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Project Title: **PILOT SCALE SINGLE STAGE FINE COAL DEWATERING AND BRIQUETTING PROCESS**

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ABSTRACT

The primary goal of the ongoing ICCI coal preparation research project is to reduce ash and sulfur content in coal by using fine grinding and other coal cleaning processes. The ultrafine coal particles that result from the grinding and cleaning operations are difficult to dewater, and create problems in their storage, handling and transportation.

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. A bitumen based emulsion, Orimulsion, has proven to be an effective hydrophobic binder, which helps not only with the briquetting process but also in the expulsion of water from the coal.

Encouraging results from the use of a ram extruder briquetting device led to experimentation in the production of briquettes using a lab scale roll briquetting device. In the first quarter of this reporting year, a commercially available lab scale roll briquetting machine was employed (Komarek B-100). Further testing was conducted for the rest of the year with the use of a pilot scale model (Komarek B220-A). Briquettes were produced and evaluated by comparing results developed by adjusting various parameters of the briquetting machines and feed material.

Results further substantiate previous findings that curing time dictates both moisture content and strengths of briquettes, and slower roll speeds produce more robust briquettes. A statistical model was set up to determine the optimal range of operating parameters. The statistical model generated from these results provided basic relationships between the roll speed and briquette form pressure.

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of several controllable operating variables and the corresponding efficiencies of the modifications implemented. Due to the complexity of the briquetting process and the time available to use the leased equipment, only two variables, namely roll speed and briquette form pressure, were studied. In this last reporting period, briquettes were produced and evaluated by comparing results developed by adjusting various operating parameters of the machine, such as feed rate, roll speed, compaction pressure and moisture content of the coal feed material.

Concurring with the results obtained in previous quarters, the curing time of the briquettes is an important factor as far as the moisture content and strength of the coal product is concerned. As the curing time increases, the moisture content of the briquettes decrease. Although the initial moisture of the briquettes produced in this quarter was higher than those in earlier tests, after a curing period of 16 hours or longer, the moisture content dropped to the targeted values of this research project. The higher initial moisture content soon after preparation of briquettes is primarily a result of the presence of more than 35% of the total weight being fine coal particles, -100 mesh x 0. This is difficult to dewater rapidly with the limited roll pressures available and an inefficient water removal system. However, due to the hydrophobic nature of the coal-binder mixture, water can still be easily released from the briquettes, provided enough time is allowed for curing, or a higher percentage of binder is used.

Results from the drop and shatter tests also indicate that the strength of coal briquettes improves after a curing period of 16 hours. The loss of water in the curing process allows the binder to bond with coal particles more effectively, thus increasing the strength of the product. However, the abrasion resistance suffers as the curing process goes on. The combination of water and binder provide better adhesion against abrasion during the tumbling tests. The loss of water during the curing process tends to reduce the abrasion resistance, and results in producing a higher weight loss in the tumbling test.

Roll speed also plays an important part in terms of strength and abrasion resistance of the briquette. A shorter compaction time during briquetting results in a decrease in strength as the roll speed increases.

A matrix of tests was designed to examine a comprehensive range of operating parameters based on previous experiments. The matrix included a total of 14 experiments in which the results provided optimum operating parameters for various moisture contents of the feed material. The statistical models generated from these results established basic relationships between the operating parameters of roll speed and briquette form pressure. For instance, for moisture contents below 11 % after 24 hours of curing, the roll speed should be maintained below 3.12 rpm while the form pressure should be above 6,880 psi. The basic relationship between roll speed and roll pressure allow one to determine optimal operating parameters.

Attempts were made to alleviate the water drainage problems seen to occur during previous tests using the roll briquetting machine. During the dewatering stage, water is expelled at both the screw feeder and at the briquetting rolls. Though improvements were made to the drainage problem, additional effort is required to totally eliminate this problem. With the installation of new arrangements for the feeding and drainage systems that are already designed, significant improvements can be made to dewatering at the screw feed and rolls. The reduced feed moisture from the feed hopper should improve the dewatering efficiency during actual briquetting, and "grooving" of the rolls will produce more robust and drier coal briquettes.

The results in this period, along with the implementation of the simple modifications to the briquetting machine mentioned above, are sufficiently encouraging to suggest that a pilot scale test in a working environment, such as a coal preparation plant, should be considered.

Actual experience within a coal preparation plant using current coal washed feed materials where on site potential operating problems can be identified and corrected as they occur, provides accelerated transfer of the technology developed by ICCI.

OBJECTIVES

The objective of this research project is to combine fine coal dewatering and briquetting processes into a single stage operation. The operation involves the utilization of a hydrophobic binder as the dewatering and briquetting agent, and a compaction device. A pilot scale commercial briquetting machine was used to determine the effectiveness of this single stage dewatering/briquetting technique.

INTRODUCTION AND BACKGROUND

Fine coal cleaning techniques, such as column flotation, can effectively liberate coal from finely disseminated minerals. However, products from these processes possess large surface areas in which conventional dewatering techniques cannot be effectively applied. Therefore, a new dewatering technique is needed in order to take full advantage of these fine coal cleaning techniques.

The development of a single stage fine coal dewatering and briquetting technique is the primary objective of this research. Previous research has shown the potential to fabricate briquettes that satisfy fine coal handling, transportation, and storage requirements using both laboratory and pilot scale models. Research conducted this year has focused on the effectiveness of this technique using a pilot scale briquetting machine.

EXPERIMENTAL PROCEDURES

1. Sample Preparation:

a. Coal Sample:

In the first quarter of this year, Illinois No. 5 Seam with a size fraction of -28 mesh x 0 and a moisture content of 22 percent was used. For the second and third quarters of this reporting year, Illinois No. 6 coal seam with an average moisture content of 25 % and particle size of - 28 mesh x 100 was used in the dewatering and briquetting tests. Illinois Basin Coal (No. 6 Seam) of three size ranges were used in this project for the last quarter. In the experiment, the -16 x 100 mesh coal had an average moisture content of 17 %, the -100 mesh x 0 coal fines had an average moisture content of 31 % and the -16 mesh x 0 (a mixture of -16 x 100 mesh and -100 mesh) had an average moisture content of 22 %. The size distribution of each coal sample for the fourth quarter is presented in Figure 1.

b. Coal-Binder Mixture Preparation:

Orimulsion was the binding agent used for the dewatering and briquetting process. Orimulsion contains 65 to 70 percent of solid bitumen and 30 to 35% of water. When preparing the coal-binder mixture for the first and second quarters, three concentrations of Orimulsion (3, 4 and 5%) by weight of dry coal was diluted with water for all the coal samples while for the third and fourth quarters, three and five percent of binder was used, respectively. A small scale muller-mixer was used to mix the diluted Orimulsion with each coal sample for 10 minutes. For this last reporting period, the final coal-binder mixtures had an average moisture content of between 27 and 31 percent. A total of 1,800 pounds of coal-binder mixtures were prepared for testing within the last quarter.

2. Briquetting Process:

A lab scale K. R. Komarek briquetting machine, Model B-100 was used exclusively for the first quarter tests, while another pilot scale Komarek briquetting machine, Model B-220A was employed for tests carried out during the remainder of the year. The coal-binder mixture was fed into the roll press by a horizontal screw, and the pilot scale briquetting machine operated at speeds ranging between 78 and 120 rpm. The sample was then compacted between the two rolls within the confine of the pockets. Each roll contains 24 pockets that are three inches wide and 12 inches in diameter. Each pocket produces a coal briquette that measures 2.5 inches long, 1.5 inches wide and 1 inch thick.

In order to effectively utilize the briquetting machine during its availability for the fourth quarter, a statistical model was set up to determine the optimal range of operating parameters. The experimental matrix was based on the central composite design and fit with the quadratic model. Based on experimental data obtained in previous quarters, two operating parameters, roll speed and briquette form pressure, were chosen as target parameters. A total of 14 experiments were performed by adjusting parameters in accordance with the experimental matrix. The roll speed was varied from 2.0 to 4.0 rpm and the briquette form pressure ranged from 5,143 to 8,604 psi. A statistical model, which implemented a fitting model of the experimental results, was completed. Detailed experimental results are given in a later section of this report.

3. Dewatering Mechanism:

During the briquetting process, the coal-binder mixture undergoes two stages of dewatering. In the feeding process, the horizontal screw feeder pushes the coal-binder mixture into the roll press. Due to the feed screw extrusion effect, water is expelled from the mixture at the pre-compaction zone, prior to the compaction stage. At the second stage of dewatering, the coal-binder mixture is compacted between two rolls that rotate against each other under high pressure. The additional water in the feed material is squeezed out of the mixture as the coal briquette is formed.

4. Modifications of Komarek Model B-220A

Several modifications were made during the fourth quarter to the pilot scale briquetting machine, Model B-220A. During the second and third reporting periods, several drainage problems were observed in the experiments. Due to the screw extrusion effect, water was squeezed out of the coal-binder mixture at the pre-compaction zone. The expelled water drained back to the hopper and increased the initial moisture content of the subsequent feed. Modifications were made in an attempt to eliminate these problems. As shown in Figure 2, the solid plate bottom of the hopper was replaced by three layers of wire screens and a layer of coarse coal. The installation of the screens improved water drainage of the hopper; thus maintaining a more consistent moisture content of the feed material. Due to the large amount of water being expelled from the hopper in past experiments, a new water collecting system was installed at the bottom of the feed hopper (Figure 3). The system consist of two individual troughs that overlaid each other. The installation of the troughs was an attempt to collect the expelled water for analysis. The water analysis planned includes biochemical oxygen demand (BOD), dissolved oxygen (DO), heavy metal concentration and pH.

