

DOE/PC/92521--T276

TECHNICAL REPORT

September 1, 1995, through November 30, 1995

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

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ABSTRACT

The primary goal of the current ICCI coal preparation research is to reduce the ash and sulfur content from coal, using fine grinding and various coal cleaning processes to separate finely disseminated mineral matter and pyrite from coal. Small coal particles are produced by the grinding operation, thus the ultrafine coal becomes very difficult to dewater. In addition, the ultrafine coal also creates problems during its transportation, storage and handling at utility plants.

The current research is seeking to combine ultrafine coal dewatering and briquetting processes into a single stage operation, using hydrophobic binders as coal dewatering and binding reagents with the help of a compaction device. From previous tests, it has been found that coal pellets with a moisture content of less than 15% and good wear and water resistance can be successfully fabricated at pressures of less than 6,000 psi using a lab scale ram extruder.

The primary objective of the research described in this quarter has been to extend the lab scale ultrafine coal dewatering and briquetting process into a pilot scale operation, based on the test data obtained from earlier research. A standard roller briquetting machine was used to dewater fine coal-binder mixtures during the briquetting process. The operating parameters, including moisture content of feed, feed rate, and roller speed, were evaluated on the basis of the performance of the briquettes. Briquettes fabricated at rates of up to 108 pellets per minute exhibited satisfactory water and wear resistance, i.e., less than 7.5% cured moisture and less than 8.3% weight loss after 6 min. of tumbling. Also, coal-binder samples with moisture contents of 40 percent have been successfully dewatered and briquetted. Briquetting of fine coal was possible under current feeding conditions, however, a better feeding system must be designed to further improve the quality of dewatered coal briquettes.

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EXECUTIVE SUMMARY

It is well known that mineral particles, including pyrite, are finely disseminated in the Illinois basin coal in the form of micron size particles. In order to separate mineral matter from coal particles efficiently the mineral matter must be liberated from the coal matrix by the use of an ultrafine grinding operation followed by a wet physical coal cleaning process (column flotation). Due to the large surface area created by the ultrafine grinding operation, these ultrafine particles entrap a large amount of water after they are recovered from the column flotation process, and make the dewatering of the filter cake much more difficult than moderately ground particles. Moreover, this ultrafine coal creates dust control problems during its transportation and results in storage and handling difficulty at coal-burning utility plants.

In order to overcome the above mentioned problems, efficient dewatering and briquetting of ultrafine coal must be developed at the downstream end of the process, following the coal cleaning process. In the first stage of the lab scale studies, dewatered coal pellets (2" diameter) were fabricated with -30 mesh by zero, -100 mesh by zero, and -400 mesh by zero coal samples. Briquetting was achieved using a lab scale ram compactor operated at a pressure less than 6,000 psi. Three percent (3%) Orimulsion was used as a dewatering and briquetting agent to expel water that exists between the coal particles, and to bond the coal particles into a strong and robust pellet. After compaction, the moisture content is gradually reduced to less than 5% when cured for a period of 24 hours in ambient conditions.

Due to the promising results obtained from the previous lab scale studies, a pilot scale fine coal dewatering and briquetting process is necessary for evaluation prior to commercial application. During this reporting period, a commercially available briquetting device was leased and used to fabricate 3/4 inch by 1 1/2 inch, pillow shaped coal pellets for testing. The dewatering characteristics and relative friability of these pellets were optimized through adjustment of coal-binder moisture concentration, coal-binder sample feed rate, and device roll speed. Research is currently in progress to determine the optimum pilot scale briquetting device operating parameters for the manufacture of larger pellets.

Illinois #5 coal (Arch) was used for testing in this quarter. The Arch coal had a moisture content of 22 percent, however, to prepare the filter cake for the dewatering and briquetting tests, a calculated amount of water and Orimulsion was added into the sample. Coal-binder mixtures with moisture contents of 25%, 33%, and 40% were produced to determine the influence of sample moisture content on briquetting of coal. The particle size distribution was maintained at 50 percent -100 mesh with a maximum particle size of 28 mesh.

The dewatering and briquetting processes were carried out using a small scale roll briquetting device. As per instruction of the lessor, the feed rate and the roller speed were adjusted to optimize the characteristics of the coal pellets. The moisture content of the coal-binder mixture was also varied to determine its influence on the operation of the briquetting device.

Tumbling tests were conducted on coal pellets at curing times of 8, 16, and 24 hours, to determine the relative friability of the coal pellets. This technique provides a means of measuring the likelihood of coal pellets to break into smaller pieces when subjected to repeated handling during their transportation and handling at a utility plant. In general, the percentage weight loss of the coal pellets tested were found to be in the range of 2% to 9% after 6 minutes in the tumbler. The tumbling tests were carried out on all coal pellets that were subjected to 24 hours of water absorption tests. Twelve pellets were tested simultaneously to simulate wear due to handling.

