

TECHNICAL REPORT
September 1 through November 30, 1994

Project Title: **ULTRAFINE COAL SINGLE STAGE DEWATERING AND
BRIQUETTING PROCESS**

DOE Cooperative Agreement Number: DE-FC22-92PC92521 (Year 3)

ICCI Project Number: 94-1/1.1A-2P

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ABSTRACT

It is well known that a large portion of the pyrite particles in the coal seams of the Illinois Basin, are finely disseminated within the coal matrix. In order to liberate these micron size pyrite particles, one must use a fine grinding operation. The ultrafine coal particles that are produced are difficult to dewater and they create problems in coal transportation as well as in its storage and handling at utility plants. The objective of this research project is to combine ultrafine coal dewatering and briquetting processes into a single stage operation. This will be accomplished by the use of bitumen based emulsions for dewatering and a compaction device for briquetting.

During this reporting period, two types of coal samples have been tested for use in the dewatering and briquetting processes. These tests were carried out in conjunction with a selected hydrophobic binder as the dewatering reagent and an uniaxial hydraulic press. The influence of compaction pressure and binder concentration (2 to 5%) on the performance of coal pellets have been evaluated in terms of their water and wear resistance. A laboratory scale ultrafine coal dewatering and briquetting extruder that can be operated continuously for coal pellets fabrication, has been designed and built, and will be available for testing in the next quarter.

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EXECUTIVE SUMMARY

It is well known that mineral particles, including pyrite, are finely disseminated in the Illinois basin coal as 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 and then applying the wet physical coal cleaning process (column flotation). Because of the large surface area created by the ultrafine grinding operation, these ultrafine coal particles (-400 mesh) 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 coal 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 needs to be developed at the downstream end of the process, following column flotation. In this research project, bitumen emulsion has been 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 with the help of a compaction device.

The Illinois Harrisburg No. 5 coal from the Galatia Mine (Kerr McGee Co.) was projected to be used for the dewatering and briquetting process tests. Due to the reconstruction of the preparation plant at the Galatia Mine, two other types of coal samples, Eastern Appalachian Mettiki (Mapco) coal and Western Kentucky coal, were used to initiate the project.

The Mettiki coal was ground to a particle size where 72.9% passed a 400 mesh screen. In order to prepare the coal-binder mixtures for the dewatering and briquetting tests, a certain amount of water and bitumen binder was added into the coal sample to produce a coal-binder mixture that had a moisture content of 45%. This make-up moisture content is equivalent to the moisture content of ultrafine coal filter cake normally obtained from a coal preparation plant. The Western Kentucky TVA coal (Paradise Plant, Tennessee Valley Authority) that was provided by SIU at Carbondale, was coal filter cake which had a moisture content of 28% and a particle size of 22.2% passing a 400 mesh screen. Additional water was added to these coal samples to prepare the coal-binder mixtures to a moisture content of 35% for the dewatering and briquetting experiments.

In order to evaluate the influence of compaction pressure on the dewatering efficiency and coal pellet strength, compaction pressures of 2,000 to 10,000 psi were applied in this fine coal dewatering and briquetting process. For the Mettiki coal samples, the moisture content of the coal pellets was reduced from 20% to 11.4% (45% moisture content in the original coal-binder mixtures) as the compaction pressures increased from 2,000 to 10,000 psi. For TVA coal, the moisture content of the coal pellets was reduced from 19.5% to 12.2% (35% moisture content in the original coal-binder mixtures).

Tumbling tests were conducted 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

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pieces when subjected to repeated handling during their transportation, and handling at a utility plant. After 10 minutes in the tumbler, the percentage weight loss of the coal pellets was found to decrease from 10.9 to 4.6% as the compaction pressure was increased from 4,000 to 10,000 psi.

Water absorption tests were conducted to evaluate the water resistance of coal pellets fabricated using bitumen emulsion. Water absorption 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. For all coal pellets fabricated at various compaction pressures and binder concentrations, the amount of water absorbed by the coal pellets was less than 1%.

Earlier studies has shown that a curing period is required to build up the strength of coal pellets and to evaporate more water from the pellets, when bitumen emulsion is used as the binding agent. Thus, the moisture content of coal pellets made at various compaction pressures was measured at various time intervals, up to 24 hours. It was found that the moisture content of the coal pellets was reduced from 16% to 6% after 16 hours of curing period at ambient room temperature.

