BIOBINDER PROCESS FOR RECONSTITUTION OF FINE COAL

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1. Introduction

Coal fines whether cleaned or reclaimed from waste ponds, are typically in the form of a wet cake that is difficult to handle, store and transport [1]. Even when blended with cleaned coarse coal product, the fines can cause plugging in chutes and hang-ups in transport systems. If stored in piles, contamination of water runoff is possible. Thermal drying of fines is prohibitively expensive, and the product can create a dust problem or even an explosion hazard. Perhaps of greater significance is the loss of fines that may occur during rail transport, and the resulting environmental damage that affects areas near these transport systems.

One solution to problems associated with coal fines is reconstitution via pelletization. It has been shown that binders such as corn starch, lignosulfonates, Shur Bond, asphalt emulsions, and lignocellulosics, can be employed to produce a strong and durable final product[2]. However, most binders studied to date significantly increase the cost of coal reconstitution, thus limiting the use of this technology. Therefore, a low-cost, or even negative cost, binder and pelletization process is needed.

To reduce the cost of coal fines reconstitution, thus expanding the market for this fuel form, Altex has developed the BioBinder process. In this process, small quantities of municipal sewage, or other biomass type sludges, are utilized as binders to agglomerate the coal fines and form fuel pellets at low cost. Since the binder in this case is a waste product that is costly to landfill, the raw binder costs are negative, thus off-setting fuel processing costs. For example, it has been estimated that through processing and ultimate landfilling, the cost to dispose of sludge is in the range of $40/ton. Incineration costs for sludge, including ash disposal, average $60/ton.[3] These high disposal fees for sewage sludge can significantly offset pellet production and transportation costs.

2. Phase I and II Efforts

Under a U.S. Department of Energy SBIR Phase I grant, Altex showed the feasibility of the BioBinder process to pelletize cleaned coal fines, and estimated process costs. This work showed the technical and economic feasibility of the process to produce a viable fuel. Under the current Phase II SBIR grant, a continuous 4.5 ton per day pilot-scale BioBinder system is being tested and evaluated. This will show the viability of using commercial equipment for continuous production of pellets. In addition to pellet production, pilot-scale combustion tests and extensive economic analyses will be performed under the program. Results of these efforts will then form the foundation for a subsequent commercialization effort, involving a coal preparation facility operator and a municipal sludge producer

3. Pilot-scale Plant

In the BioBinder process, a sludge binder is used to agglomerate the coal particles together into a robust fuel pellet. The BioBinder pelletized fuel is created by mixing the coal with the sludge binder, biologically deactivating the sludge, and finally extruding, sizing and drying the pellets. The initial moisture in the coal and sludge binder is sufficient for extruding pellets. As the material is extruded, the agglomerates are cut and sized to the desired length, depending on the application. Pellets are then transported through a dryer to reduce any residual moisture. Once formed and dried, the pellets can be transported and stored, until ready for use at an energy production site. If needed, proprietary, low cost agents can be applied to enhance properties to the fuel, such as increased weatherability.

Based on previous Altex and equipment supplier tests, the BioBinder process was expected to be implemented using commercially available equipment. This expectation was supported by continuous system tests performed in the Phase II program. A schematic of the BioBinder pilot-scale test system, utilizing commercial machinery, is shown in Figure 1.

