the briquettes. A short compaction time during the briquetting process resulted in a decrease in strength as the roll speed increased. On the other hand, due to the high amount of ultra-fine coal in the mixture, the moisture content of the product was insensitive to the speed of the roll.

E. The installation of the wire screen in conjunction with the vacuum system eliminated the back-drainage problem.

IV. Accomplishments in the Fourth Quarter
Due to the high amount of -400 mesh coal present in the samples during the third quarter, hexane was used as a solvent to reduce the viscosity of the binder, thus improving the distribution of Orimulsion onto the fine coal surfaces. It was stated in the earlier section that if a higher percentage of +400 mesh coal had been present in the sample tested, it would not have been necessary to use a solvent to produce robust briquettes with low moisture content. The objective of this study was to test the effect of using Orimulsion without a solvent with a higher amount of +400 mesh coal in the fine coal samples.

A total of six laboratory and two pilot-scale experiments were performed in this quarter using Illinois No. 5 coal from the Galatia Mine. The size distribution of the sample used in this quarter is shown in Figure 1. Samples for the six laboratory experiments were prepared under the conditions listed in Table 1, while the pilot-scale experiments were prepared with a binder concentration of 5%. The SPX automatic hydraulic press and a pellet die were once again used to produce the coal pellets. The pilot-scale K. R. Komarek briquetting machine, Model B-220QC, was used for both pilot-scale experiments.

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Table 1. Summary of Experimental Conditions

A. Results of the laboratory experiments

i. Effects of curing time on the moisture content of pellets

As seen in Figure 2, the moisture content of all the pellets produced decreased as the curing time increased. Pellets in all the experiments reached a moisture content of about eight percent after 24 hours of curing. These results concur with the previous findings that the hydrophobic nature of the binder/coal mixture permits water to evaporate from the pellets more readily than coal fines without binder.

ii. Effects of curing time on the friability of pellets

For most of the experiments, the results suggested that the friability of the pellets is insensitive to curing time (Figure 3). However, for experiments one and two, the weight loss increased dramatically as the curing time increased. This can be explained by the fact that during the early stage of curing in these experiments, the higher moisture contents provided better cohesiveness of the pellets by bonding the coal particles together. As the curing period
progressed, the moisture contents of the pellets decreased, thus reducing the bond strength between the coal particles.

iii. Effects of binder concentration on the moisture content of coal pellets

Figure 4 shows that the “green” moisture content of the pellets is subjected to the influence of binder concentration. As the binder concentration increased, the “green” moisture content of the pellets decreased. At a higher binder concentration, the compaction process was more effective due to the higher amount of binder available for the fine coal surfaces. On the other hand, the moisture content of the pellets was not affected by the amount of binder present after 24 hours of curing.

iv. Effects of binder concentration on the friability of coal pellets

Results from this study indicated that at the early stage of curing, the friability of the pellets was independent of the binder concentration (Figure 5). However, after 24 hours of curing, the weight loss of the pellets with a lower concentration of binder dramatically increased. During the early stage of curing, the friability of the pellets was reduced by both the moisture and binder content. As the curing time increased, the moisture within the pellet continued to evaporate, thus reducing the increasing the friability of the pellets. At a high concentration of binder, the moisture content did not play as crucial a role in terms of pellet friability. The cohesiveness of the pellets came mostly from the binder itself in this scenario. Consequently, after 24 hours of curing, the weight loss of these pellets remained minimal.

v. Effects of solvent on the moisture content of coal pellets

Figures 6 and 7 show the effects of using a solvent on both the “green” and cured moisture contents of fine coal pellets. As seen in Figure 6, the coal/binder mixtures with a solvent were consistently lower in moisture content, ranging from 1.6 to 2.5% as the binder concentration increased. The presence of a solvent improved the distribution of the binder onto the fine coal surfaces, thus enhancing the dewatering effect during compaction. On the other hand, the long term effect of the solvent on the moisture content of the pellets appeared to be insignificant. Figure 7 shows that the moisture content of the pellets, after 24 hours of curing, had less than 1% difference in all the experiments.
vi. Effects of solvent on the friability of coal pellets

The impact of a solvent on the friability of coal pellets is significant, particularly at low binder concentration levels. Figure 8 shows the percent weight loss in the drop test of all the experiments after 24 hours of curing. It is obvious that mixtures with a low binder concentration and no solvent performed poorly in the drop and shatter tests. As the binder concentration was increased, the amount of weight loss gradually decreased. At the highest concentration of binder that was tested, 7%, the weight loss between the mixture with and without a solvent was not substantial. From this trend, it is concluded that the use of a solvent helped to distribute the binder onto the coal surfaces more effectively, thus decreasing the friability of the coal pellets at low binder concentrations. On the other hand, at higher concentrations of binder, the impact of a solvent was less obvious due to the greater availability of binder for the coal surfaces.