A lab. scale ram extruder was designed and built for the ultrafine coal dewatering and briquetting process. This dewatering and briquetting machine can be operated continuously using an hydraulic pump to provide the compaction pressure for 2" coal pellet fabrication. This machine will be tested to optimize its operating parameters for the manufacture of ultrafine coal of acceptable moisture content and in a strong briquette form.

OBJECTIVES

The objectives of this research project are to combine ultrafine coal dewatering and briquetting processes into a single stage operation using an hydrophobic binder as the dewatering and briquetting agent, and with the aid of a compaction device. A laboratory scale ultrafine coal pelletizing machine will be built and tested to optimize the ultrafine coal dewatering efficiency, and at the same time, to fabricate strong and robust coal pellets to meet coal transportation needs.

INTRODUCTION AND BACKGROUND

In the ultrafine coal cleaning process, small coal particles (-400 mesh) are produced during the pulverizing operation. After the coal cleaning process, these ultrafine particles are difficult to dewater and create problems in coal transportation, storage and handling at utility plants.

Research work on ultrafine 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 products have a moisture content of less than 15% and possess high strength and water resistance that satisfies coal transportation, storage and handling requirements.

EXPERIMENTAL PROCEDURES

1. Sample Preparation:

a. Mettiki (Mapco) Coal:

Coal samples were obtained from Mapco Coal Company at Maryland, and were crushed to -3/8" x 0 particles at UMR, using a laboratory scale Jaw Crusher and a Roll Crusher. These coal samples were then pulverized to 72.9% -400 mesh using a Hammer Mill and a Ring Pulverizer.

b. TVA Coal (Western Kentucky Coal):

The TVA coal was received from SIU. The coal samples are Jameson Cell flotation concentrates that were filtered using a lab. scale vacuum filter. These coal samples have a particle size of 52% less than 100 mesh and a moisture content of 28%. No further grinding was conducted on these TVA coals.

c. Coal-Binder Mixtures 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 Mettiki coal was used to prepare the coal-binder mixture, 2% of bitumen (3.3% of Orimulsion) by weight of dry coal was diluted with a certain amount of water. This diluted Orimulsion was then mixed with coal particles for 2 min. using a lab. scale mixer. This final coal-binder mixture has a moisture content of approximately 45%.

For the TVA coal, the concentration of Orimulsion used to prepare TVA coal-binder mixtures was the same as the binder concentration used in preparing Mettiki coal mixtures. The final coal mixtures have a moisture content of 35%, due to the fact that the TVA coals have a coarser particle size than Mettiki coal samples.

2. Dewatering and Briquetting Process:

After complete mixing, the coal-binder mixture was fed into a compaction mold. The compaction pressure was increased to within the range of 2,000 to 10,000 psi for not more than 2 to 3 min. The setup of the dewatering and briquetting process is shown in Figure 1.

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:-

Moisture content of coal pellet = [(initial weight of coal pellet - oven dried weight of coal pellet) / initial weight of coal pellet] x 100%

4. Water Absorption Test:

The water absorption test was carried out in order to examine the water resistance of the coal pellet when water is encountered during its transportation, i.e., rain and snow. The water evaporation 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.

The water absorption tests were carried out by submerging the coal pellets in water for 24 hours. 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 is considered 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 weighed, the coal pellet is placed in a tumbler and the tumbler is rotated at 60 rpm for 10 minutes. A sketch of the tumbler arrangement is shown in Figure 2.
- After tumbling, the coal pellet is removed from the jar and re-weighed. The percentage weight loss is then calculated and used as the coal pellet abrasion resistance index.

RESULTS AND DISCUSSION

1. Dewatering and Briquetting Reagents:

Orimulsion was used in this research as a dewatering and binding reagent. The Orimulsion was made by dispersing the bitumen substance into a liquid phase (water) with the help of interfacial reagents in a high shear mixing mill. More specifically, these emulsions can be considered as bitumen-water mixtures composed of tiny sub-micron size bitumen droplets suspended in water. The Orimulsion used in this research is a trade name of a bitumen that was obtained from Venezuela.