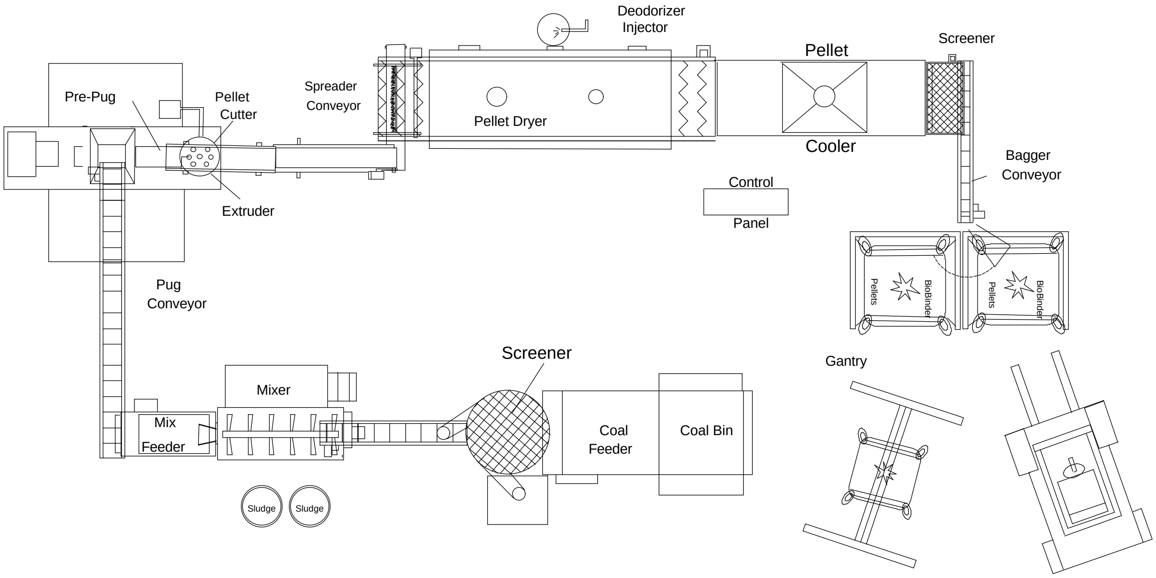

Figure 1. BioBinder Process Pilot-scale Test Equipment

4. Test Results

During Phase II pellet production tests equipment operating parameters were varied to determine their effects on the pellet production rate, operating cost, and fuel pellet quality. Also, feed material properties and formulas were varied. Although the pilot-scale system is sensitive to feed variations, it is also very forgiving. Other pelletization technologies require tight controls on feed properties to maintain pellet quality. The BioBinder system can withstand changes in feed moisture of 25 to 40 %, while still producing a good quality pellet. The feeders are designed to handle coal fines that vary from 0 to 35 % moisture. It is the cooperation between the extruder and dryer that allows for the handling of relatively wet feed materials. Other pelletization or briquetting processes require pre-drying of these feed materials before the agglomeration step. Another benefit of the process is that very few fines are created in the pelletization step and further processing. During Phase II pellet production tests, the process was found to be reliable and required only a minimum amount of maintenance.

There is currently no universally recognized standard tests for pellet quality. Most studies utilize similar tests, but the conditions and procedures often vary widely. In Battelle's study of coal reconstitution [4], several tests were outlined that measured pellet quality. Altex incorporated into the BioBinder program five tests related to strength, abrasion resistance, and long term storage from the Battelle study. In Table 1, abbreviated test results of four BioBinder product samples are given. Two samples were produced by the continuous pilot-scale process, one at a commercial pelletization equipment manufacturer, and one by an earlier lab-scale sample from the Phase I effort. All of these BioBinder mixes used the froth flotation fines from a Pittsburgh bituminous seam. Note the high axial compression strength of 254 to 432 lbf/cuin. This compares to maximum loads of only 200 lbf/cuin in the Battelle study, for a cured extruded pellet using Shur Bond and cornstarch as binders[4].

There is a substantial loss in strength when the pellets have been submerged under water for three days, but there is no disintegration of the pellets. When redried, over 90% of the original pellet strength is recovered. Moisture adsorption can be reduced and pellet strength maintained for severe weather exposure, by the application of proprietary additives. Also, freezing and thawing the material over three cycles did not substantially degrade pellet strength. Therefore, BioBinder pellets can withstand weather, as well as handling.

