IMPROVING COAL QUALITY
AN IMPACT ON PLANT PERFORMANCE

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ABSTRACT

One of the most common methods for purchasing coal by utility and industrial consumers is based on delivered cost per million Btu. The problem with this method is that it provides a "superficial" cost of burning a specific coal. None of the other properties of the coal are taken into account in the monetary evaluation process. Unfortunately, the cost per million Btu basis usually makes high quality coals appear to be more expensive to burn. The impact of higher boiler efficiency, lower net unit heat rate and reduced coal and ash handling costs are not reflected in the typical cost per million Btu number. These performance factors can substantially affect the ultimate cost of using a particular coal. This paper will address coal quality improvement methods along with areas of plant performance affected by coal quality.

INTRODUCTION

Recently, more attention has been given to what impacts a certain coal will have on overall plant performance. In the past, coals were typically specified for moisture, ash, Btu and sulfur content by the boiler manufacturer. These specifications were usually derived from local coal sources or typical coals the unit might use. Depending on the unit's intended operation (base load, cycling) and how much money was available at the time of construction, it was not unusual to provide for little or no fuel flexibility. As economic and environmental situations change, alternate fuel sources and coal cleaning techniques must be explored. This paper will describe several commercial coal cleaning methods and some of the economic gains that can be realized by utilizing a higher quality coal product. Even if a boiler can burn lower quality (high moisture, high ash and low Btu/lb) coal with no problems, it is generally more economical to use a higher quality coal if available at a reasonable evaluated delivered cost. It's the coal quality impacts that need to be identified and quantified to arrive at a "true cost" of burning one coal versus another. The Electric Power Research Institute (EPRI) has spent considerable time, resources and effort in determining the impacts of coal quality on power plant performance. EPRI has developed a Coal Quality Impact Model that should help quantify the potential impacts of coal quality on power plant performance (1,2). Several other less complicated coal quality models are available that have been developed within the industrial sector. These may be easier to utilize and could provide general indications of the major cost impacts.

Why Improve Coal Quality

If it costs money, reduces yield, and takes more time, why would a coal supplier want to wash coal? Further, why would a consumer be willing to pay for a higher quality coal? The answer is that a higher quality product is easier to market, lowers transportation costs on a Btu basis, and provides cost saving operational advantages at the power plant. Coal washing, or beneficiation, also provides a more consistent and controllable product and reduces certain deliterious elements. It seems that there are limited amounts of raw coal that have a consistent enough quality that they wouldn't benefit from washing. It should be noted that some coals will benefit more from washing than others. Coals that contain large amounts of extraneous ash are easier to wash than coals with a high inherent ash content. In many cases the cost per million Btu of washed coal will compare favorably to raw products, when the coals are evaluated using some sort of coal quality impact model. As will be shown, lower ash and higher Btu/lb are not the only advantages gained by cleaning coal.

COAL CLEANING TECHNIQUES

aw coal is generally crushed prior to washing co liberate as much ash and pyrite from the coal matrix as possible. There are many methods utilized for washing coal depending on the coal's characteristics and the degree of beneficiation desired. Several of the most common are: heavy media baths, froth flotation, heavy media cyclones and Deister tables. Each of these techniques works better on certain size fractions of the raw product. The first step in most preparation facilities is to screen the coal into two or more size fractions. After the coal is washed, it can be dried to remove the moisture picked up during the cleaning process. Vacuum filters, centrifugal dryers, and thermal dryers are examples of common methods utilized to dry the washed product.