When Orimulsion is mixed with the ultrafine coal filter cake, the bitumen droplets become evenly dispersed throughout the coal sample, due to its water based characteristics. Because of the hydrophobic nature of the bitumen material and its chemical affinity for coal particle surfaces, the dispersed bitumen droplets can easily be adsorbed onto the coal particles and cause the water from the coal particle surface to be expelled during the mixing process. After thorough mixing, the bitumen coated coal mixtures are ready to be fed into a compaction device and be reconstituted into coal pellets.

2. Particle Size Analysis:

Figure 3 shows the particle size analysis of both the Mettiki and TVA coal samples. The Mettiki coal was prepared so that the particle size allowed 83.76% to pass a 200 mesh screen, using a lab. scale fine grinding pulverizer. The TVA coal was prepared by SIU and is a regular coal preparation plant product that has been cleaned and filtered

using a Jameson Cell and lab. scale vacuum filter. This coal sample has a particle size of 40.2% passing a 200 mesh screen.

3. Proximate Analysis of Coal Samples

Table 1 shows the proximate analysis of the coal samples used in these tests. It can be seen from Table 1 that the Orimulsion used as a binding agent has a very high heating value, 17,860 Btu. Therefore, the coal pellets produced all have higher heating value than their original coals.

Table 1. Proximate analysis of coal and dewatered coal logs

Types of samples	Volatile Matter, %	Ash %	Fixed Carbon%	Heating* Value, BTU/lb
Mapco "Mettiki"				
Coal	18.86	11.19	69.95	13,557
Orimulsion coal log				
"Mettiki coal"	19.99	12.34	67.67	13,600
TVA Coal from SIU				
	32.14	8.81	59.05	13,802
Orimulsion coal log				
"TVA coal"	33.34	8.64	58.02	13,870
Orimulsion (after drying process)				
	92.27	0.22	7.52	17,860

* The BTU tests were conducted on oven dried samples.

4. Influence of Compaction Pressure on the Dewatering Efficiency:

In order to evaluate the effect of compaction pressure on the dewatering efficiency of ultrafine coal, compaction pressures of 2,000 to 10,000 psi were applied to the coal-binder mixtures for both the Mettiki and TVA coals, using a lab. type uniaxial hydraulic press. The original coal-binder mixtures prepared for these tests had moisture contents of 45% for Mettiki coal and 35% for TVA coal respectively.

As shown in Figure 4, the moisture content of each coal pellet made was measured and plotted against the compaction pressure applied. For Mettiki coal, the moisture content of coal pellets produced decreased from 20.2% to 11.4%, as the compaction pressures increased from 2,000 to 10,000 psi. When using TVA coal for the dewatering tests, the moisture content of the coal pellets decreased from 19.7% to 12.2% as the compaction pressures increased from 2,000 to 10,000 psi. The slight difference on the dewatering efficiency of Mettiki coal and TVA coal is probably due to the different particle size distribution and surface nature of these two coal samples.

5. Influence of Compaction Pressure on the Wear Resistance of Dewatered Coal Pellets (Mettiki Coal):

Tumbling tests were carried out to evaluate the wear resistance of coal pellets by following the test procedures described in the Experimental Procedures section. The dewatered coal pellets were tumbled in the tumbler at a speed of 60 rpm. After 10 min. of tumbling, the percentage weight loss of the coal pellets was used to evaluate the wear resistance of the coal pellets. As shown in Figure 5, the percentage weight loss of coal pellets decreased from 10.9 to 4.6% as the compaction pressure increased from 4,000 to 10,000 psi. The coal pellets made at 2,000 psi broke into pieces and no data was recorded. According to the test results obtained, it was noted that the higher the compaction pressure, the greater the wear resistance of the coal pellets produced.

6. Influence of Binder Concentration on the Properties of Coal Pellets (Mettiki Coal):

Figure 6 shows the effect of various binder concentrations on the wear resistance of coal pellets that were made at 6,000 psi. From the tumbling test results, it can be seen that the percentage weight loss of coal pellets decreased from 18.9 to 4.6% as the binder concentration increased from 1 to 5%. For coal pellets made without the addition of a binder, they completely disintegrated during the tumbling test. These test results show that the wear resistance of coal pellets is improved by increasing the binder concentration.