5. Evaluation of Fine Coal Dewatering And Briquetting Efficiency:

a. Moisture Content Determination of Dewatered Coal Briquettes:

In order to determine the moisture content of the coal briquettes that were being produced by the Komarek machine, the briquette weights were recorded (immediately after the production), and were placed in an oven at 110° C for at least 24 hours. The briquettes were then reweighed periodically until the weight was constant. The following equation was used to evaluate the moisture content:

$$\% \text{ Moisture} = \{(Wi - Wd) / Wi\} * 100 \% \qquad (1)$$

where Wi is the initial weight of the briquettes and Wd is the dried weight of the briquettes.

b. Water Absorption And Curing Tests:

The water absorption test was used to study the effect of binder curing time on water resistance of the coal briquettes. To conduct the absorption test, briquettes were placed under water for 24 hours after being exposed to atmosphere for pre-determined curing periods. Typical curing periods were 0, 8, 16, and 24 hours after the manufacture of the briquettes. The percentage weight gained by the briquettes after 24 hours of soaking in water, was used to measure the water resistance of the briquettes.

During the fourth quarter, 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 24 hours. The weight of the briquettes was recorded before and after placing them in the drying oven for 24 hours.

c. Tumbling Tests:

A tumbling test was used to evaluate the abrasion resistance of the coal briquettes. The test procedure was derived from ASTM standard test D441-45; named "tumbler test for coal." After predetermined curing times, briquettes (initial weight recorded) were placed in a tumbler rotating at a speed of 60 rpm, for six minutes. The briquettes were weighed and the percentage of weight loss (- 6 mesh x 0) was calculated and used as an index to evaluate the abrasion resistance of the briquettes. In the first quarter of this reporting year, only a single briquette was tested in this test. However, for the rest of the year, the number of briquettes involved in the test increased to at least seven briquettes to more closely simulate actual product handling situations. This test is an exaggeration of the handling of briquettes in practice, however, it has used as a means of comparison for briquettes made under different test conditions.

d. Drop And Shatter Tests:

The drop and shatter test was used, starting in the second quarter, to evaluate the strength and friability of the coal briquettes. The test procedure was derived from ASTM standard test D440. After predetermined curing times, the coal briquettes were released from a height of one meter and allowed to free fall and impact on a concrete floor. The coal pieces were then recovered and the weight loss (- 6 mesh x 0) was determined.

RESULTS AND DISCUSSION

1. Effects of Curing Time on Moisture Content of Briquettes

During the fourth quarter, a total of 36 different sets of experiments with the Illinois No. 6 coal, in the size range shown in Figure 1 using the pilot scale briquetting machine. As seen in the experimental data from previous quarters, curing time has a significant impact on the moisture content of the briquettes. In the fourth quarter, the average initial moisture content of the briquettes was about 18 %. As shown in Figure 4, after 8 hours of curing, the average moisture content dropped to about 13 %. Concurring with previous findings of previous quarters, as the curing time increased, the moisture content of the briquettes continued on a downward trend. At 24 hours, the average moisture content reduced to 8%. Rather than being trapped within the briquette, the hydrophobic coal-binder mixture allowed water to evaporate from the surface more easily, thus dramatically reducing the briquette's moisture content as time went on.

The effectiveness of the hydrophobicity of the briquette was further demonstrated by the results of saturation tests. The net amount of water reabsorbed during the tests increased with curing time. However, the actual moisture content never reached the initial level of the freshly produced briquettes. Furthermore, during the 24 hours re-curing period, the amount of moisture evaporated was constant, regardless of the first round of curing.

2. Effects of Curing Time on Abrasion Resistance of Briquettes

The tumbling tests were used to evaluate the abrasion resistance and friability of the coal briquettes. In terms of abrasion resistance, results from this quarter once again showed that the percent weight loss of the briquettes increased with curing time for the first 16 hours of curing. As shown in Figure 5, after 24 hours of curing, the amount of weight loss decreased from the value obtained after 16 hours. A possible explanation may result from the amount of water present in the briquette during that period. For example, in the first 16 hours, a relatively higher amount of moisture was still present within the briquette. The presence of water inhibits the binding effects of the coal-binder mixture. After 16 hours of curing, the moisture content of the product was substantially lowered and allowed the binding effects of Orimulsion to manifest itself, thus increasing the abrasion resistance of the products.

3. Effects of Curing Time on Strength of Briquettes

The objective of introducing the drop and shatter test in the second quarter was to evaluate the strength of the product. Results from the fourth quarter show that, as seen in previous quarters results, as the curing time increased the amount of weight loss in the drop test also increased (Figure 6). The increasing trend was particularly obvious after 16 hours of curing. This may be attributed to the fact that the strength of the briquettes depends on both moisture content and the binding effect, for example, when freshly produced, i.e. at 0 hour of curing, the relatively high moisture content in conjunction with the binder, provides higher strength and better cohesion between the coal particles. As curing time increases, the moisture content of the briquettes decrease, thus lowering their strength and making them brittle.

4. Effects of Binder Concentration on Briquette Characteristics

Three different concentrations of Orimulsion, namely 3, 4 and 5 %, were used in the experiments carried out in the second quarter. Figure 7 shows the results of the samples from the second quarter, after 24 hours of curing under different concentrations. Results show that after 24 hours of curing, the cured and saturated moisture contents for all samples were approximately 5 and 8.5% respectively. Also, as shown in Figure 8, the concentration of the binder used had a significant impact on the strength of the briquettes as time elapsed. The weight loss observed in the tumbling test dramatically reduced from 48% for 3 % binder concentration, to 7 % for 5 % binder concentration. Also, in the case of the drop and shatter test, the percent weight loss fell from 10.4 % for 4 % Orimulsion to 0.08 % for 5 % Orimulsion. These results clearly shown that the higher concentrations of Orimulsion improve the strength of the briquette significantly, as a result of better bonding between the coal particles.

5. Effects of Roll Speed on Briquette Characteristics

Early results from the first two quarters of the briquetting machines suggested that the cured and saturated moisture content gradually increased as the roll speed increased (see Tables 1 and 2). At higher roll speeds, the briquettes were subjected to less residence time inside the pocket, with a corresponding reduction in compaction time for the water to be released. However, comparing results for longer curing times, the difference in moisture content was not significant (< 1%) for different roll speeds, i.e. longer curing time gave the same moisture content.

Also, the significance of roll speed on the strength of the briquettes is important. Results throughout the year from both tumbling and drop tests indicate that the amount of weight loss increased as the roll speed increased. As described earlier, the reduced residence time at higher roll speeds contributes to less compaction during briquetting, thus reducing the strength and abrasion resistance of the product.

6. Effects of Roll Speed and Form Pressure on Moisture Content of Briquettes

In the fourth quarter of this reporting year, a total of 14 experiments, as shown in Table 3 and 4, were dedicated to the studying of roll speed in conjunction with form pressure. Due to the complexity of the briquetting process and limited time available for the leased machine, only two operating parameters, namely form pressure and roll speed, were studied. The objective of this study was to determine the optimal operating conditions and an attempt to establish basic relationship between operating variables. As mentioned in an earlier section of this report, different experimental conditions were examined and the corresponding results were analyzed and used in a statistical model. One of the relationships established between the two parameters is in Figure 9. At a given form pressure and roll speed, it is possible to determine the expected moisture content after 24 hours of curing using this particular briquetting machine and settings. For example, using a roll speed of 2.43 rpm and form pressure of 8,075 psi, the expected moisture content after 24 hours is 9.20%. Additionally, for a given target moisture content, a range of operating conditions can also be determined.

7. Economic Analysis of Komarek Briquetting Machine Model B-220A

Table 5 shows a simple first approximation of an economic evaluation of the dewatering and briquetting process, using a pilot scale briquetting machine. The costs for electricity were calculated on the basis of 4 cent/kWh. The maintenance cost is primarily equipment related, such as the replacement of briquetting rolls every three years. The capital cost is based upon a 15 years depreciation schedule. Based on the experimental conditions used in this reporting period, the machine has the capacity to produce dewatered briquettes at a rate of 0.15 to 0.19

tons of dry coal per hour, at a total cost of $5.81 to $6.83/ton. In order to increase this production rate, this pilot scale machine has the capability to expand to a five-roll briquetting machine. The cost evaluation on the five roll briquetting machine has also been evaluated based upon the cost data obtained from the single roll briquetting machine. It can be seen from Table 5 that the total costs are reduced to a range of $5.21 to $6.83/ton, by increasing the production five times. The analysis suggests that the higher the production rate, the lower the overall process cost that can be achieved.

8. Influence of Coal-Binder Feed Rate on Coal Briquette Characteristics Using A Lab Scale Briquetting Machine

In the first quarter of this reporting year, the effects of feed rate on briquette characteristics were studied on the lab scale briquetting machine. As shown in Table 6, the experimental results indicate that the dewatering characteristics improved as the feed rate increased. In terms of abrasion resistance, the results show that as the feed rate increased, the weight loss during the tumbling test reduced by as much as 10 % . The influence of coal-binder feed rate on the quality of dewatered coal briquettes can be attributed to the pre-densification of material prior to compaction at the briquetting rolls. As the briquetting roll speed remains constant and the feed rate is increased, the feeder screw delivers and packs the material more tightly at the pre-densification zone. This creates additional densification and more favorable product characteristics can be produced.

9. Influence of Coal-Binder Moisture Content on Coal Briquette Characteristics Using A Lab Scale Briquetting Machine

A study of coal-binder moisture content on the coal briquette characteristics was carried out in the first quarter. Results have shown that the characteristics of briquettes manufactured by the single roll-type briquetting machine were significantly affected by the moisture content of the coal-binder mixture. A coal-binder moisture content of 33% resulted in acceptable briquettes, however, as the moisture content was increased to 40%, the quality of briquette decreased. Although all briquettes cured to below 8% moisture after 16 hours, the briquettes made from the 40% moisture coal-binder mixture gained considerably more water during the saturation tests (Table 7).