B. Results of pilot-scale experiments

Two briquetting experiments were carried out on July 8\textsuperscript{th} at the Komarek research facility at Anniston, Alabama. The objective of these experiments was to validate the findings in the laboratory experiments, i.e., it was not necessary to use a solvent for the -100 mesh coal given that a higher amount of +400 mesh coal was available. Due to the brief time available at the facility, only three data points were obtained. These results did provide the general trends of the briquette characteristics.

i. Effects of higher amounts of +400 mesh coal on the moisture content of briquettes

Figure 9 shows a comparison of the moisture contents between the last group of experiments (>90% -400 mesh, with a solvent) and the current set of experiments (37% -400 mesh, binder only). The results suggested that the higher percentage of +400 mesh materials had a significant impact on the moisture content of the briquettes. There was a significant decrease in moisture with a higher percentage of coarse material in when no solvent was used. The reduction in surface area due to the higher amount of coarse material, improved the distribution of the binder onto the coal surface, thus improving the hydrophobicity of the coal/binder mixture.

ii. Effects of higher amounts of +400 mesh coal on the friability of briquettes

In terms of friability of the briquettes, the impact of +400 mesh coal was evident (Figure 10). There was an eight percent decrease in weight loss of briquettes during the drop and shatter test. The wider size distribution of the
material improved the packing density of the briquette, thus reducing weight loss.

iii. Effects of screen openings on the moisture content of the briquettes

The objective of installing a screen along the feel barrel was to enhance the dewatering efficiency of the coal fines feed and to solve the back drainage system. Two different screen sizes, 25 and 50 microns openings, were used for the experiments conducted on this trip. Figure 9 shows that, the screen opening has an effect on the “green” moisture of the briquettes. There was a 4% difference in the initial moisture content of the briquettes. However, the difference in moisture between the two experiments narrowed dramatically; and after 20 hours of curing, there was no significant difference in moisture content.

iv. Effects of screen openings on the friability and strength of coal briquettes

Besides moisture content, the size of the screen opening also affected the strength and friability of the briquettes. As mentioned in an earlier section, the weight loss of the briquettes in the drop and shatter test increased with curing time. This trend held true for both of these experiments. However, as shown in Figure 10, the trend for the product from the 50 micron screen increased in a more dramatic fashion. After 24 hours of curing, the weight loss for the briquettes of the 50 micron screen was about 8 percent as compared to the a loss of less than 4 percent for the 25 micron screen product.

In the crushing test, results indicated that the briquettes produced with the smaller opening screen possessed higher initial strength (Figure 11). However, after long periods of curing, the compressive strength of the briquettes that were made with the wider opening had the higher strength.

v. Water analysis

Water samples were collected during the pilot-scale experiments and preliminary analyses were performed (Table 2). Results indicated that pH values were low compared to typical mine water, which normally has a value of around 7. This is definitely a concern regarding the ejected water quality and will be addressed in future work. However, it should be noted that in an actual production environment, the water obtained from the briquetting process would only be a minor portion of the entire water system. Besides the pH values, the rest of the results, including Oxidation-Reduction Potential, Conductivity, Total Dissolved Solids and Dissolved Oxygen, appeared to comply with the environmental standard. However, a detailed study is still needed in order to obtain a more accurate analyses of the ejected water.
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Table 2. Average Values from Analyses of Ejected Water

IV. Discussion on the Economics of the Process

A preliminary economic evaluation of the dewatering and briquetting process was done for the December 1, 1995 – February 29, 1996 reporting period. Based on the pilot-scale machine mentioned previously in this report, the total cost for installation and operation was estimated between $3.84 to $6.90 per ton for production rates between 1.71 and 0.79 tph, respectively (using a 5-roll machine).