Water absorption tests were also conducted on pellets cured over 8, 16, and 24 hour time periods to evaluate the water resistance of coal pellets fabricated using the pilot scale briquetting device. These tests were carried out by submerging the coal pellets in water for 24 hours. The amount of moisture gained was used as a measurement for evaluating the water resistance of the coal pellets. Research in this reporting period substantiated further the finding of previous experiments which showed that a curing time is required to build up the strength of coal pellets, and to evaporate more water from pellets when using bitumen emulsion as a binding agent. The moisture content of coal pellets made at various feed rates, roller speeds, and moisture contents, were measured after curing time periods of 8, 16, and 24 hours. It was found that the moisture content of the coal pellets was reduced substantially during a 16 hour curing period. Furthermore, coal pellets that were cured up to 16 hours absorbed lesser amounts of water than coal pellets that were immediately submerged after they were made.

The coal pellets used in these tests were produced using a commercial briquetting test machine. This machine was operated continuously using hydraulic cylinders to provide the compaction pressure for the fabrication of the coal pellets. While the compaction pressure is not directly transferred to the pellets, the hydraulic cylinders apply the force necessary to maintain the desired gap between the briquetting rollers. The feed rate and roll speed can be adjusted to vary the dewatering efficiency and durability of the coal pellets. Further testing is underway to determine the optimum operational parameters for a roll type briquetting device capable of producing larger size pellets at approximately one ton per hour production rate.

During this research period, a problem has been encountered with sample feeding. Due to the adhesiveness of high moisture coal, arching occurs within the coal hopper. Caking of the auger is another problem common to feeding of high moisture coals. One possible solution may be the use of a dual auger feed system. Further research is in progress to find the best solution to these feed problems.

OBJECTIVES

The objectives of this research project are to combine fine coal dewatering and briquetting processes into a single stage operation using a hydrophobic binder as the dewatering and briquetting agent, and with the help of a compaction device. A small commercial roll briquetting test machine was leased and tested to optimize the ultrafine coal dewatering efficiency, and at the same time, fabricate strong and robust coal pellets to meet coal transportation needs.

INTRODUCTION AND BACKGROUND

In the ultrafine coal cleaning process, small coal particles ($-100\text{M} \times 0$) are produced during the pulverizing operation. After the coal cleaning process, these fine coal particles are difficult to dewater and create problems in coal transportation, storage, and handling at utility plants.

Research work on fine coal dewatering and briquetting has resulted in the development of a single stage operation that is potentially more effective and economic than conventional thermal drying and briquetting processes. The final coal pellets have a moisture content of less than 15% and possess strength and water resistance that satisfy coal transportation, storage and handling requirements.

EXPERIMENTAL PROCEDURES

1. Sample Preparation:

a. Coal Sample:

Illinois basin coal (No 5. Seam) was received with a moisture content of approximately 22 percent. The maximum particle size was 28 mesh and the particle size distribution is shown in Figure 1. This figure shows that 83.5% of coal particles are less than 50 mesh and 55% of the total sample is smaller than 100 mesh.

b. Coal-Binder Mixture Preparation:

Orimulsion (bitumen emulsion) was used as a binding agent for the dewatering and briquetting processes. Orimulsion contains 60 to 75% of solid (bitumen) material and 40 to 25% of water. When preparing the coal-binder mixture, 3% of bitumen (5% of Orimulsion) by weight of dry coal was diluted with an appropriate amount of water. This diluted Orimulsion was then mixed with coal particles for less than 5 minutes, using a lab scale Hobart mixer. The final coal-binder mixtures had moisture contents of approximately 25, 33, and 40 percent before compaction.

2. Dewatering and Briquetting Process:

After complete mixing, the coal-binder mixture was fed into a pilot scale briquetting device. The roll speed was increased from 31 to 108 pellets per minute. Briquetting is achieved by the compaction of the two rollers rotate against each other to produce coal pellets, see Figure 2. The briquetting device consists of two rollers mounted on the ends of shafts cantilevered between bearing blocks. The rollers consist of 18 pillow shaped cavities in which the material is fed and compacted. The lower roller is held in a fixed position, while hydraulic cylinders restrain the upper roller and thus maintaining a constant gap between the two rollers. The rollers are driven by a pinion and set of companion gears mounted in the rear of the bearing blocks. Material is supplied to the rollers with a horizontal screw (see Figure 3.) driven by a variable speed drive unit.

3. Moisture Content Determination of Dewatered Coal Pellets:

The initial weight of coal pellets was measured at the same time as they were fabricated. These coal pellets were oven dried at 110°C until the weight of the coal pellets reached a constant weight. The moisture content of the coal pellets was then determined by the following equation:

$$\text{Moisture content of coal pellet} = [(\text{initial weight of coal pellet} - \text{oven dried weight of coal pellet}) / \text{initial weight of coal pellet}] \times 100\%$$

4. Water Absorption Test:

The water absorption test was carried out in order to examine the effect of binder curing time on water resistance of the coal pellet. The water evaporation (curing) test evaluates the rate of water evaporation from the coal pellet. The amount of water absorbed and the rate of water evaporation can be used as an index to evaluate the hydrophobicity of the coal pellet. Saturation tests were conducted at curing times of 8, 16, and 24 hours.