The wear resistance of briquettes also deteriorated as the moisture content of the coal-binder mixture increased. As the moisture content of the mixture increased from 33% to 40%, the weight loss of briquettes over a 6 minutes tumbling time, doubled. However, all briquettes cured for at least 16 hours results in a small weight loss of less than 10 %.

In these tests, the influence of increased coal-binder moisture content on briquettes was largely due to the difficulty in material feeding into the briquetting machine. Specifically, as the moisture content of the coal-binder feed sample increased above 30%, the feeder screw was less efficient in delivering feed material.

10. Influence of Size Fraction on Coal Briquette Characteristics

During the 4th quarter of this reporting year, experiments were conducted on -100 mesh x 0 feed material. However, as seen from Table 3, the initial moisture and cured moisture contents of these experiments were above the targeted value of 15%. Possible solutions to this particular problem include increasing the binder concentration or mixing fine coal materials (-100 mesh) with coarser coal particles, such as -28 mesh x 100. Due to time constraints and variability of rolls pressure and speed on the equipment, only the option of mixing the -100 mesh x 0 coal with coarser coal, was attempted. Results of the mixed samples produced briquettes that contain acceptable levels of moisture content after curing. The presence of coarser coal particles provides bigger voids that which facilitate the evaporation and drainage of moisture.

11. Problems Encountered During Briquetting Experiments And Possible Solutions

As mentioned in earlier sections of this report, several modifications were made to the equipment in an attempt to improve water drainage during the briquetting experiments. However, the newly installed screening system, although it provided some improvement for water drainage at the hopper, did not perform as expected. In order to eliminate the back drainage problem, a new design is required. Figure 10 shows a new arrangement for the feeding system, that if installed, will include a wire mesh bottom along the length of the coal feed path. This new system has been designed to further facilitate drainage of expelled water and stabilize the moisture content of feed material. Other design considerations to solve this problem include concentric metal rings along the feed path and/or the provision of a groove in each roll pocket. The disappointing results of the drainage system prohibited the study and analysis of expelled water which will be carried out at a future date.

Arching of the feed material was another problem encountered during the operation of the briquetting machines. Due to the tacky nature of the high moisture coal-binder mixture, an arching effect occurs in the feed hopper which impedes the coal-binder mixture from entering the feeder auger. This resulted in insufficient mixture being delivered to the compaction zone and resulted in poor quality coal briquettes. The current solution employed manually pushed material into the hopper to ensure an adequate amount of feed material was delivered at all times during the production of briquettes. In an automated environment, a vertical auger or vibratory feed screw are possible solutions to this problem and should be studied in future work (Figure 10). The improvements suggested above were not able to be implemented because of funding limitations and the restricted availability of the lab and pilot scale briquetting machines.

CONCLUSIONS

1. Results in this reporting quarter using a pilot scale briquetting machine indicates that the presence of fines, which made up to 35% of the total weight of the product, affects the initial moisture of the briquettes. However, after 16 hours of curing time, the moisture level decreases to acceptable values (< 15%).

2. Results in this reporting quarter demonstrate the importance of the coarse particles within the product. The presence of coarser particles provides voids that facilitate the evaporation of water from the briquette.

3. Curing time has a significant impact on both moisture content and water resistance of the coal briquettes. As the curing time increases, the hydrophobic nature of the coal-binder mixture not only promotes the evaporation of water, it also prevents the re-entry of moisture into the briquettes.

4. Curing time also affects the abrasion resistance and strength of the briquettes. With the pilot scale briquetting machine, the weight loss in both tumbling and drop tests increases with the curing time. However, in the tumbling test, after 16 hours of curing, the binder effects of the Orimulsion improved the abrasion resistance of the briquettes.

5. The binder concentration does not have a significant effect on the moisture content after long periods of curing. Conversely, the weight loss in both tumbling and drop tests increased at lower binder concentrations. At higher concentrations, such as 5 %, the binder provided better bonding between the coal particles and resulted in stronger briquettes.

6. The moisture content of coal briquettes was affected by the roll speed of the briquetting machine. As the roll speed increased the residence time of coal-binder inside the pocket is reduced and less amounts of water are squeezed out during the briquetting process. For longer curing times, the difference in moisture content is insignificant.

7. Roll speed is also important in terms of the strength and abrasion resistance of the briquettes. A short compaction time during briquetting resulted in a decrease in strength as the roll speed increased.

8. Basic relationships were established between roll speed and briquette form pressure for defining moisture content of the finished coal briquette product. Using appropriate combinations of roll speed and form pressure, a targeted moisture content of briquettes can be achieved.

9. A statistical model suggests that when high feed rates are used in conjunction with both low machine roll speeds and high form pressures, robust briquettes with low final moisture content can be produced.

10. A simple economic evaluation of the briquetting process studied indicates that the higher the machine production rate, the lower the overall dewatering and briquetting cost.

11. In the lab scale briquetting device, with its limited ability to dispose of water, the moisture content of the coal-binder mixture affects the operating capabilities of the briquetting device. More specifically, as the moisture content increases, the loose coal mixture becomes more difficult to be fed to the rolls, thus limiting the success of the briquetting process.

12. The roll speed of the lab scale machine also greatly affected the performance of the briquetting device. Briquettes with the lowest moisture and best strength characteristics were manufactured at higher feed rates using the lab scale machine.

13. Attempts were made to solve the back-drainage and feed short-comings of the pilot scale of briquetting machine. Although improvements were made, still more work is required to eliminate these problems. New feeding and drainage systems are needed in order to meet the coal drying and briquetting requirements of this project.

14. In order to minimize capital investment necessary to economically benefit from the coal dewatering and briquetting process developed here, efforts have been made to identify equipment that is readily available and can, with modest modifications, produce the results required. Moreover, considerations have been given to ensure that the physical size and modular nature of the selected and modified equipment can be easily added to existing coal preparation plants without major alterations. Although a new design of equipment may be necessary to produce the best results when more experience is available, at this stage in the research and development effort, existing commercially available equipment is the avenue being pursued.

DISCLAIMER STATEMENTS

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Table 1. Influence of Roll Speed on Coal Briquette Characteristics for Lab Scale Briquetting Machine

Conditions: Komarek B100 Briquetting Machine
- 28 mesh x 0 particle size
Feed Moisture = 33 %
Binder Concentration = 3 %

Roll Speed, pellets/min	Curing Time, hrs	Initial Moisture Content, %	Cured Moisture Content, %	Saturated Moisture Content, %	Weight Loss 6 mins, %
31	8	16.5	6.7	17.2	7.4
	16	16.4	4.7	15.2	4.9
	24	16.7	4.3	8.8	3.3
43	8	16.9	6.8	17.5	9.2
	16	17.0	4.6	15.2	5.5
	24	17.2	4.4	8.9	1.3
63	8	17.5	7.1	18.1	8.2
	16	17.4	4.6	15.4	6.3
	24	17.6	4.3	8.8	3.8
90	8	17.9	7.4	18.6	8.0
	16	18.0	4.8	15.9	5.9
	24	18.3	4.7	9.2	3.5
108	8	18.5	7.5	18.9	8.3
	16	18.3	5.3	16.3	6.2
	24	18.5	4.9	9.2	3.9

1. Cured Moisture Content, %: Moisture content after pre-determined curing period.
2. Saturated Moisture Content, %: Moisture content after 24 hours of submerging in water
3. Wt. Loss 6 mins, %: Weight loss after 6 minutes of tumbline test.

Table 2. Influence of Roll Speed on Coal Briquette Characteristics for Pilot Scale Briquetting Machine

Conditions: Komarek Model B220A Briquetting Machine
Illinois No. 6 Coal Seam
28 mesh x 100 mesh particle size

Roll Speed, rpm	Curing Time, hrs	Cured Moisture[1], %	Saturated Moisture[2], %	Wt. Loss in Tumbling[3], %	Wt. Loss in Drop Test[4], %
2.8	8	8.64	12.69	N/A	4.18
	16	7.07	10.94	45.53	4.65
	24	5.78	9.18	54.29	13.79
	32	4.33	8.64	57.88	13.47
3.8	8	12.52	17.07	N/A	6.53
	16	8.30	13.36	34.55	4.78
	24	7.18	12.49	45.51	7.15
	32	4.71	8.95	47.38	8.89
4.1	8	12.67	18.12	N/A	3.14
	16	8.63	14.35	34.16	2.06
	24	7.66	13.15	48.69	8.37
	32	4.93	8.87	53.80	8.96
6.3	8	14.43	20.29	N/A	11.90
	16	9.10	15.13	43.56	2.06
	24	8.48	15.09	49.54	7.15
	32	5.65	9.82	56.81	10.84

1. Cured Moisture Content, %: Moisture content after pre-determined curing period.
2. Saturated Moisture Content, %: Moisture content after 24 hours of submerging in water.
3. Wt. Loss in Tumbling, %: Weight loss after 6 minutes of tumbling test.
4. Wt. Loss in Drop Test, %: Weight loss after drop and shatter test at height of 1 meter.