The moisture content of each coal pellet that was made with various binder concentrations was also measured. Figure 7 shows that the moisture content of the coal pellets produced decreased from 16.22 to 12.8% as the binder concentration increased from 1 to 5%. These test results indicate that more water can be expelled from a coal pellet at higher binder concentrations. The optimum binder concentration for the ultrafine coal dewatering and briquetting process will be determined based on the overall economic studies that will be conducted at a later stage of this project.

7. Water Absorption Tests:

The water absorption tests were carried out on coal pellets made at various compaction pressures and binder concentrations, by submerging the coal pellets in water for 24 hours. The percentage weight gained by the pellets was used as an index to evaluate the water resistance of coal pellets. According to the test results, all coal pellets tested showed weight gains of less than 1%. These test results indicate that coal pellets made with Orimulsion have a high water resistance and will not absorb water during transportation and storage periods.

8. Design of Dewatering and Briquetting Machine:

Over the current reporting period, all coal pellets tested were fabricated using a lab. type hydraulic press that can only provide an intermittent operation. In order to apply the continuous dewatering and briquetting process in practice, an hydraulic ram extruder has been designed and built for continuous operation. The setup and major components of this machine are illustrated in Figure 8. This ram extruder is currently being tested and will soon be operated for coal pellet fabrication.

CONCLUSIONS AND RECOMMENDATIONS

1. From a proximate analysis data on Orimulsion, it was found that it has a very high heating value. Therefore, the coal pellets made with Orimulsion have higher heating values than the original coal samples.
2. The compaction pressure used to make pellets is one of the most important factors to affect the dewatering efficiency and strength of coal pellets fabricated when Orimulsion is used as a binding agent. During the compaction process, more water can be squeezed out of the coal pellets and more dense and robust coal pellets can be produced at higher compaction pressures, than at lower compaction pressures.
3. The binder concentration is another factor that affects the ultrafine coal dewatering efficiency and the strength of coal pellets formed. When using a higher binder concentration in the dewatering and briquetting process, coal particles are coated with a thicker bitumen layer, and thus, more water is expelled from the coal pellet than when the coal pellet is made with a lower binder concentration during the compaction process.

4. The Illinois Harrisburg No.5 coal will be used for the dewatering and briquetting process tests next quarter, as soon as the reconstruction at the preparation plant at the Galatia Mine is completed.
5. The laboratory scale ram extruder will be tested for manufacturing ultrafine coal pellets of acceptable moisture content.

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 Energy 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 Energy & Natural Resources, Illinois Coal Development Board, Illinois Clean Coal Institute, nor any person acting on behalf of either:

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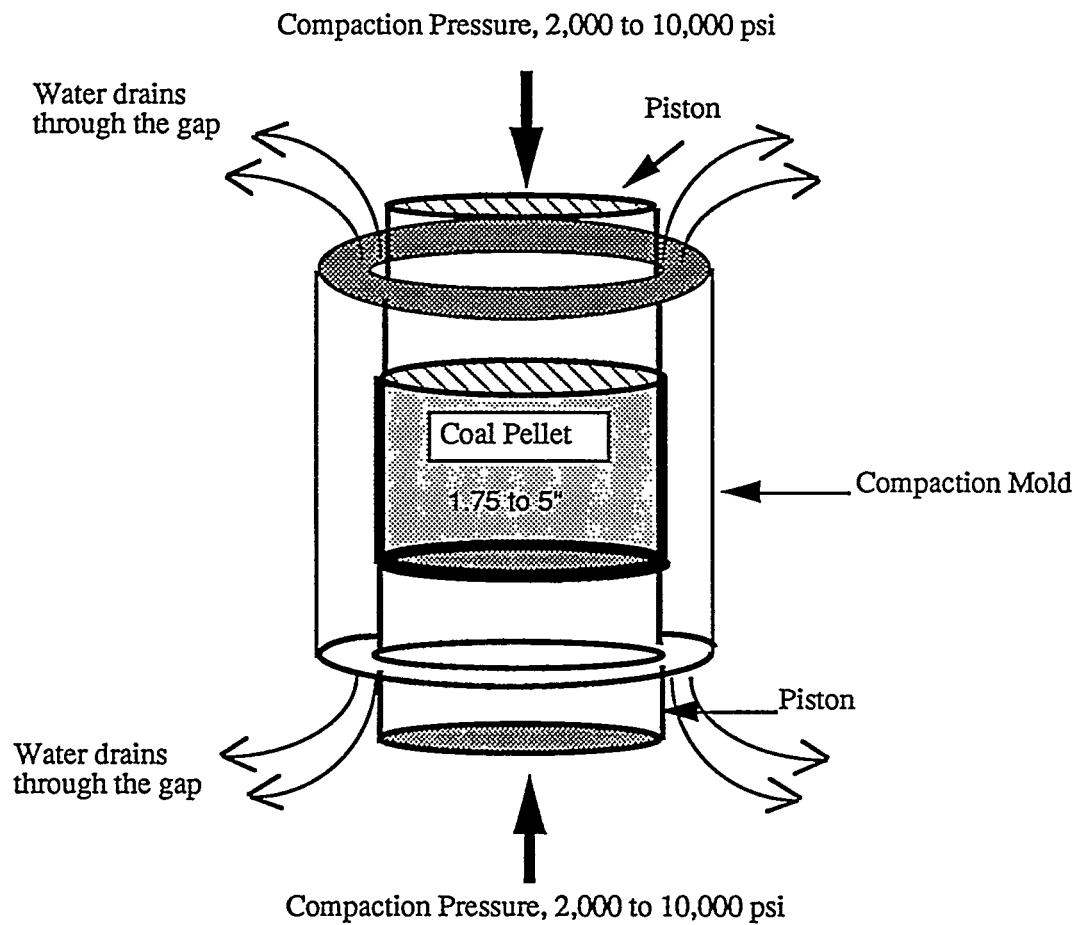