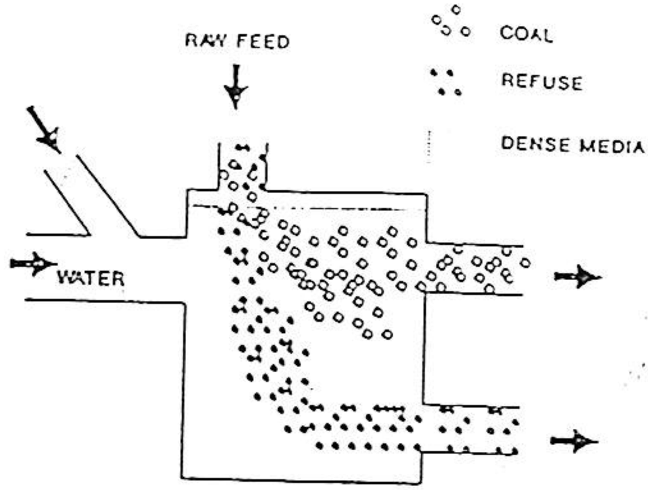

FIGURE 1. HEAVY MEDIA BATH

Heavy Media Baths

Heavy media baths are used to clean the large and medium sized particles (generally greater than 1/4"). Heavy media baths are simply containers filled with water and crushed magnetite or other material, to create a solution with a specific gravity that allows coal to float off the top while the refuse (rocks, minerals, pyrites) sinks to the bottom. Since a large quantity of the particles contain both coal and rock, the actual specific gravity will affect both yield and quality. The specific gravity used is generally about 1.4 and may vary from 1.3 to .6. The coal and refuse are extracted from heir respective levels in the bath for further processing. Figure 1 is a simple diagram showing the principle components of a heavy media bath.

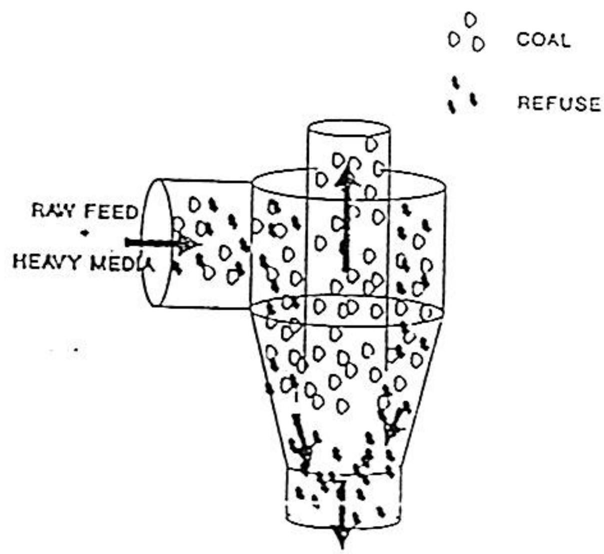

FIGURE 2. HEAVY MEDIA CYCLONE

Heavy Media Cyclones

Heavy media cyclones work similarly to heavy media baths with the exception being that cyclonic action is utilized to aid in the separation of coal from refuse. This allows more flexibility in controlling the specific gravity and generally uses less magnetite per ton of coal. The cyclone separators can also be used with water only. Due to the lower efficiency of the water only cyclone, the refuse of the first cyclone is typically washed in a second water only cyclone. Cyclone separators are generally used for the medium sized particles (3/4" to 28 mesh) although system designs can accommodate other sizes. A diagram of a heavy media cyclone is shown in Figure 2.

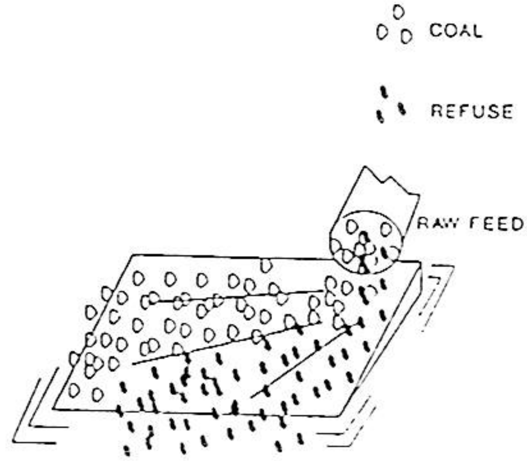

FIGURE 3 DEISTER TABLE

Deister Tables

These devices are used to separate the mid-size coal in the range of 1/4" x 28 mesh. By a combination of a ribbed surface that is tilted and vibrated, the coal and refuse particles are stratified on the table. The heavier refuse particles fall to the bottom of the table, while the coal is shifted to the side of the table and removed. Each table is sensitive to the amount of coal it can process o preparation plants utilizing this echnology may have many tables (Figure 3).