Table 3. Experimental Conditions for The Matrix Design

Conditions: Komarek Model B220-A Briquetting Device
Illinois No. 6 Coal Seam
-16 mesh x 0 particle size
Binder Concentration: 5 %

Run Number	Feed Moisture, %	Feed Screw Speed, rpm	Roll Speed, rpm	Briquette Form Pressure, psi
1	30.9	135	2.4	5512.7
2	30.9	135	2.6	6891.5
3	30.9	162	3.0	6891.5
4	27.0	135	3.0	6891.5
5	27.0	135	3.0	6891.5
6	27.0	135	3.0	6891.5
7	28.0	110	2.4	8269.8
8	28.1	135	3.8	6891.5
9	26.8	135	3.0	6903.3
10	26.8	135	3.0	6891.5
11	26.8	135	3.6	5513.2
12	29.5	135	3.0	5103.2
13	30.9	135	3.6	8269.8
14	30.9	135	3.0	6891.5

Table 4. Summary of Briquetting Experiments for The Matrix Design

Conditions: Komarek Model B220-A Briquetting Device
Illinois No. 6 Coal Seam
-16 mesh x 0 mesh particle size
Binder concentration : 5%

Run Number	Curing Time, hours	Cured Moisture Content[1], %	Saturated Moist. Content[2], %	Re-cured Moist. Content[5], %	Wt. Loss in Tumbling[3], %	Wt. Loss in Drop Test[4], %
1	0	21.32	22.42	16.8	19.88	1.24
1	8	17.71	21.85	14.9	12.84	0.94
1	16	12.41	19.38	14.3	52.30	6.17
1	32	8.24	17.41	13.6	33.28	8.25
2	0	20.98	22.48	15.6	15.23	1.49
2	8	16.28	20.93	15.3	29.29	1.32
2	16	11.66	20.02	15.7	35.69	3.63
2	32	9.33	18.19	13.3	32.22	7.52
3	0	25.22	24.04	17.5	20.29	2.96
3	8	17.84	22.16	11.0	24.16	4.25
3	16	12.70	21.22	14.2	51.04	16.01
3	32	11.17	20.17	15.6	42.24	7.96
4	0	24.12	25.49	16.4	8.61	4.01
4	8	21.85	24.59	14.2	25.83	5.93
4	16	18.19	23.46	12.7	44.58	10.63
4	24	13.91	21.61	12.9	38.52	13.42
5	0	23.18	24.90	19.4	12.82	2.55
5	8	22.19	24.94	15.0	8.23	6.56
5	16	16.67	23.36	13.0	55.19	11.63
5	24	14.32	22.53	11.8	48.41	14.86

1. Cured Moisture Content, %: Moisture content after pre-determined curing period.
2. Saturated Moisture Content, %: Moisture content after 24 hours of submerging in water.
3. Wt. Loss in Tumbling, %: Weight loss after 6 minutes of tumbling test.
4. Wt. Loss in Drop Test, %: Weight loss after drop and shatter test at height of 1 meter.
5. Re-cured Moisture Content, %: Moisture content after 24 hours of recuring period.

Table 4 - continued

Run Number	Curing Time, hours	Cured Moisture Content[1], %	Saturated Moist. Content[2], %	Re-cured Moist. Content[5], %	Wt. Loss in Tumbling[3], %	Wt. Loss in Drop Test[4], %
6	0	24.77	25.28	18.0	17.48	2.49
6	8	21.04	24.11	10.5	41.03	5.52
6	16	16.71	23.25	10.5	56.34	15.66
6	24	12.88	21.14	10.7	64.44	23.00
7	0	18.64	21.82	12.3	12.24	2.13
7	8	13.93	20.76	11.6	8.24	3.03
7	16	10.42	18.10	9.4	23.91	3.81
7	24	8.30	18.60	10.3	33.45	1.96
8	0	20.40	23.39	16.8	18.40	0.66
8	8	16.87	22.78	15.7	26.60	2.57
8	16	12.37	21.13	12.2	24.93	3.93
8	24	12.66	19.45	10.4	44.09	3.07
9	0	18.92	22.23	12.9	16.54	0.34
9	8	16.02	21.07	13.3	8.11	1.49
9	16	12.67	19.13	11.5	12.09	0.67
9	24	11.29	19.79	13.5	20.60	1.73
10	0	19.91	22.66	17.3	7.18	0.38
10	8	16.26	21.32	12.3	4.81	1.82
10	16	13.11	20.24	11.9	11.69	1.99
10	24	11.05	19.74	13.3	16.68	2.13
11	0	21.04	23.51	23.0	11.56	0.83
11	8	16.96	21.70	11.5	16.87	3.43
11	16	12.88	21.39	11.5	18.06	3.71
11	24	13.24	21.55	13.6	34.03	5.52
12	0	21.46	23.59	19.4	0.67	1.04
12	8	17.79	22.84	13.2	10.56	1.69
12	16	15.44	21.83	9.4	12.14	4.12
12	24	13.77	21.64	11.7	17.74	0.95

1. Cured Moisture Content, %: Moisture content after pre-determined curing period.
2. Saturated Moisture Content, %: Moisture content after 24 hours of submerging in water.
3. Wt. Loss in Tumbling, %: Weight loss after 6 minutes of tumbling test.
4. Wt. Loss in Drop Test, %: Weight loss after drop and shatter test at height of 1 meter.
5. Re-cured Moisture Content, %: Moisture content after 24 hours of recuring period.

Table 4 - continued

Run Number	Curing Time, hours	Cured Moisture Content[1], %	Saturated Moist. Content[2], %	Re-cured Moist. Content[5], %	Wt. Loss in Tumbling[3], %	Wt. Loss in Drop Test[4], %
13	0	22.28	24.08	17.5	24.37	3.24
13	8	18.09	23.59	12.3	13.11	6.32
13	16	15.37	21.84	8.7	24.55	7.25
13	24	11.24	20.88	9.1	39.58	4.44
14	0	20.67	22.91	15.6	14.78	1.52
14	8	16.35	22.29	12.8	8.35	2.26
14	16	12.60	N/A	8.2	16.52	5.63
14	24	9.11	18.66	8.3	40.61	3.51

1. Cured Moisture Content, %: Moisture content after pre-determined curing period.
2. Saturated Moisture Content, %: Moisture content after 24 hours of submerging in water.
3. Wt. Loss in Tumbling, %: Weight loss after 6 minutes of tumbling test.
4. Wt. Loss in Drop Test, %: Weight loss after drop and shatter test at height of 1 meter.
5. Re-cured Moisture Content, %: Moisture content after 24 hours of recuring period.

Table 5. Cost Study of The Fine Coal Dewatering And Briquetting Process Using a Roll Briquetting Machine

Single Roll Briquetting Machine

Net Production Rate, t/hr	0.15	0.19
Operating Costs, $/t		
Electricity	0.54	0.78
Maintainence	1.41	1.12
Binder Cost	1.96	1.96
Subtotal, $/t	3.91	3.86
Capital Cost, $/t		
15 years Depreciation	1.90	2.97
Total Cost, $/t	5.81	6.83

Five-Rolls Briquetting Machine

Net Production Rate, t/hr	0.75	0.95
Operating Costs, $/t		
Electricity	1.46	2.10
Maintainence	1.41	1.12
Binder Cost	1.96	1.96
Subtotal, $/t	4.83	5.18
Capital Cost, $/t		
15 years Depreciation	0.38	0.59
Total Cost, $/t	5.21	5.77

Table 6. Influence of Coal-Binder Feed Rate on Coal Briquette Characteristics for Lab Scale Briquetting Machine

Conditions: Komarek B100 Briquetting Machine
- 28 mesh x 0 particle size
Feed Moisture = 33 %
Binder Concentration = 3 %

Feed Rate, Setting	Curing Time, hrs	Initial Moisture Content, %	Cured Moisture Content[1], %	Saturated Moisture Content[2], %	Weight Loss 6-min.[3] %
6	8	20.9	8.5	21.9	18.7
	16	20.8	6.9	16.7	6.4
	24	21.1	6.3	10.5	5.2
6.5	8	19.6	8.1	20.2	13.7
	16	19.4	6.1	16.4	7.4
	24	19.8	5.5	10.2	4.2
7.0	8	18.7	7.2	19.5	9.2
	16	18.8	5.6	15.8	5.0
	24	18.7	5.1	10.2	3.1
7.5	8	18.1	6.7	18.9	7.1
	16	18.1	5.0	15.5	6.9
	24	18.0	4.8	9.1	2.4
8.0	8	16.9	6.8	18.0	7.6
	16	17.4	5.2	15.5	4.9
	24	17.3	4.9	9.6	2.7
8.5	8	16.5	6.7	17.2	7.4
	16	16.4	4.7	15.2	4.9
	24	16.7	4.3	8.8	3.3

1. Cured Moisture Content, %: Moisture content after pre-determined curing period.
2. Saturated Moisture Content, %: Moisture content after 24 hours of submerging in water
3. Wt. Loss 6 mins, %: Weight loss after 6 minutes of tumbline test.

Table 7. Influence of Coal Binder Moisture Content on Coal Briquette Characteristics for Lab Scale Briquetting Machine

Conditions: Komarek B100 Briquetting Machine
- 28 mesh x 0 particle size
Feed Moisture = 33 %
Binder Concentration = 3 %

Sample Moisture Content, %	Curing Time, hrs	Initial Moisture Content, %	Cured Moisture Content[1], %	Saturated Moisture Content[2], %	Weight Loss 6-min.[3], %
25	8	15.2	9.8	16.7	8.8
	16	15.0	4.3	11.2	4.5
	24	15.3	4.0	7.9	2.5
33	8	16.5	6.7	17.2	7.4
	16	16.4	4.7	15.2	4.9
	24	16.7	4.3	8.8	3.3
40	8	22.4	12.4	24.5	17.1
	16	23.4	8.2	17.7	8.9
	24	22.7	6.7	15.4	8.0

1. Cured Moisture Content, %: Moisture content after pre-determined curing period.
2. Saturated Moisture Content, %: Moisture content after 24 hours of submerging in water
3. Wt. Loss 6 mins, %: Weight loss after 6 minutes of tumbline test.