The water absorption tests were carried out by submerging the coal pellets in water for 24 hours after being exposed to the atmosphere for a pre-determined curing period. The percentage weight gained by the coal pellets was used to evaluate the water resistance of the coal pellets.

5. Tumbling Test:

In order to determine the strength and abrasion resistance of coal pellets, a tumbling test has been shown to be a good technique to make this evaluation. The tumbling test is derived from a modification of the "ASTM Standard Test Method of Tumbler Test for Coal D441-45". The test procedure is described as follows:

- After the coal pellet is made and cured, the coal pellets are allowed to soak in water for up to 24 hours. After saturation, the pellets are placed in a tumbler and the tumbler is rotated at 60 rpm for 6 minutes.
- After tumbling, the coal pellet is removed from the tumbler and re-weighed. The percentage weight loss is then calculated and used as the coal pellets abrasion resistance index.

RESULTS AND DISCUSSION

1. Influence of Coal-Binder Feed Rate on Coal Pellet Characteristics

The most influential aspect of fine coal briquetting using a roll type briquetting machine, is the coal-binder mixture feed rate to the briquetting rollers. As shown in Table 1, the dewatering characteristics improved as the feed rate increased. A feed rate dial setting of 6 produced pellets with a higher initial moisture content (21%) as compared with those pellets manufactured at a feed rate of 8.5 (16.5% initial moisture content). However, given a 16 hour curing period, the moisture content of all pellets dropped to below 9 percent. The moisture content of saturated pellets further substantiated research previously completed, i.e., the longer the curing period, the better the water resistance of coal pellets. While feed rate has shown an impact on the water resistance of coal pellets, the time period allowed for curing has a greater impact.

The feed rate also affects the amount of weight loss experienced by the pellets over a 6 minute tumbling test. As the feed rate increased from 6 to 8.5, the weight loss observed dropped approximately 10 percent. In addition, all pellets manufactured at feed rates greater than 7 lost less than 10% of their weight.

The influence of coal-binder feed rate on the quality of dewatered coal pellets 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 at the pre-compaction zone (see Figure 3.). This creates additional densification and more favorable pellet characteristics can be produced.

2. Influence of Briquetting Device Roller Speed on Coal Pellet Characteristics

The speed at which the briquetting roller turns also affects the characteristics of the coal pellets (see Table 2.). A roller speed of 31 pellets per minute produced pellets with an initial moisture content of 16.5 percent. As the roller speed was increased to 108 pellets per minute (3.5 times the original roller speed) the initial moisture content increased only

2 percent. All pellets cured for at least 16 hours had moisture contents of less than 5.5% and moisture contents of approximately 16% upon saturation after curing. Generally, as the roller speed increased dramatically, the dewatering characteristics were only slightly less favorable.

Regardless of roller speed, the weight loss experienced by all pellets remained less than 10 percent. As shown in Table 2, while roller speed had some affect on wear resistance the curing time had a greater impact. For pellets cured at least 16 hours after briquetting, a weight loss of approximately 6% was observed. This encouraging result indicates that the briquetting process is potentially capable of consistently producing good quality coal pellets at high production rate.

3. Influence of Coal-Binder Moisture Content on Coal Pellet Characteristics

The characteristics of pellets manufactured by the small roll-type briquetting machine were also significantly affected by the moisture content of the coal-binder mixture. A coal-binder moisture content of 33% resulted in acceptable pellets, however, as the moisture content was increased to 40%, pellets became less satisfactory. Although all pellets cured to below 8% after 16 hours, the pellets made from the 40% moisture coal-binder mixture gained considerably more water during the saturation tests (see Table 3).

The wear resistance of pellets was also impacted by the moisture content of the coal-binder mixture. As the moisture content of the mixture increased from 33% to 40%, the weight loss observed over a 6 minute tumbling time doubled. However, all pellets cured for at least 16 hours showed less than 10% weight loss.

The influence of increased coal-binder moisture content on briquetting is largely due to the increased difficulty in material feeding. More specifically, as the moisture content of the unpelletized sample increased to above 30%, the feeder screw was less able to deliver material to the briquetting rollers.

4. Feeding Problems and Possible Solutions

Due to the adhesiveness of the high moisture coal-binder mixture, two feeding problems were observed during the operation of the briquetting machine. As shown in Figure 4, an arching affect occurred in the feed hopper and impeded the coal-binder mixture from entering the feeder auger. Therefore, insufficient mixture was delivered to the compaction zone and resulted in poor quality coal pellets. Figure 5 shows the caking effect of the high moisture coal-binder mixture occurred along the groove of the auger, and thus decrease the feeding efficiency of the system. In the small scale tests, these problems were overcome by forcing the coal-binder mixture into the groove of the auger, with the help of a tapping stick.