Table 1 Altex-Lab and Commercial Pellet Test Results

Sample	**Altex 01 Product.**	**Altex 02 Product.**	**Altex 03 Lab**	**CS 01B Comm.**
Cured/Dried Pellets				
Bulk Density(lb/cuft)	27.40	28.47	27.30	28.80
Drop Test - 15 feet	3/pass	4/pass	4/pass	5/pass
Axial Compression Test(lbf/cuin)	432	254	305	407
Abrasion Test % Fines Created	6.2	11.2	1.67	1.68
Freeze/Thaw Cycles	3	3	3	3
11 Week Storage Test				
% Strength - Covered	xxx	xxx	93	xxx
% Strength - Uncovered	xxx	xxx	96	xxx

5. Economic Evaluation

A key factor in promoting the use of the BioBinder process is the cost per ton of the pellets relative to the baseline coal. An economic analyses was performed for the BioBinder process, and the results compared to baseline coal costs. Both capital and operating costs were considered.

To establish costs of major equipment elements, cost quotes were solicited from equipment manufacturers. Table 2 gives a listing of purchased equipment. Installation costs were based on a percentage of equipment costs. The ratio was estimated from equipment supplier experience. A contingency factor of 10 percent was also used in this estimate. A 12 year depreciation schedule was used in the cost analysis.

To define operating, labor and maintenance costs, equipment supplier inputs were utilized. Expendable material costs were based on coal fines cost of $30/ton and sludge disposal cost of $30 ton. Coal fines cost and sludge disposal costs are variable, depending on the specific case. To be conservative, a coal fines cost of $30/ton was used in the baseline analysis. The sludge negative cost for disposal is site specific. According to our survey, digested sludge, which is costly to produce, has a disposal cost of from $16/ton to over $100/ton. The lower cost is typically for rural land applications of sludge from low capacity water treatment plants. Undigested sludge typically costs $50 to $60/ton to incinerate and then dispose of the resulting ash. For the purpose of the analysis, a conservative sludge disposal cost was of interest. Therefore, a disposal cost of $30/ton was assumed for the analysis.

Using these inputs, an economic analysis was performed to determine the cost-per-ton of pellets for the baseline conditions. In addition, cost elements were individually varied to determine the sensitivity of pellet costs to various elements that influence cost. The sensitivity analysis showed that the primary elements controlling the pellet cost are coal and sludge disposal costs and coal to sludge ratio. Other elements that are secondary, but still significant, are sludge moisture content and sludge transportation costs. Sludge disposal costs are significant in that they can totally offset other pellet production costs. This is also illustrated by the baseline results. Table 2 presents the baseline case capital cost estimates.

Operating cost estimates for the process are given in Table 3. As shown, operating costs include raw material, truck transport of sludge, utilities, labor, operating supplies, plant overhead, taxes and insurance and annual capital charges. Adding these costs together provides the yearly cost, from which cost-per-ton of product and cost-per-million Btu in the product can be determined. These are listed in the last two columns. As shown, the cost-per-ton of product is $21.72. This compares with the assumed baseline coal cost of $30/ton. Therefore, even for the conservatively high baseline coal fines cost of $30/ton, the product cost is 27 percent less than the parent coal cost ($30/ton). Furthermore, if, as expected, coal fines costs are less than the parent coal cost of $30/ton, then additional reductions are possible. As shown in Table 4, compared to the baseline parent coal, cost-per-million Btu of the BioBinder fuel can be from 27 to 100 plus percent lower in cost per million Btu. This shows the substantial cost savings that can be achieved using this reconstitution process.