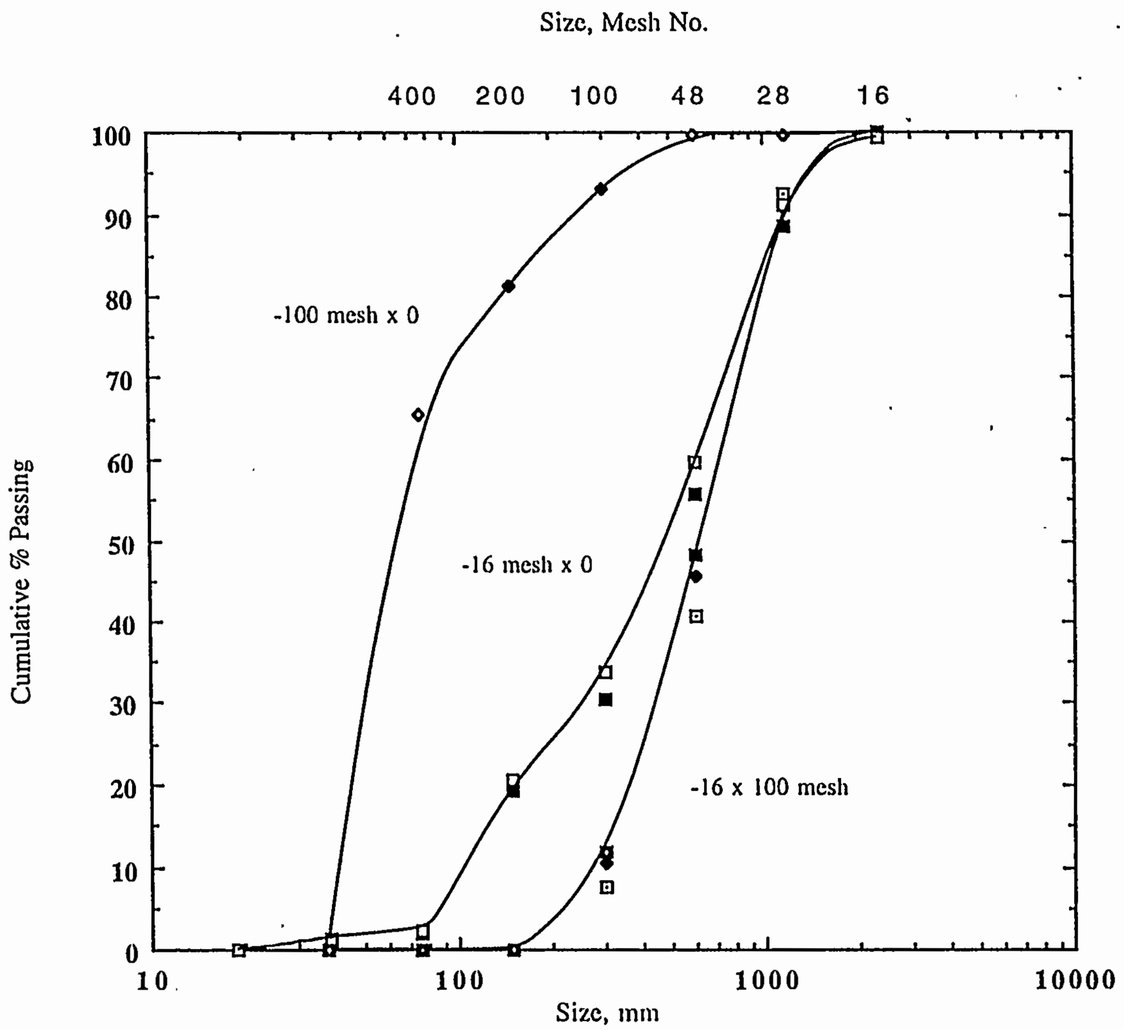


Figure 1. Size Distributions of Illinois No. 6 Seam Samples Used in Briquetting Machine Tests.

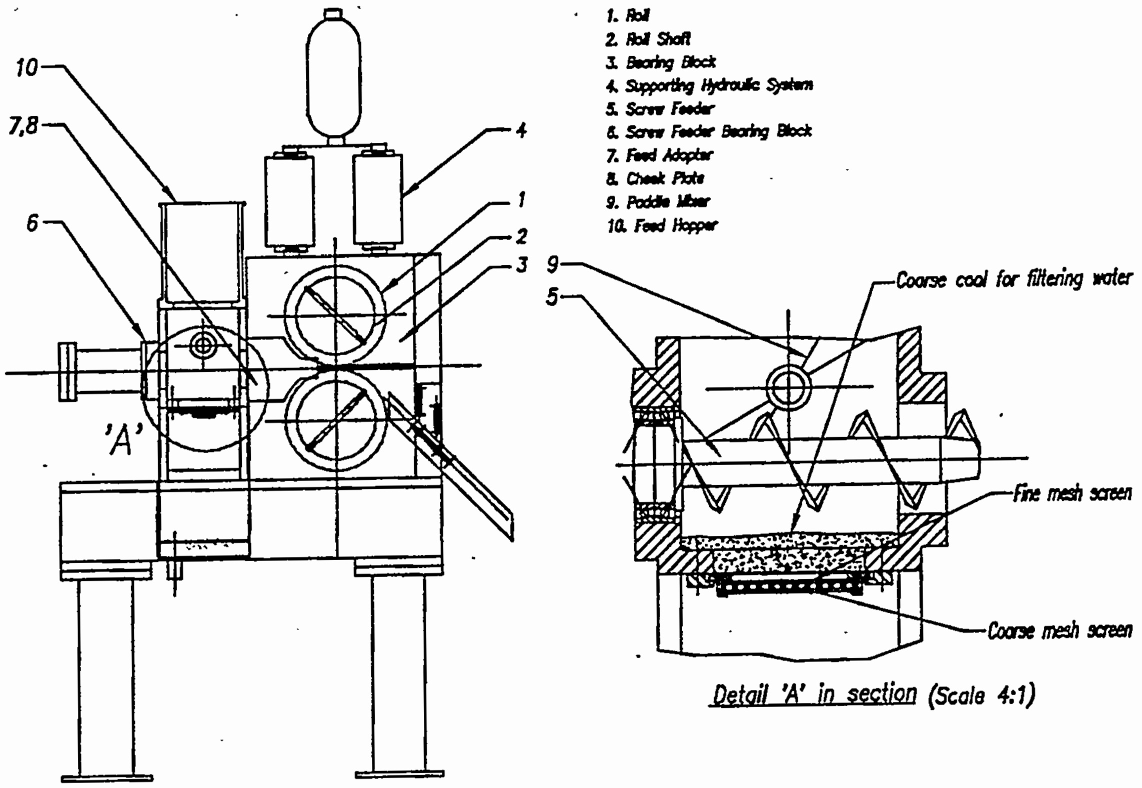


Figure 2. Modification of feed hopper

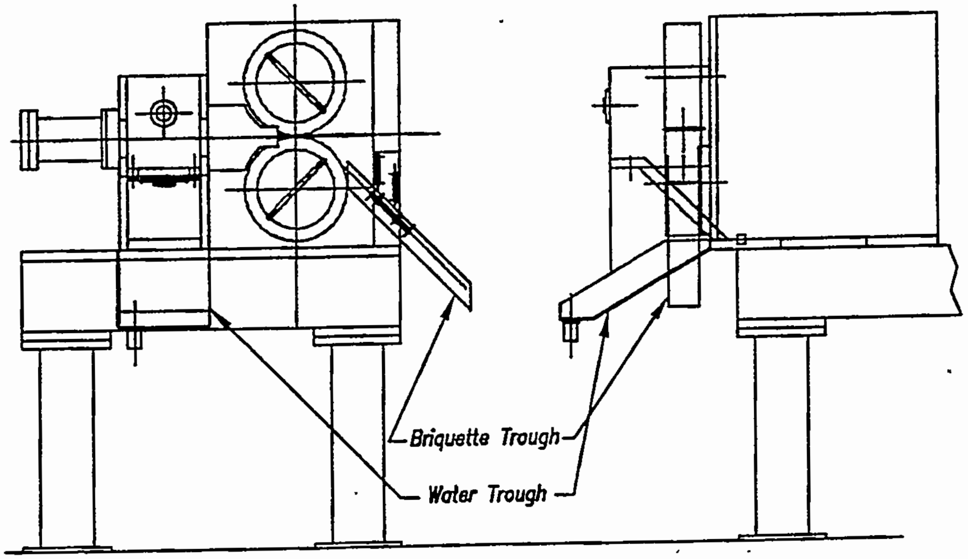
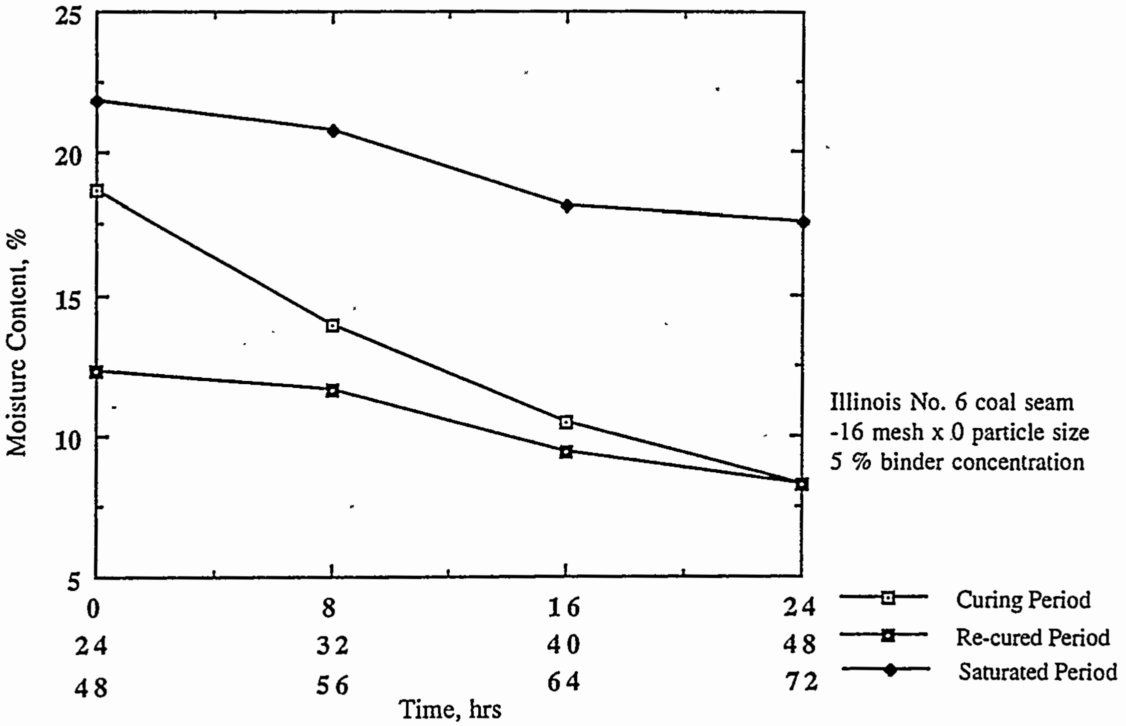