Figure 1. Dewatering Compaction Mold Design.

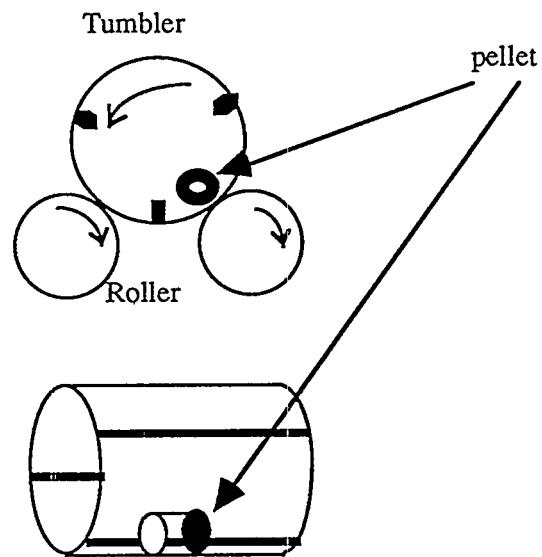


Figure 2. Sketch of tumbling test.

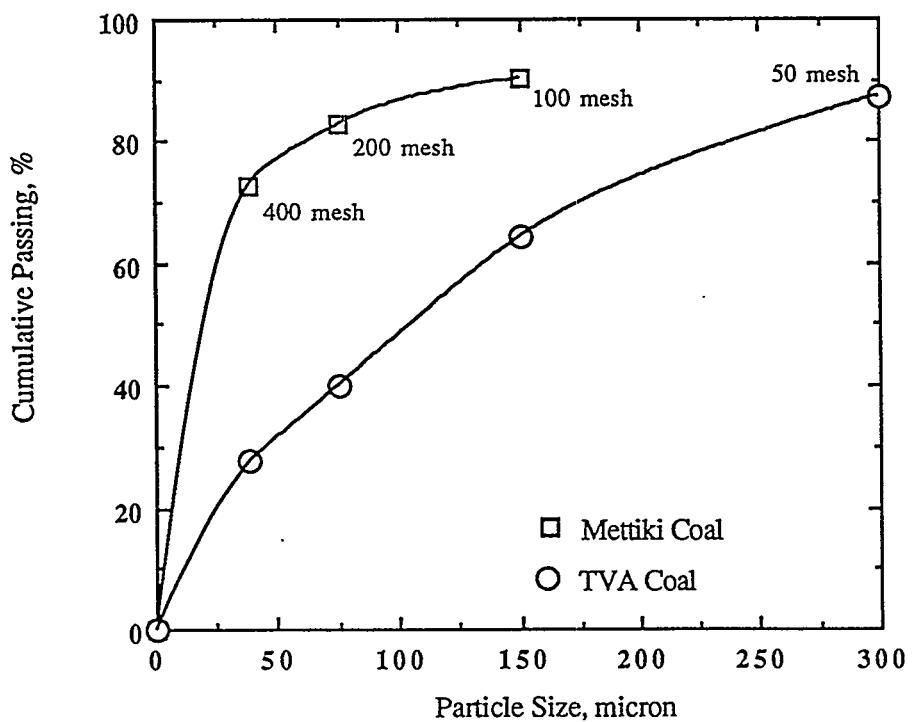


Figure 3. Particle size analysis of Mettiki and TVA coal samples used in experiments.