Table 2. Capital Costs Estimate
1000 ton/day Plant

Purchase Equipment	**Quantity**	**Total Cost**		
			Total PE	**$2,971,000**
Bucket Elevator	**2**	**$ 16,000**		
Feed Bin	**1**	**$ 11,000**	**Direct Cost**	
Screw Conveyor	**1**	**$ 17,000**	**40% of PE**	**$1,188,400**
Mixer	**1**	**$ 150,000**		
Former	**1**	**$ 450,000**	**Indirect Cost**	
Dryer/cooler	**1**	**$2,200,000**	**24% of PE**	**$ 713,040**
Belt Conveyor	**3**	**$ 32,000**		
Cyclone	**2**	**$ 30,000**	**Contingency & Fees**	
Screener	**1**	**$ 65,000**	**10% of PE**	**$ 297,100**
Total		**$2,971,000**	**Total**	**$5,169,540**
			Working Capital (1/12 Annual Operating Costs)	**$ 471,434**
			Total Investment Capital	**$5,586,974**
			Annual Capital Charge 8% of Fixed Capital	**$413,563**

Table 3. BIOBINDER COSTS WORKSHEET

4/26/94

	$/TON	TON/YR	$/YR	@ 4% H_2O $/TON PROD	@ 4% H_2O $/MMBtu PROD
RAW MATERIAL:					
COAL FINES(DRY)	30	212500	$6,375,000	$24.48	$0.95
SLUDGE	-30	150000	-$4,500,000	-$17.28	-$0.67
SLUDGE TRANSPORTATION			$337,500	$1.30	$0.05
UTILITIES			$1,780,000	$6.84	$0.27
TOTAL LABOR			$976,950	$3.75	$0.15
OPERATING SUPPLIES			$27,000	$0.10	$0.00
PLANT OVERHEAD			$195,000	$0.75	$0.03
PROPERTY TAXES AND INSURANCE			$52,200	$0.20	$0.01
DEPRECIATION/CAPITAL CHARGE			$413,563	$1.59	$0.06
TOTAL ANNUAL OPERATING COSTS			$5,657,213.00	$21.72	$0.85

Table 4. COAL COST FACTOR

	ANNUAL OPERATING COSTS			COST SAVINGS vs.
COAL FINES		@4%H_2O	@4%H_2O	PARENT COAL COST (@ $1.15/MMBtu)
$/TON	$/YR	$/TON PROD	$/MMBtu PROD	$/MMBtu
$0	($725,329)	($2.79)	($0.11)	$1.26
$5	$344,254	$1.32	$0.05	$1.10
$10	$1,413,838	$5.43	$0.21	$0.94
$15	$2,483,421	$9.54	$0.37	$0.78
$20	$3,553,004	$13.64	$0.53	$0.62
$25	$4,622,588	$17.75	$0.69	$0.46
$30	$5,657,213	$21.72	$0.85	$0.30

6. **Conclusions and Plans**

Using commercially available equipment of 4.5 tons per day capacity, continuous operation pilot-scale tests showed that the BioBinder process can produce a viable fuel pellet of consistent quality. This fuel is able to withstand the handling, transport and storage it would be subjected to as a stoker or pulverized coal fuel source. The process is flexible, and is able to withstand changes in feed quality and moisture and produces little fines upon handling. Commercial equipment was used in the production of fuel pellets and showed good performance with minimal maintenance. This experience supports the viability of continuous pellet production at full-scale.

Besides good pellet characteristics, the BioBinder pellets are inexpensive. As in any coal fines based pellet, fines cost drives the pellet cost. The other important driver is the sludge disposal cost. Even assuming a conservative disposal cost, the sludge disposal cost can totally offset the pelletization cost, yielding a low cost pellet. Economic analyses showed that pellet costs can be 26% to over 100% lower in cost than the parent coal, depending on the coal fines cost. This is a substantial economic advantage of the BioBinder fuel.

Results to date have continued to show the technical and economic viability of the BioBinder process. At the conclusion of the pilot-scale test program, pellets will be available for future stoker combustion and pulverization tests. Results from pellet production and combustion tests will be used to further develop and evaluate the potential of this technology.

References

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3. Private communication with Don Brown, Operations Manager for Newark/Fremont Sanitation District, Fremont California, January 6, 1993.

4. H. Nicholas Conkle, “ Pelletizing/Reslurring as a Means of Distributing and Firing clean Coal” Battelle Final Report on DOE Contract No. DE-AC22-90PC90166 September 29, 1992.