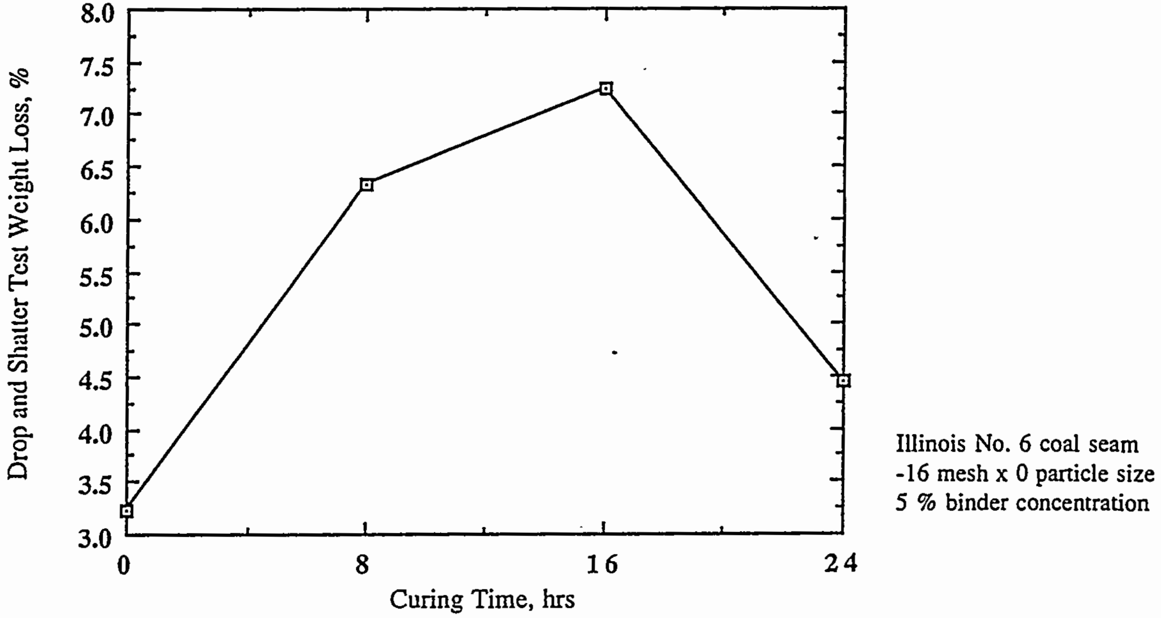
Figure 3. Newly installed water collecting system