Froth Flotation
This method is used to clean the very fine size fractions of coal (typically 1/2mm x 0"). Fine coal cleaning can be the most effective preparation method due to more extraneous ash being liberated. This method works because reagents added to the water only adhere to the fine coal particles. This film on the coal particles enables them to be attached to air bubbles introduced to the cleaning tank and float towards the top. The refuse particles will sink to the bottom for removal purposes. Figure 4 shows a diagram of a typical froth flotation cell.

Coal Drying Techniques
There were several drying or dewatering techniques mentioned previously. Depending on the desired moisture content, several of the drying techniques are utilized in sequence. For the larger size fractions, the coal will be run across fixed screens and vibrating screens and then rinsed. This product can be introduced into a centrifugal dryer that will literally spin the moisture out of the coal without the use of heat (similar to the spin cycle on a home washing machine-see Figure 5). The fine size fractions are separated in thickening tanks and then the water is removed by vacuum filters. The filter cake is then scraped off the filter disk and remixed with the spin-dried larger coal. A diagram of a vacuum filter dewatering system is shown in Figure 6. If a lower moisture content is required, this mixture is then fed into a dryer that utilizes coal refuse, oil, or gas to produce a hot gaseous medium as the drying and the transport mechanism.

TYPICAL PREPARATION PLANT

Figure 7 is a simple schematic of a preparation plant washing three sizes of coal. The large coal goes to a heavy media bath, the mid-sized to Deister tables, and the fine coal to froth flotation cells. The drying cycle uses dewatering screens, centrifugal dryers, vacuum filters and a thermal dryer. The actual methods used will depend on the coal properties and the economics of each situation.

IMPACT ON POWER PLANT COSTS AND PERFORMANCE

Material Handling Costs
The effects of utilizing a higher quality coal on power plant costs begin with transportation. A plant will burn fewer tons of higher Btu/lb. washed product than lower quality coal. The net result is that more Btu's are shipped for the same per ton cost. Higher Btu/lb. coal also requires less handling on a daily basis and allows for more run time from the coal bunkers while maintaining fewer tons in inventory. Since washed coal generally has less mineral matter associated with it, there will be less fly and bottom ash resulting from the combustion process. Power plants typically have to pay to have the bottom ash and fly ash removed from the plant site. This cost will be lower due to the percent reduction of ash in the washed coal. For instance, if you burn