One of the possible solutions to the above mentioned problems is to use an additional vertical auger within a conical hopper, see Figure 6. The secondary auger would feed material into the primary auger to avoid the arching effect of the coal-binder mixture in the hopper. Moreover, the secondary auger can also force the coal-binder mixture into the primary auger to reduce the possibility of caking problem. It is believed that a good feeding system can lead to the success of high moisture coal briquetting process.

CONCLUSIONS AND RECOMMENDATIONS

1. Coal pellets with good water and wear resistance can be manufactured using a roller-type briquetting device.
2. Coal-binder mixture feed rate is the most important factor to the success of briquetting fine coal. While the use of a feeder screw to deliver material to the rollers is satisfactory, further research in the area of material feeding techniques is necessary to enhance the performance of the briquetting device.
3. The roller speed also greatly affect the performance of the briquetting device. Pellets with favorable dewatering and strength characteristics were manufactured at an acceptable rate of 108 pellets per minute using the briquetting device tested.
4. Pre-packing occurs due to the relationship between material feed rate and roller speed. This allows additional densification of coal-binder mixture before compaction. As the feed rate is decreased and the roller speed is maintained constant, or the feed rate remains constant and the roller speed increases, pre-packing is less prevalent.
5. 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 rollers, thus limiting the success of the briquetting process. Although the briquetting of coal-binder mixture with a moisture content of 40% was possible, the pellet characteristics improved as the sample moisture content decreased. However, it is believed that the briquetting of high moisture coal-binder mixture can be improved by an efficient feeding system.
6. More research will be conducted on a larger scale briquetting machine to fabricate required size briquettes at a higher production rate. A more efficient feed system will be investigated to improve the quality of dewatered coal pellets.

DISCLAIMER STATEMENTS

DOE and Illinois Cooperative Projects - "This report was prepared by Dr. John W. Wilson & University of Missouri-Rolla with support, in part by grants made possible by the U.S. Department of Energy Cooperative Agreement Number DE-FC22-92PC92521 and the Illinois Department of Commerce and Community Affairs through the Illinois Coal Development Board and the Illinois Clean Coal Institute. Neither Dr. John W. Wilson & University of Missouri-Rolla nor any of its subcontractors nor the U.S. Department of Energy, Illinois Department of Commerce and Community Affairs, Illinois Coal Development Board, Illinois Clean Coal Institute, nor any person acting on behalf of either:

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Figure 1. Particle size analysis.