Figure 4. Effects of Curing Time on Moisture Content of Briquettes



Illinois No. 6 coal seam
-16 mesh x 0 particle size
5 % binder concentration

Figure 5. Effects of Curing Time on the Strength of Briquettes



Illinois No. 6 coal seam
-16 mesh x 0 particle size
5 % binder concentration

Figure 6. Effects of Curing Time on Abrasion Resistance of Briquettes

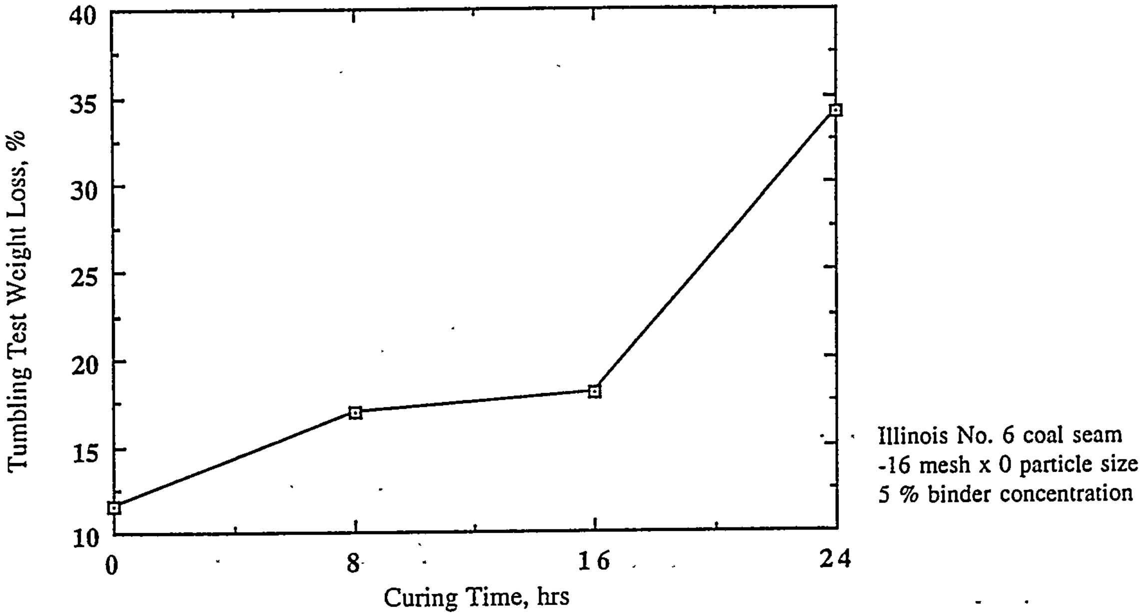


Figure 7. Effects of Binder Concentration on Briquette Moisture Content

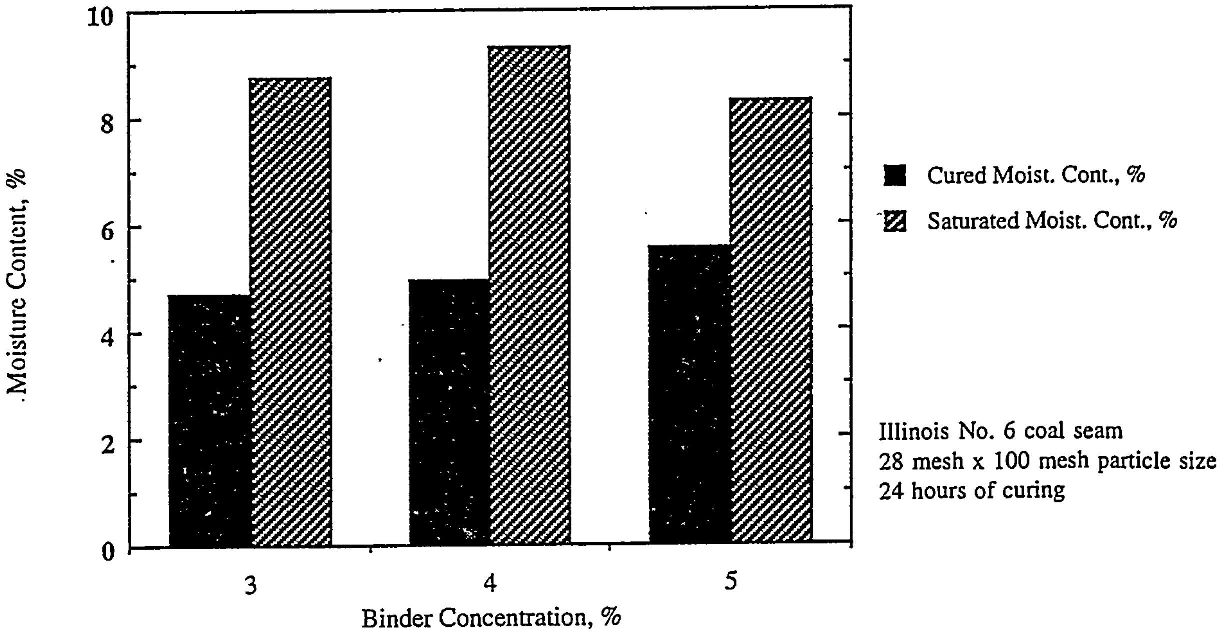
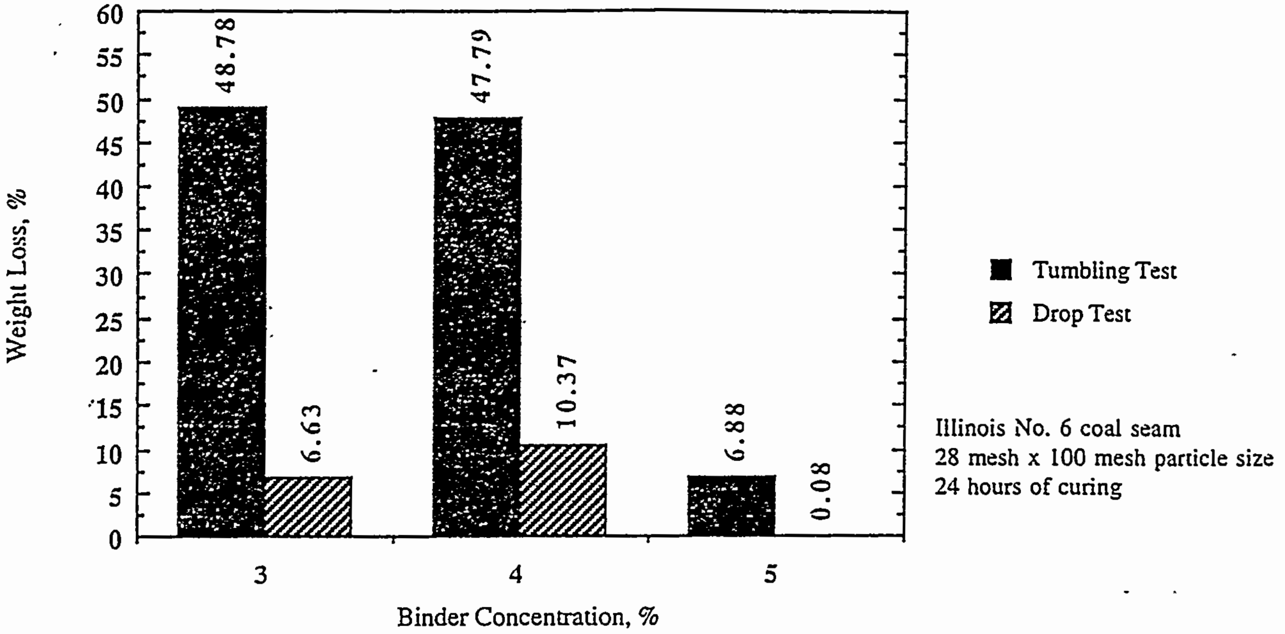
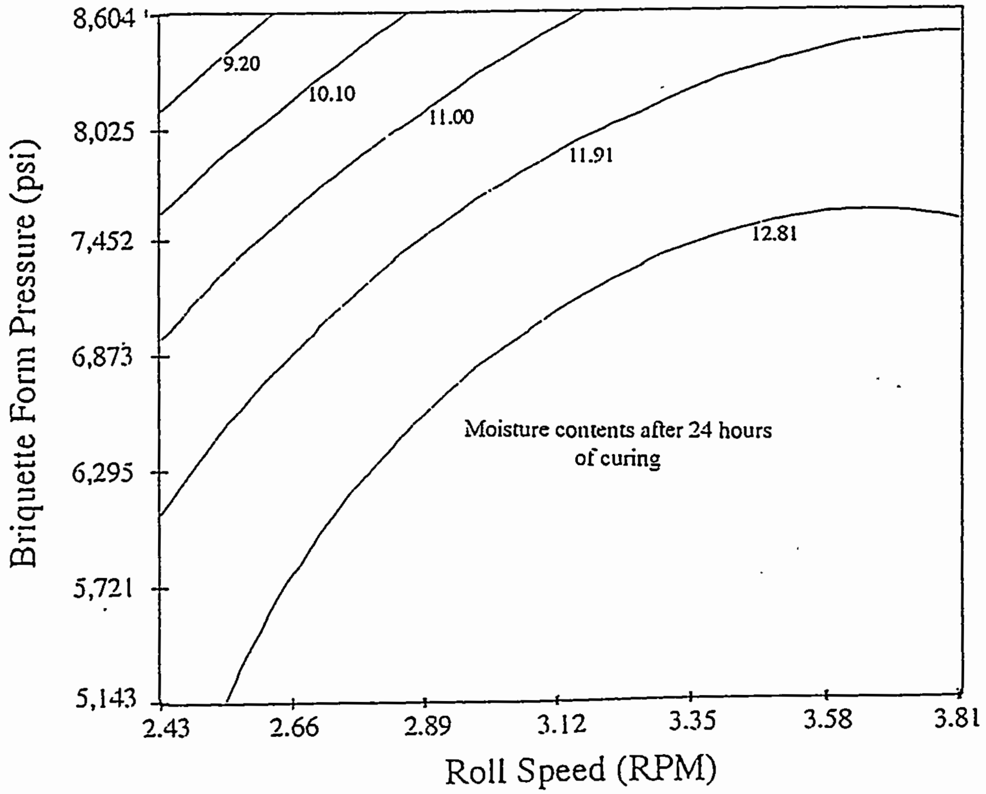


Figure 8. Effects of Binder Concentration on Briquette Strength



Illinois No. 6 coal seam
28 mesh x 100 mesh particle size
24 hours of curing

Figure 9. Relationship between Roll Speed and Briquette Form Pressure



Moisture contents after 24 hours of curing

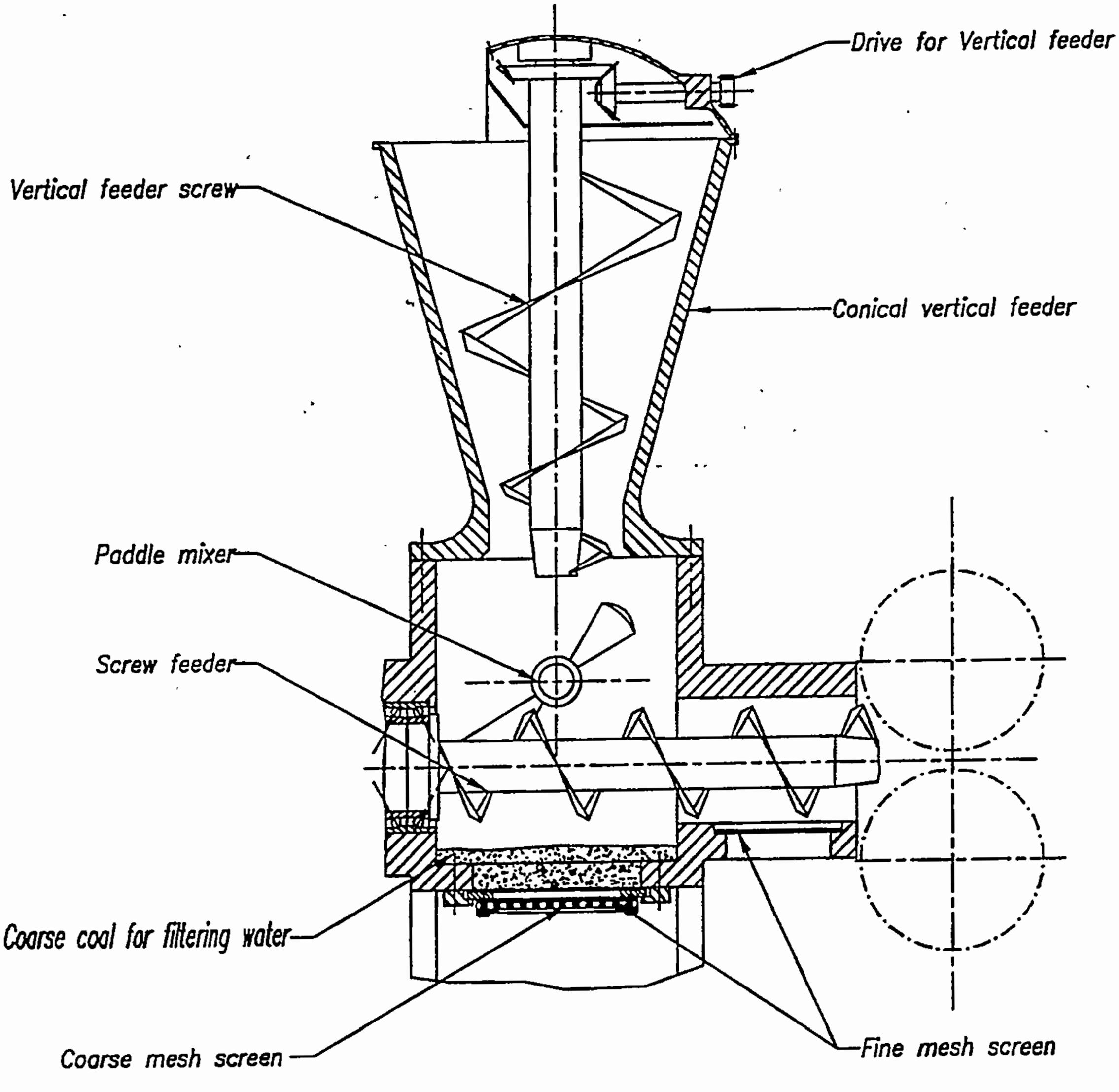


Figure 10. *Proposed modification of feed system*

ADDENDUM TO THE PROJECT 95-1/1.1A-2P
1995-96 FINAL REPORT

A general summary of the results of the experiments carried out with a simple ram compactor (1994/5), lab scale briquetting machine and a pilot model briquetting machine (1995/6), has been summarized in the attached table.

This table indicates the moisture contents and durability of briquettes formed for several particle size feeds under a variety of controllable conditions, such as compaction pressure, roll speed, feed rate and binder contents. Although this information shows clearly that coal briquettes can be manufactured with less than 15% moisture, it was not possible to successfully produce coal briquettes on a consistent basis from the finer coal sizes of -200 x 0 and -400 x 0, with the equipment used.