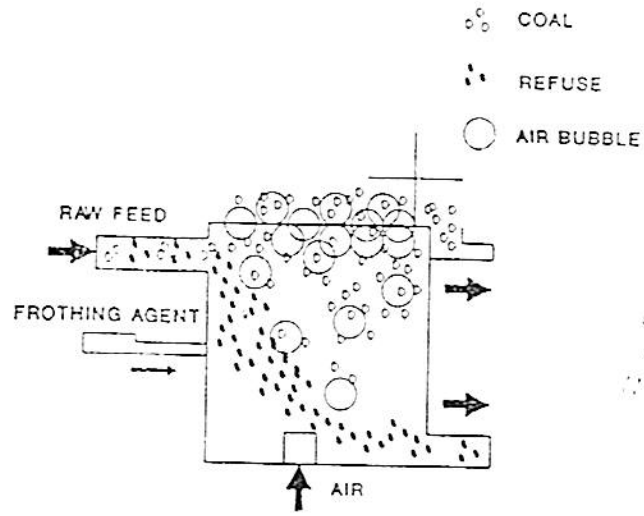

FIGURE 4. FROTH FLOTATION CELL

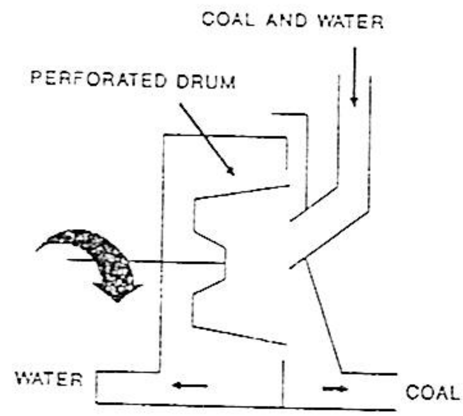

FIGURE 5. CENTRIFUGAL DRYER

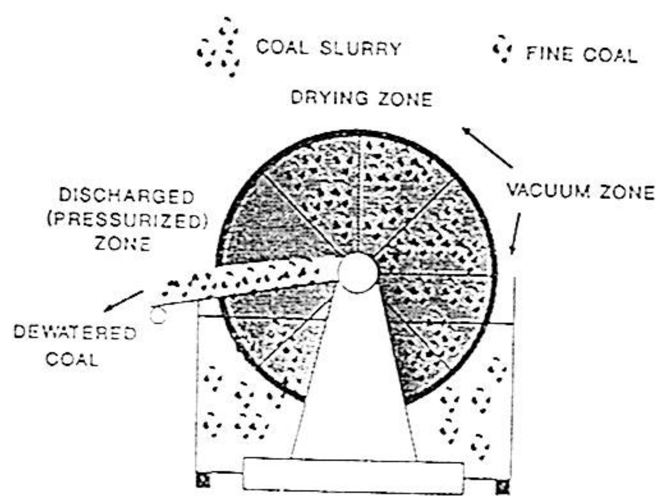

FIGURE 6. VACUUM DISK FILTER

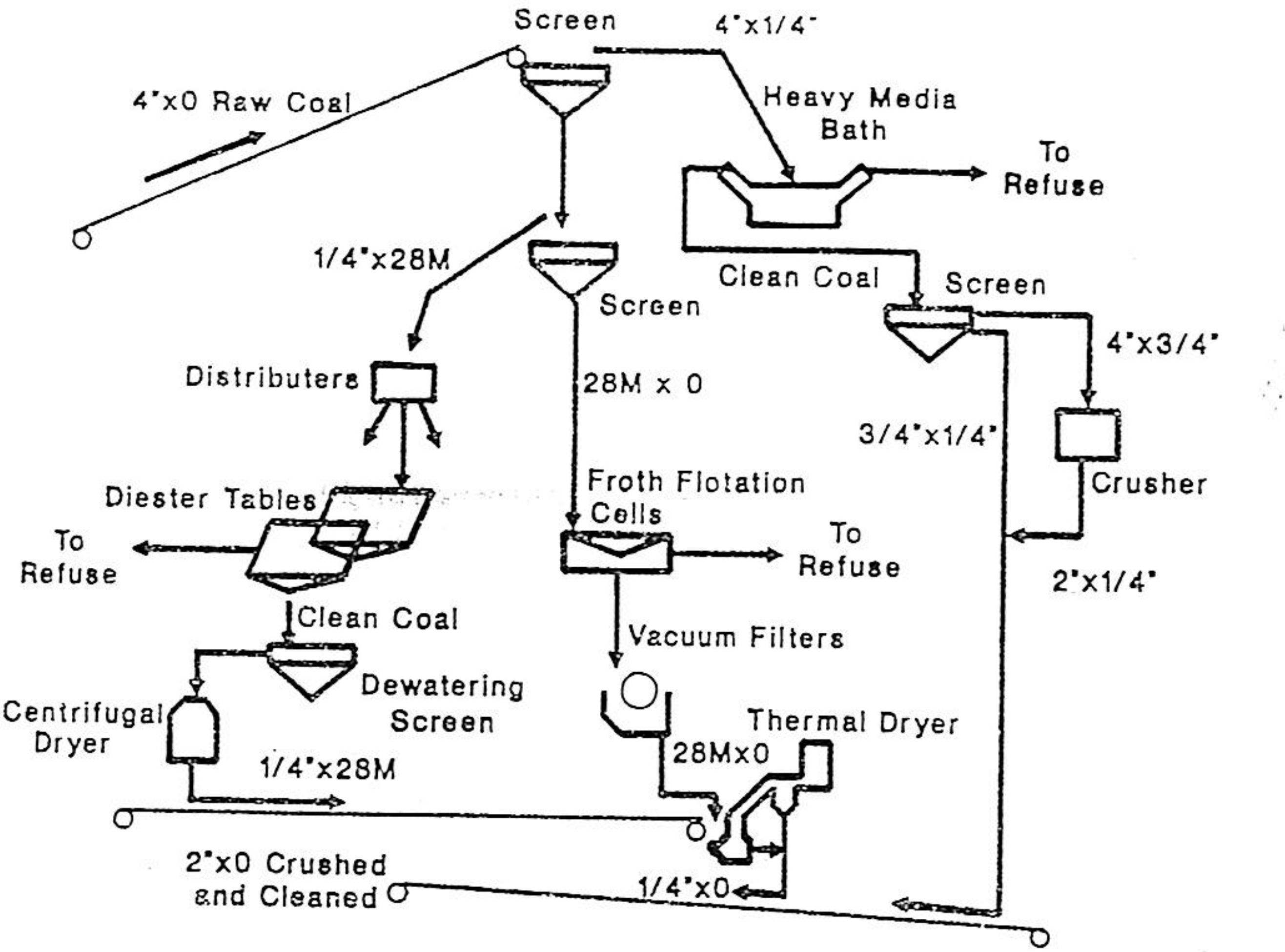

Figure 7. Example Coal Preperation Plant

100,000 tons with 5% ash you would handle 5,000 fewer tons of resultant fly and bottom ash when compared to burning 100,000 tons of coal with a 10% ash content. More importantly, the 5% ash coal could have a corresponding increase in heating value resulting in only 95,000 tons being burned. This results in even fewer tons of ash generated.

Impact on Combustion Equipment - Erosion Potential

Any crushing, grinding or transporting equipment that comes in contact with either the coal or the combustion by-products is subject to wear due to erosion. This could include crushers, pulverizers, coal pipes, mill exhausters, convection pass tubes, ash systems and clinker grinders. Since washing coal removes large amounts of extraneous rocks and minerals such as pyrites, quartz, limestone and shale, the plant equipment will not wear as quickly. For example, the wear on pulverizing equipment is caused by hard minerals such as quartz and pyrite, not the grindability of the coal. Removing a portion of these minerals through washing can reduce mill wear considerably.

Several authors have presented methods for predicting this wear (3,4). Direct impingement of fly ash on boiler tubes causes tube wall erosion and reduced boiler life. Water wall tubes and, to a greater extent, convection pass tubes are subject to this erosion wear. Lower ash contents in washed coals will reduce the amount of wear. It should be mentioned that tube wear due to erosion is a difficult factor to quantify as it is a process that happens over several years. Suffice it to say that lower suspended solid content in the flue gas will translate into a lower erosion potential for the boiler internals.

Combustion Process - Slagging & Fouling

Since a washed coal has less ash and typically lower sulfur content, there is a potential for better control of slagging and fouling. Generally speaking, fouling is reduced due to the removal of ash that contains large amounts of calcium and sodium in addition to removing other ash that may act as an aggregate (much like gravel in cement). Slagging indices can be modified by washing coal. This means that a slagging index may be higher or lower after washing depending on the nature of the minerals removed (5). The end result is typically less slag buildups due to the lower ash content in the coal (6). An important factor to consider is that coal can be somewhat "custom tailored" to produce a desired slagging characteristic by the degree or method of cleaning it receives.