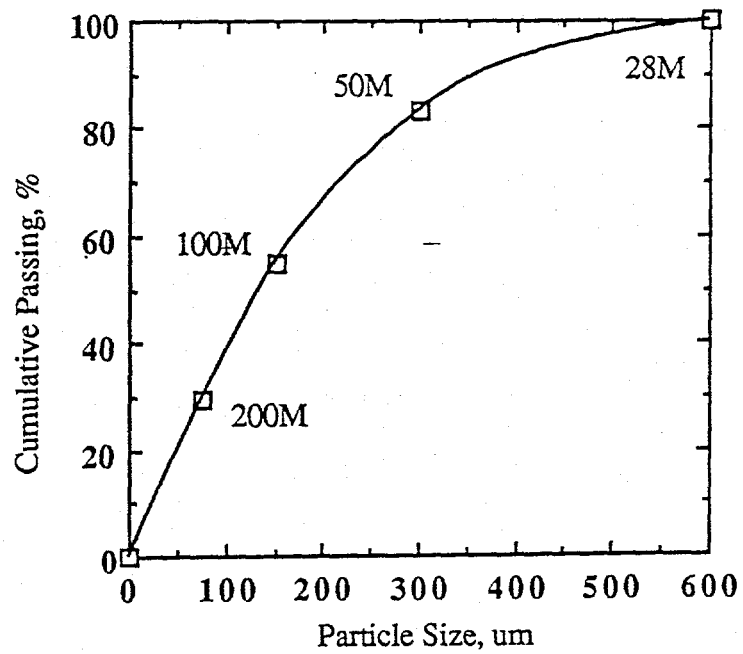


Figure 2. Current Roll Briquetting Machine

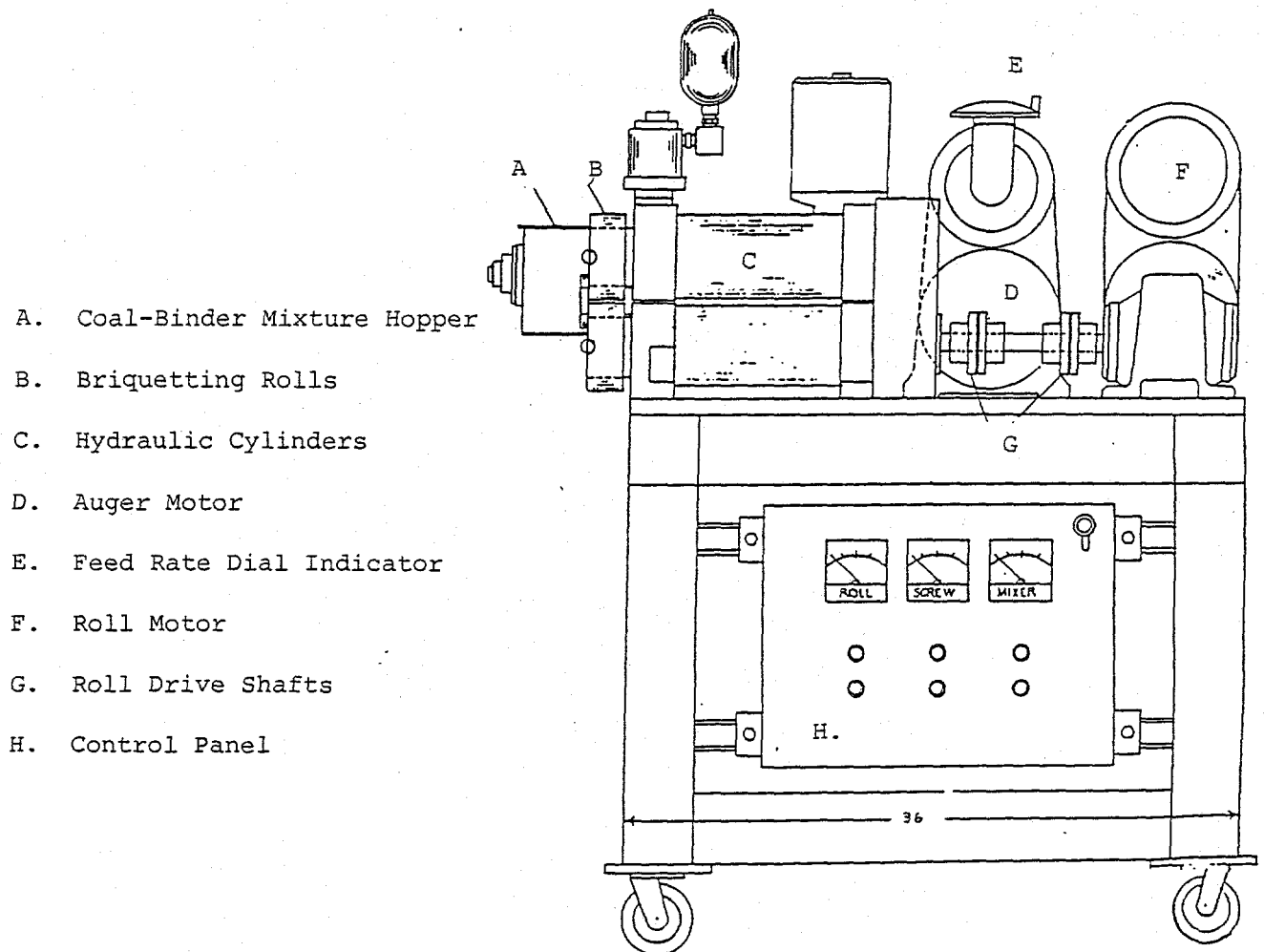
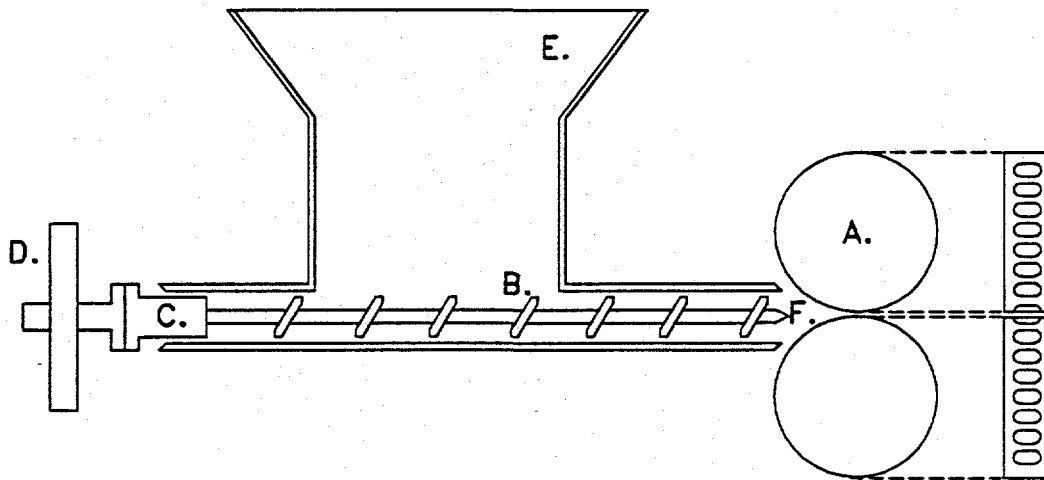


Figure 3. Auger Type Feeder used in Current Briquetting Device



- A. Briquetting Rollers, 18 pellets per revolution
- B. Auger Feeder
- C. Auger Drive Shaft
- D. Drive Shaft Fly Wheel
- E. Coal Hopper
- F. Pre-Densification Zone