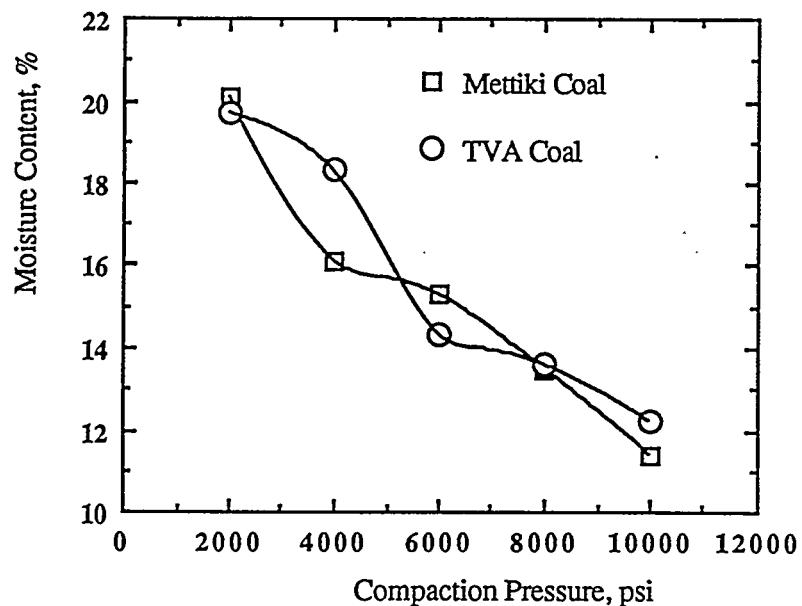


Figure 4. Influence of compaction pressure on the moisture content of coal pellets.

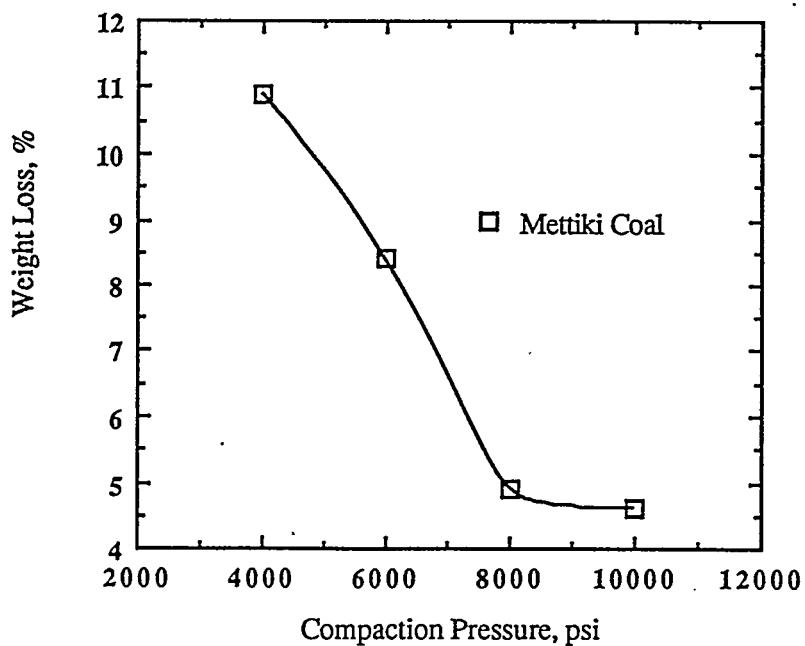


Figure 5. Influence of compaction pressure on the wear resistance of coal pellets. (Tumbling tests)