These estimates were made with the assistance of Komarek personnel using detailed operational data. In this analysis, the cost of electricity was based on $0.06/kwh, a maintenance cost was included for replacing rolls and maintaining the equipment, an Orimulsion cost of $1.15 per ton of product was used, and a 15-year depreciation schedule was used for capital costs.

Although not done yet, a commercial-scale implementation of the combined process would undoubtedly reduce the estimated cost, but until field-testing is done at Kerr McGee’s plant, a better estimate cannot be made. Field testing of the process is still being pursued with both Komarek and Kerr McGee.

CONCLUSIONS AND RECOMMENDATIONS

Research this past year was done in the laboratory and with a pilot-scale (commercial) briquetting machine (Komarek B-220A). In using the pilot-scale machine initially, certain shortcomings were noticed concerning the briquetting of wet material. These problems were rectified early in the year by incorporating selected modifications to the machine, which enhanced dewatering of the feed material just before briquette formation.

Briquettes were produced with Illinois No. 5 coal feed material of different moisture contents, different levels of binder and solvent, and at various settings of machine parameters. The best results from testing, using –100 mesh material (with 37% –400 mesh content), required no solvent and consistently achieved low cured-moisture content...
(about 8%) and low deterioration (approximately 4% weight loss) of briquettes. These figures indicate quite robust products for ultimate handling and transport.

The commercial viability of this combined process looks promising economically, with substantial throughput at the preparation plant, i.e., in the neighborhood of $3.84 per ton based on pilot-scale results. However, field testing will be required to better estimate eventual actual costs.

More specific conclusions regarding this past year’s experimentation include the following:

1. Results in the fourth quarter confirmed that moisture content decreased as the curing time increased. Regardless of the binder concentration, the moisture content of the pellets dropped to about eight percent after 24 hours of curing.

2. Based on the results obtained, there appeared to be a weak correlation between the curing time and the percent weight loss in the drop tests. In most cases, the weight loss of the pellets increased as the curing time increased.

3. As the binder concentration increased in the coal/binder mixture, the “green” moisture content decreased. However, the moisture content for all the experiments reached a consistent value of eight percent, after 24 hours of curing.

4. The friability of the coal pellets decreased as the binder concentration increased, particularly after a long period of curing in the tests conducted without a solvent.

5. The use of a solvent along with a binder improved the dewatering during compaction but there were no distinct long term gains in its effect on the moisture content of the briquettes.

6. For extremely fine coal, the effective distribution of binder onto the coal surface (achieved through the use of a solvent) helped in decreasing the friability of the briquettes, especially at low binder concentrations.

7. With coarser coal (a higher percentage of +400 mesh), better reduction in green moisture was observed even without the use of a solvent. This may be attributed to the increased permeability of the coal when compared to that of coal which was predominantly -400 mesh in size distributions.

8. Higher percentages of +400 mesh coal also caused a reduction in the weight loss during drop tests.
9. Steps taken to alleviate the back-drainage problems proved successful. There was an impact of the size of the screen mesh on the quality of the briquettes. This may have resulted from the size of coal particles and the capacity of the suction pumps.

10. Water analyses indicated that pH values of the expelled water were lower than regular mine water discharges, which have values around 7. The rest of the results from water analyses, such as ORP, TSS and DO complied with acceptable standards. Detailed testing is needed to determine the cause of lower pH values and to ensure that the expelled water quality complies with environmental standards.
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Figure 1. Size Distribution of Illinois No. 5 Coal Samples

Cumulative Wt. % Passing vs. Particle Size, µm

Figure 2. Effects of Curing Time on the Moisture Content of Pellets

Moisture Content, % vs. Curing Time, hrs
Figure 3. Effects of Curing Time on the Friability of Pellets

Figure 4. Effects of Binder Concentration on the Moisture Content of Pellets
Figure 5. Effects of Binder Concentration on the Friability of Pellets

Figure 6. Effects of Solvent on the "Green" Moisture Content of Pellets
Figure 7. Effects of Solvent on the Moisture Content of Pellets

Figure 8. Effects of Solvent on the Friability of Pellets
Figure 9. Solvent Effect on Moisture Content of the Briquettes

![Figure 9](image)

* sample prepared with hexane as solvent

Figure 10. Solvent Effect on the Friability of the Briquettes

![Figure 10](image)

* sample was prepared with hexane as solvent
Figure 11. Curing Time Effect on the Crushing Strength of Briquettes