Figure 4. Arching of Coal-Binder Mixture in Hopper

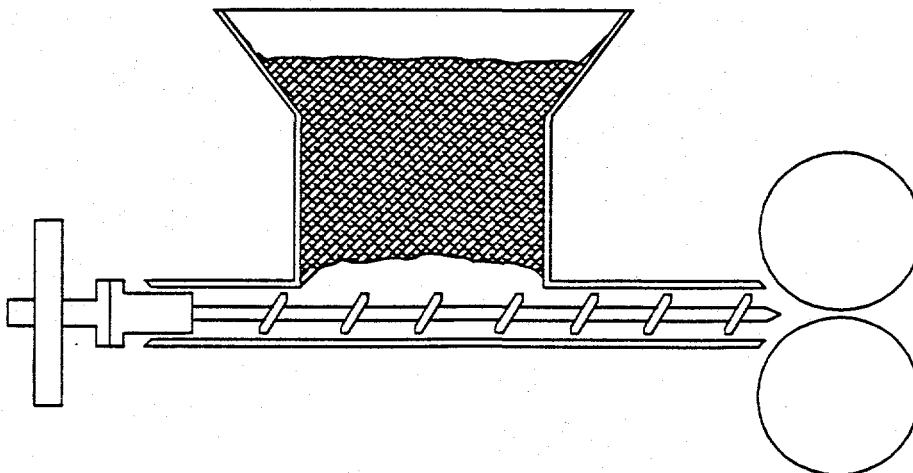


Figure 5. Caking of Coal-Binder Mixture on Auger Feeder

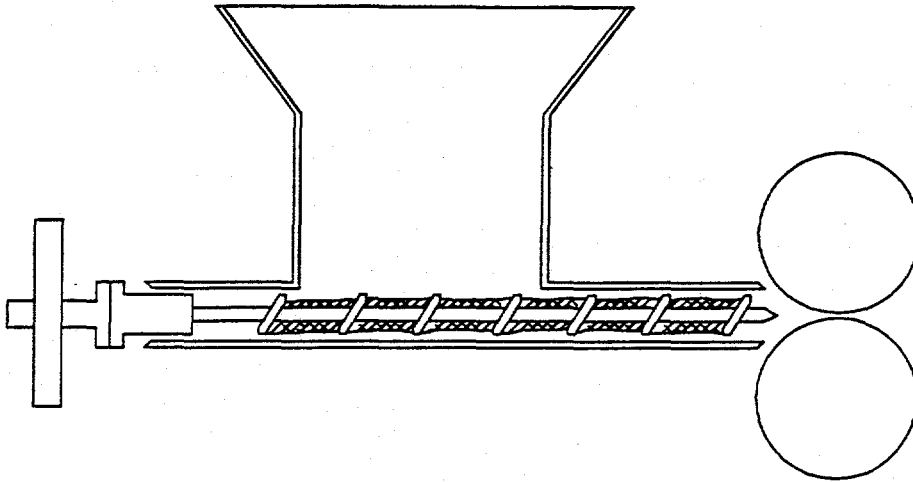


Figure 6. Possible Solution to Current Feeder Problems

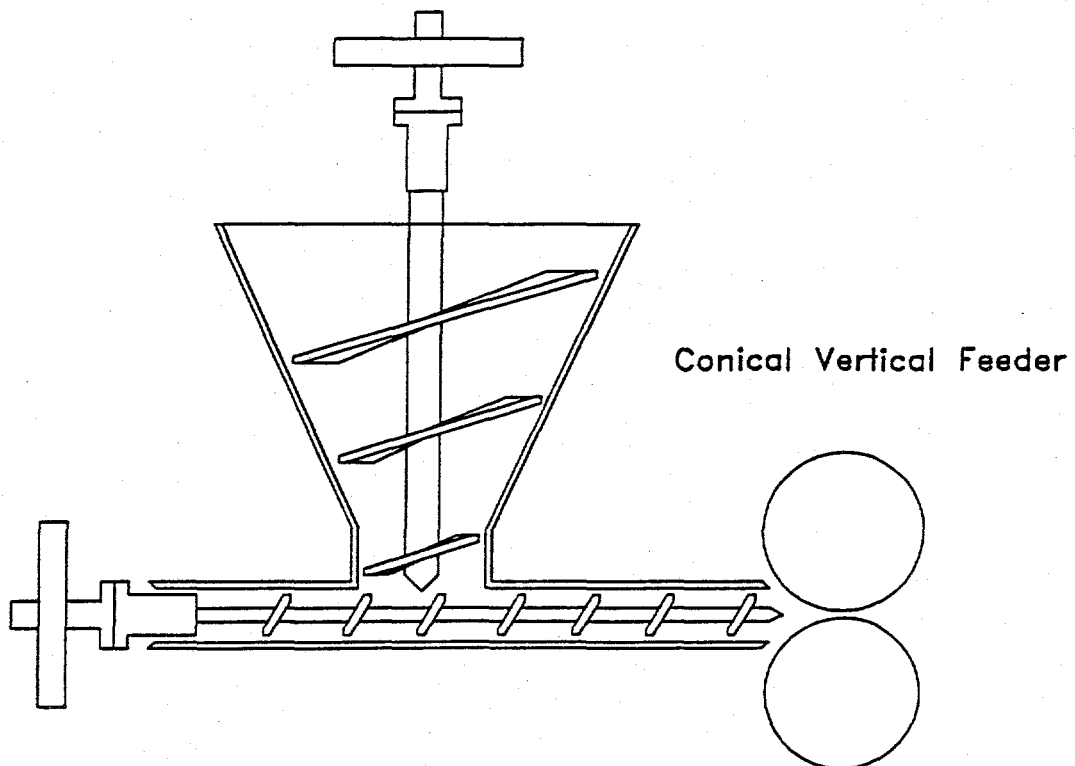


Table 1. Influence of Coal-Binder Feed Rate on Coal Pellet Characteristics

Test Conditions: Roller-Type Briquetting Device
 3% Orimulsion
 2000 psi hydraulic restraint of rollers
 - 28M x 0 particle size
 31 pellets per minute roller speed
 0.031 inch roller clearance
 33% coal-binder sample moisture content

Feed Rate, Setting	Curing Time, hr.	Init. Moist. Content, %	Cur. Moist. Content, %	Sat. Moist. Content, %	Wt. Loss 6-min, %
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	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	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

Table 2. Influence of Roller Speed on Coal Pellet Characteristics

Test Conditions: Roller-Type Briquetting Device
 3% Orimulsion
 2000 psi hydraulic restraint of rollers
 - 28M x 0 particle size
 8.5 feed rate setting
 0.031 inch roller clearance
 33% coal-binder sample moisture content

Roller Speed, pellets/min.	Curing Time, hr.	Init. Moist. Content, %	Cur. Moist. Content, %	Sat. Moist. Content, %	Wt. Loss 6-min, %
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

Table 3. Influence of Coal-Binder Moisture Content on Coal Pellet Characteristics

Test Conditions: Roller-Type Briquetting Device
 3% Orimulsion
 2000 psi hydraulic restraint of rollers
 - 28M x 0 particle size
 31 pellets per minute roller speed
 8.5 feed rate setting
 0.031 inch roller clearance

Sample Moist. Content, %	Curing Time, hr.	Init. Moist. Content, %	Cur. Moist. Content, %	Sat. Moist. Content, %	Wt. Loss 6-min, %
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

PROJECT MANAGEMENT REPORT
September 1, 1995 through November 30, 1995

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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 projected cost for major equipment was \$3,500 for the first quarter of this project. The small commercial briquetting machine leased since the end of previous project (DOE DE-FC22-92PC92521(Year 3), ICCI 94-1/1.1A-2P) was used to carried out the dewatering and briquetting tests. Therefore, no expense occurred in the category of major equipment.

The projected budget for the major equipment will be used in the second quarter to either purchase or modify a large pilot scale briquetting machine.