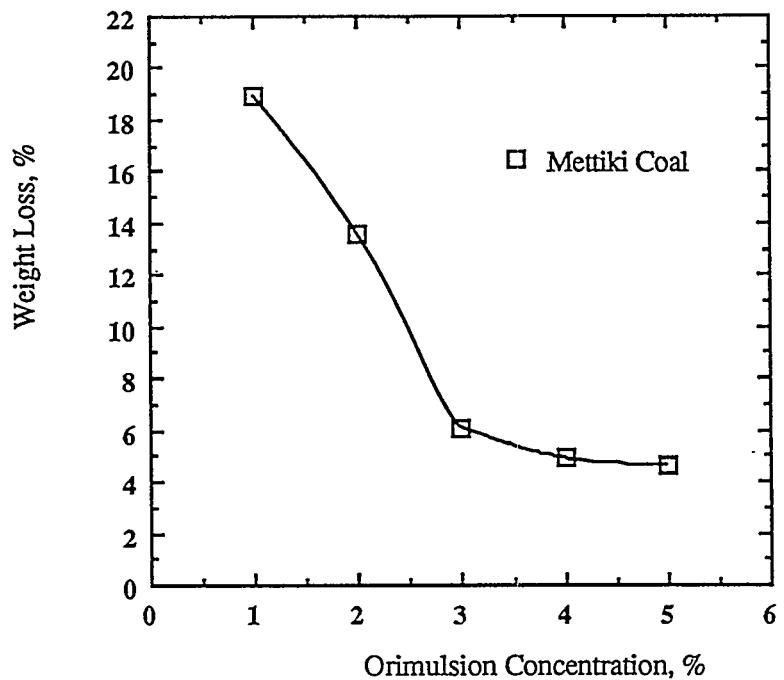


Figure 6. Influence of binder concentration on the wear resistance of coal pellets.

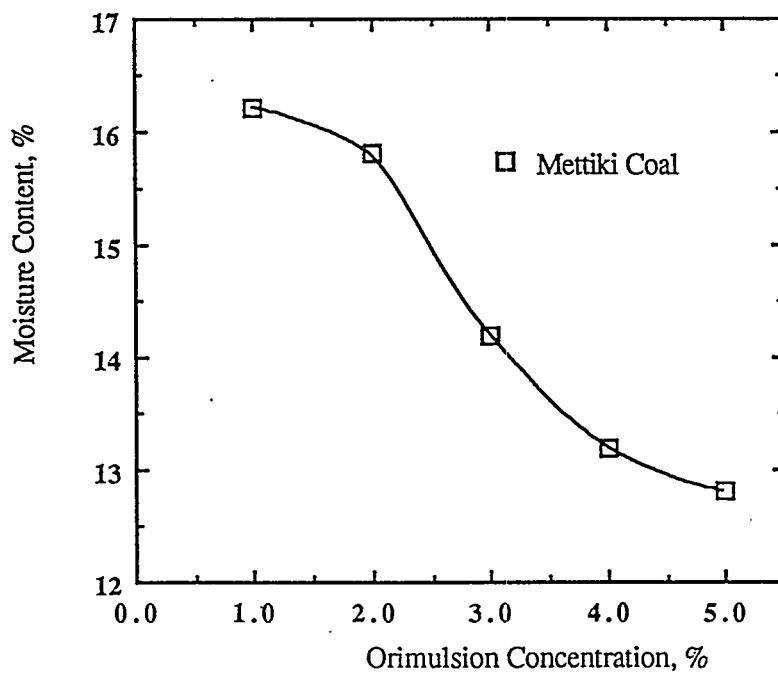


Figure 7. Influence of binder concentration on the moisture content of coal pellets.