In order to further exploit the benefits of the briquetting process and thus utilize readily available commercial equipment, it is recommended that further modifications be made to a roll briquetting machine. The primary object would be to improve the speed of removal of water from the auger feed and roll pockets while providing a better feeding technique of the coal/binder mixture through the briquette machine.

Experience obtained to date with the briquetting process suggests that the proposed changes will be successful, and a demonstration of the briquetting system on a semi-commercial scale at an operating coal preparation plant, should follow.

The proposed commercial testing at a mine will provide accurate technical and cost information to enable the integration of this dewatering process in a coal preparation plant circuit.

A SUMMARY OF COAL FEED MOISTURE REDUCTION AND BRIQUETTE DURABILITY FOR THE TESTS PERFORMED BY MINING ENGINEERING, UMR

Type of Equipment	Size Fraction	Binder Conc. %	Coal Feed Moisture %	Pressure Applied, psi	Feed Rate rpm	Roll Speed rpm	Moisture of fresh Briquettes*	Moisture after 8 hours	Moisture after 16 hours	Wt. Loss (6 min) 8 hrs (%)	Wt. Loss (6 min) 16 hrs (%)
Lab Briquette	28 M x 0	3	25,33,40	2,000+	120+	≤1.7	16 - 20.5	~8.0	~4.9	~9.0	~6
Pilot Briquette	29 M x 100	3	34	6,700+	90+	≤3.8	N/A	~12.0	~8.5	N/A	~40
Pilot Briquette	28 M x 100	4	32	6,700+	90+	≤3.8	N/A	~14.0	~9.0	N/A	~36
Pilot Briquette	28 M x 100	5	35	7,500+	86+	≤3.8	16 - 25	~17.0	~12.0	N/A	~11
Pilot Briquette	16 M x 100	5	28	8,300+	110+	≤2.4	18 - 22	~14.0	~10.4	~8.3	~24
Ram Compactor	28 M x 0	2 - 5	32	up to 7,000	N/A	N/A	14.3 - 16	~9.5	~6.0	~5	~5
Ram Compactor	28 M x 100	3	32	up to 7,000	N/A	N/A	15 - 16.2	~10.2	~8.2	~11	~10
Ram Compactor	-100 x 0	2 - 5	32	up to 7,000	N/A	N/A	19 - 21	~11.7	~7.6	~9	~8
Ram Compactor	-400 x 0	2 - 5	35	up to 7,000	N/A	N/A	16 - 20	~14.0	~9.5	~8.5	~7

NOTE: This table represents the average results of the tests carried out under varying conditions and are NOT optimum results.

* Proposed changes to feed and removal of water from briquetting machine, will reduce these moisture levels.

PROJECT MANAGEMENT REPORT
June 1, 1996, through August 31, 1996

Project Title: **PILOT SCALE SINGLE STAGE FINE COAL DEWATERING AND BRIQUETTING PROCESS**

DOE Cooperative Agreement Number:	DE-FC22-92PC92521(Year 4)
ICCI Project Number:	95-1/1.1A-2P
Principle Investigator:	J. W. Wilson, Department of Mining Engineering, University of Missouri-Rolla
Other Investigators:	R. Q. Honaker, SIUC-Mining: Y. Ding, UMR-Mining
Project Manager:	K. Ho, ICCI

COMMENTS

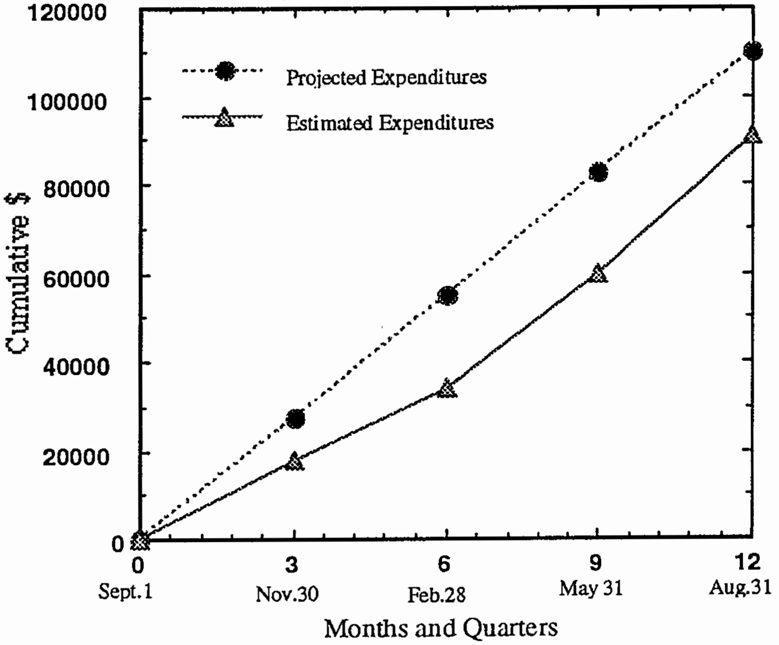
The pilot scale briquetting machine, Komarek B-220A, has been leased and tested at UMR. Experiments were performed using this machine and several modifications to the machine, such as incorporation of water drainage and collecting systems, have been completed.

EXPENDITURES - EXHIBIT B

CUMULATIVE PROJECTED AND ESTIMATED EXPENDITURES BY QUARTER

Quarter*	Types of Cost	Direct Labor	Fringe Benefits	Materials & Supplies	Travel	Major Equip.	Other Direct Costs	Indirect Costs	Total
Sept. 1, 1995 to Nov. 30, 1995	Projected	$15,197.5	$2850.3	$272.5	$500	$ 3,500	$378.5	$4,799.7	$27,498.5
	Estimated	$11,173.0	$1,116.2	$100.00	$1,236.7	$ 0	$450.00	$3,519.0	$ 17,595.1
Sept. 1, 1995 to Feb. 28, 1996	Projected	$30,395.0	$5,700.5	$545.00	$1,000	$7,000	$757.00	$9,599.5	$54,997.0
	Estimated	$20,865.0	$2,803.0	$663.00	$2,284.4	$ 0	$757.00	$6,843.0	$34,215.0
Sept. 1, 1995 to May 31, 1996	Projected	$45,592.5	$8,550.8	$817.5	$1,500	$ 10,500	$1,135.5	$14,399	$82,495.5
	Estimated	$33,560.8	$4,858.7	$681.1	$2,597.5	$1,100.3	$1,135.5	$10,708.4	$54,642.3
Sept. 1, 1995 to Aug. 31, 1996	Projected	$60,790	$11,401	$1,090	$2,000	$14,000	$1,514.0	$19,199	$109,994.0
	Estimated	$60,790	$11,401	$1,090	$3,800	$12,000	$1,314.0	$19,599	$109,994.0

***Cumulative by Quarter**



COSTS BY QUARTERS

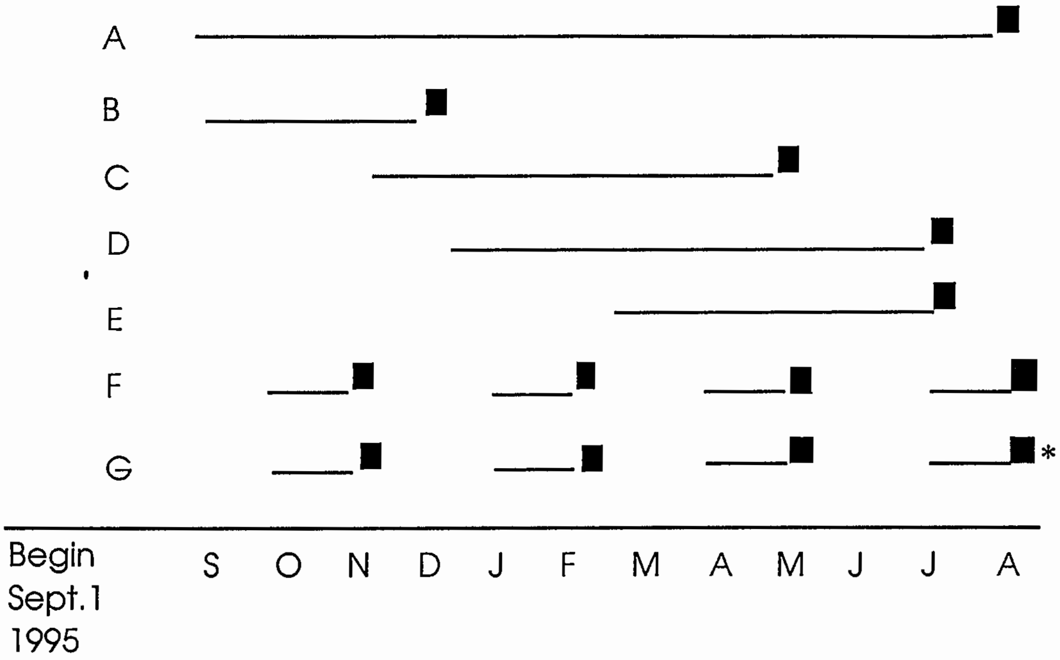
Ultrafine Coal Single Stage Dewatering and Briquetting Process

—○— = Project Expenditures

—△— = Estimated Expenditures

Total Illinois Clean Coal Institute Award = $109,994.0

SCHEDULE OF PROJECT MILESTONES



Major milestones of the proposed project

A. Research assistant and technician employed.
B. Tests on commercially available pelletizing machines has been completed.
C. Modify the most appropriate commercially available pelletizing machine.
D. Evaluate the operating parameters of the selected commercial pelletizing machine.
E. Collaborate with industry to develop a customized commercial dewatering and pelletizing machine.
F. Technical report prepared and submitted.
G. Project management report prepared and submitted.
* submitted September 3, 1996