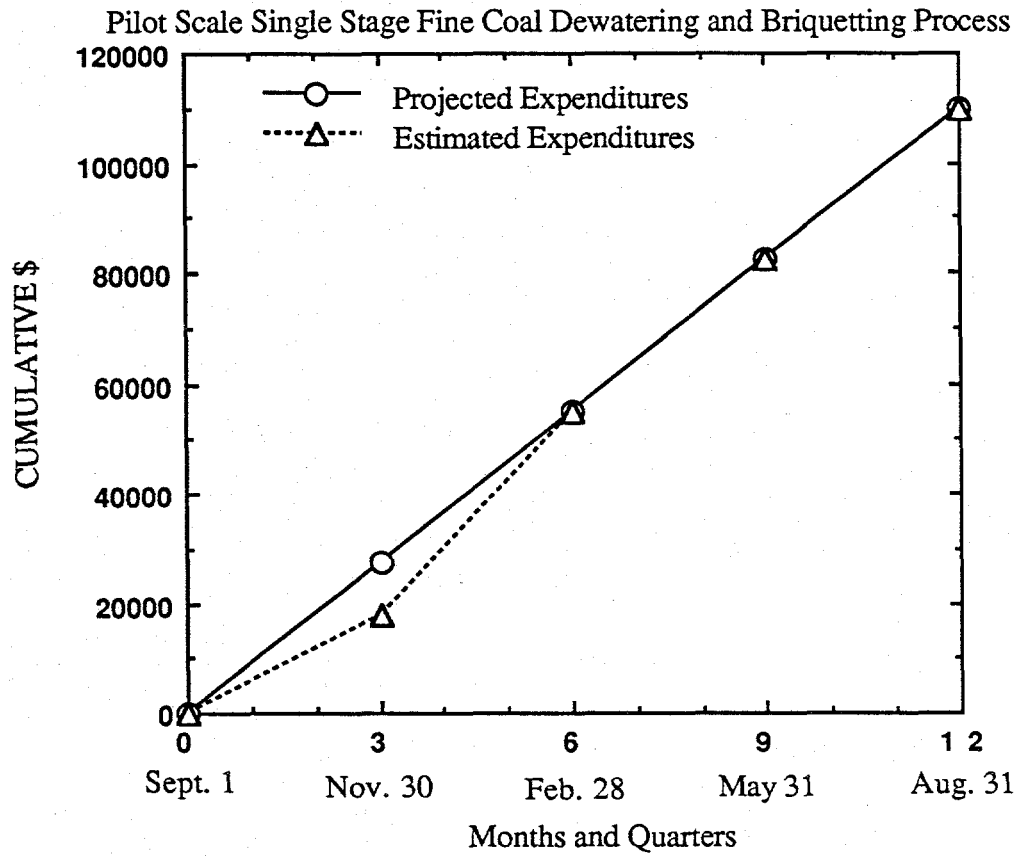
EXPENDITURES - EXHIBIT B

CUMULATIVE PROJECTED AND ESTIMATED EXPENDITURES BY QUARTER

Quarter	Types of Cost	Direct Labor	Fringe Benefits	Materials Supplies	Travel	Major Equipm.	Other Direct Costs	Indirect Costs	Totals
Sept. 1, 1995 to Nov. 30, 1995	Projected	15,197.50	2,850.25	272.50	500	3,500	378.50	4,799.75	27,498.50
	Estimated	11,173.00	1,116.16	100.00	1,236.7	0	450.00	3,519.02	17,595.11
Sept. 1, 1995 to Feb 29, 1996	Projected	30,395	5,700.50	545	1,000	7,000	757.00	9,599.50	54,997.00
	Estimated	30,395	5,700.50	545	1,236.7	7,000	757.00	9,658.43	55,292.16
Sept. 1, 1995 to May 31, 1996	Projected	45,592.50	8,550.75	817.50	1,500	10,500	1,135.50	14,399.25	82,495.50
	Estimated	45,592.50	8,550.75	817.50	1,500	10,500	1,135.50	14,399.25	82,495.50
Sept. 1, 1995 to Aug. 31, 1996	Projected	60,790	11,401	1,090	2,000	14,000	1,514.00	19,199	109,994.00
	Estimated	60,790	11,401	1,090	2,000	14,000	1,514.00	19,199	109,994.00

Cumulative by Quarter

COSTS BY QUARTERS

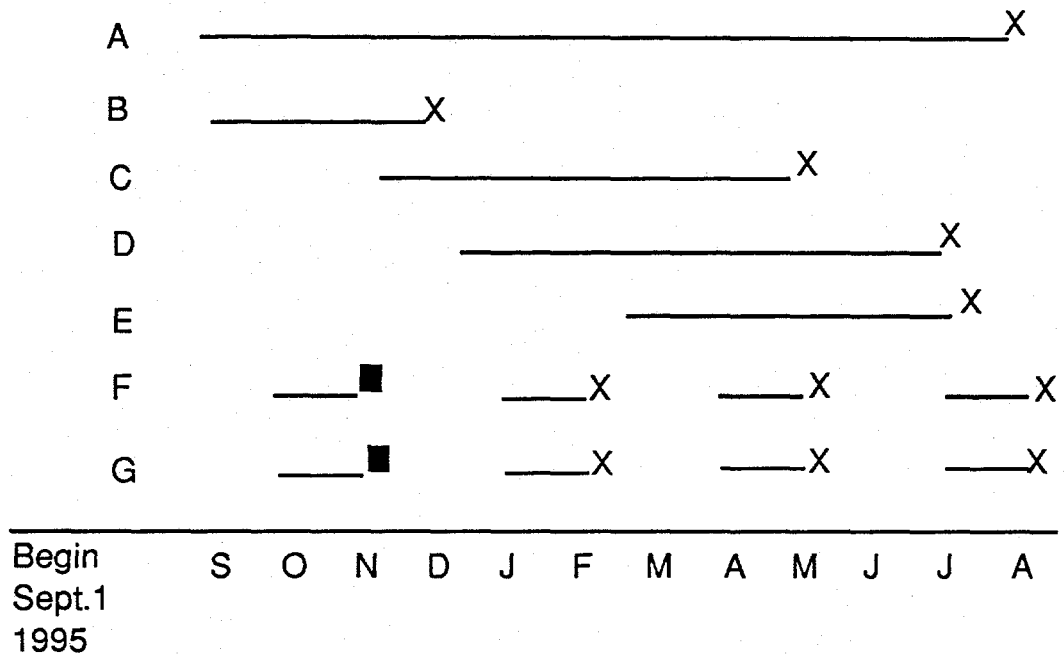


○ = Projected Expenditures ———

△ = Estimated Expenditures ———

Total Illinois Clean Coal Institute Award = \$ 109,994

SCHEDULE OF PROJECT MILESTONES



Major milestones of the proposed project

- A. Research assistant and technician employed.
- B. Tests on commercially available pelletizing machines.
- 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.

Comments:

The tests on a small commercial roll briquetting machine for fine coal dewatering and briquetting has been completed. A larger scale commercial briquetting machine has being scheduled for further tests.