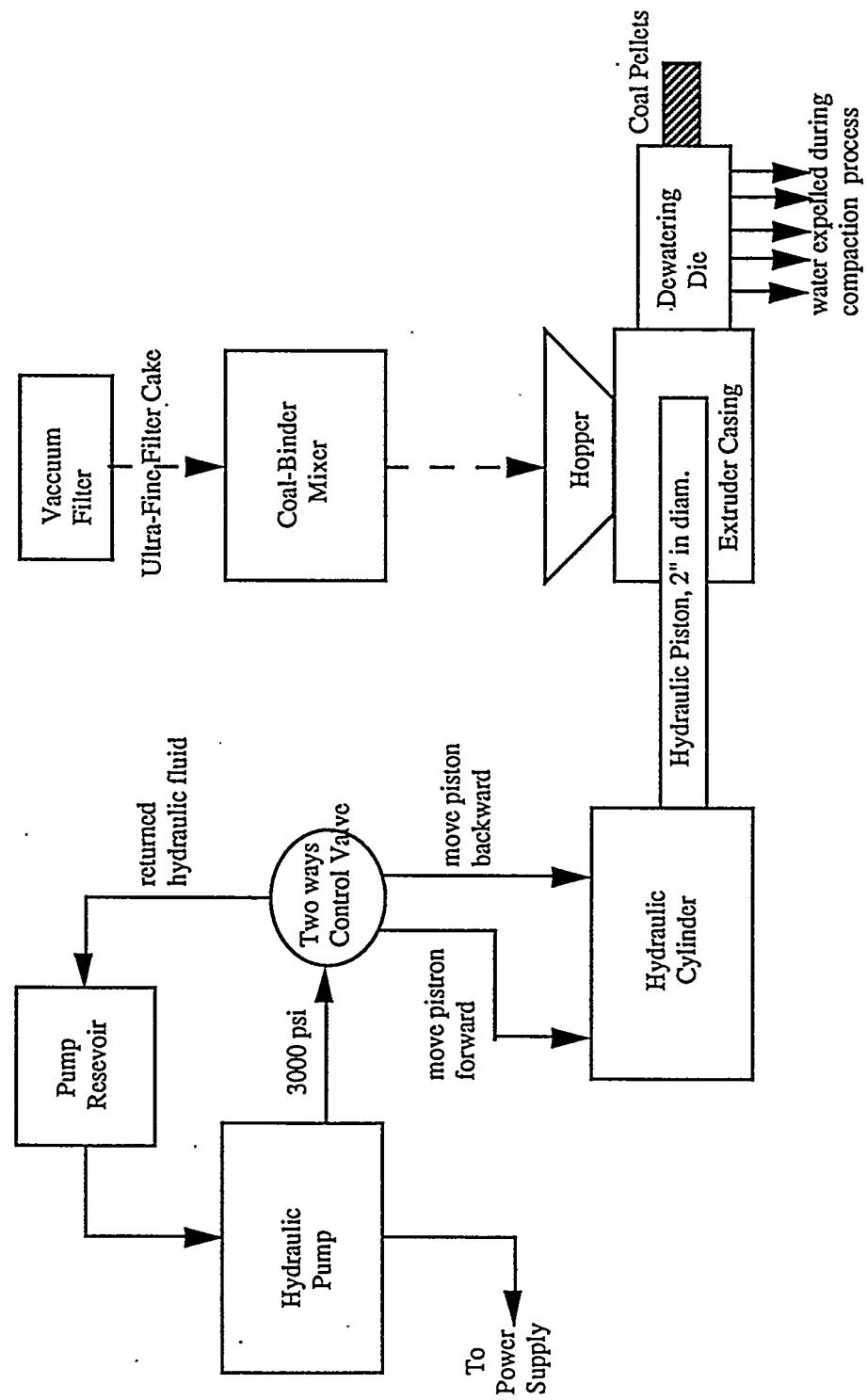


Figure 8. Setup and major components of dewatering and briquetting machine

PROJECT MANAGEMENT REPORT
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COMMENTS

The fringe benefits listed in the projected budget are 25% of the direct labor cost. According to the information provided by the payroll office at UMR, the fringe benefits have been revised, and are now 31.3% of the direct labor cost in the estimated actual expenditures.

The projected cost for materials and supplies was \$5,000 for the first quarter of this project. Since the construction of the prototype dewatering and briquetting machine was made by using existing parts and supplies at the coal lab at UMR, the cost for materials and supplies was only \$250. Therefore, part of the cost saved in the materials and supplies was used to offset some of the extra expenditures, in the fringe benefits.

After testing and optimizing the operation of the prototype dewatering and briquetting machine, another more sophisticated dewatering and briquetting machine will be built based on the data collected from the prototype machine. Therefore, part of the budget for the materials and supplies projected in the first quarter will be used during the second and third quarters.