Boiler Efficiency Improvement

Considerable gains in boiler efficiency can be realized by utilizing a high quality coal. Measured boiler efficiences have increased as much as 3-4% when switching to a high quality coal. This increase can be derived from several factors. The more consistent quality of a washed coal can allow for tighter excess oxygen control. This in turn can lead to savings in boiler efficiency due to dry gas loss (7). Also, the air heater gas out temperature can be controlled closer to the acid dew point with the knowledge that the sulfur content will remain quite constant. A reduction in sulfur content will reduce the acid dew point of the flue gas. This will allow for operating the boiler at lower exit gas temperatures that will further improve boiler efficiency. This consistency in sulfur content can lead to big savings in equipment replacement costs by greatly reducing the cold end corrosion of air heater elements, ductwork, precipitator internals, ID fan rotors and stack liners. Another boiler efficiency increase is related to carbon burnout. The pulverizers do not have to grind as many tons/hr of a higher Btu/lb coal. This means that a finer grind (% pass 200 mesh) can be utilized with no loss of pulverizer capacity. This, in turn, will reduce carbon carryover and loss on ignition (LOI). Because there is less ash, even the same LOI will result in a lower loss due to unburned carbon. Coal that goes through a dewatering and/or drying process will also have a corresponding lower moisture in the flue gas loss. Net turbine heat rate can also be impacted by lower slagging, i.e., less steam attemperation.

Precipitator Performance

Typically, the lower ash content of a washed coal will help to decrease outlet emissions from a precipitator installation. This is due to the lower inlet grain loading to the precipitator. Lower precipitator efficiencies are then required to maintain the same outlet emission rate. While this may not sound like a money saving asset at face value, a little interpretation can help explain this advantage. There are three ways this can help reduce operating costs. First of all, if an installation was marginally sized from the beginning and/or the precipitator is in need of maintenance, a lower ash product could save money by eliminating a derate due to opacity limitations. Secondly, a lower ash coal lowers the required precipitator efficiency which ,in turn, allows for a larger margin of equipment failure before derates due to opacity are necessary. And third, if a precipitator has a large specific collection area (350 SCA or greater) and maintains high power levels, a lower ash coal will allow for the reduction of input power while maintaining the same outlet emissions. This translates into a direct savings in the net unit heat rate due to lower auxiliary power consumption.

Scrubbers and Other Sulfur Removal Equipment

Power plants built to conform to new source performance standards can also benefit from utilizing washed coals. The savings in this area result from credits available from sulfur removal during coal preparation. Most scrubbers are required to remove 90% of the sulfur, if a portion of the sulfur is removed during washing this may (depending on environmental laws) be used to reduce the amount of scrubbing necessary. Less scrubbing lowers the amount of lime to be used, and refuse generated. This will also provide flexibility in operation.

SUMMARY

By utilizing a higher quality washed coal, power plants can realize many cost savings. Some are long term wear and tear type savings that are harder to predict but serve as a life extension program. Other benefits are realized immediately such as increased mill capacity or improved boiler efficiency/unit heat rate. In either case, the potential benefits should be evaluated against the additional costs introduced by coal cleaning to determine the total evaluated cost impacts of different coal qualities. Simple comparisons utilizing evaluation programs can be developed quite easily using spread sheet programs like Lotus 123. The authors utilize a two part program; the first calculates combustion parameters such as fouling and slagging indices, mill capacity, and fly ash resistivity; the second compares the material handling and boiler efficiency cost associated with burning any two particular coals. Examples of the coal and boiler sections of the combustion program are shown in Figures 8, and 9. An example of the comparison program is shown in Figure 10. As the electric industry becomes more competitive and gathers more data, the cost impacts of fuel quality will become better quantified and more useful. Most utilities are already using some form of coal quality impact models that will become more sophisticated in the future. All this should provide lower electricity costs and better environmental control as we progress in the coal quality science area.

ACKNOWLEDGEMENT

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COAL ANALYSIS

	AS REC'D	DRY						
BTU/# =	13334	13998	SILICA =	44.46	IT RED =	2670	SO2/MBTU =	1.90
VOLATILE =	39.42	41.38	ALUMINA =	32.85	ST RED =	+2700	#ASH/MBTU =	4.59
FIX CARBON =	49.73	52.20	TITANIUM =	1.22	HT RED =	+2700	B/A RATIO =	0.23
MOISTURE =	4.74	0.00	IRON =	12.19	FT RED =	+2700	SLAG INDEX =	0.32
ASH =	6.12	6.42	CALCIUM =	3.2	IT OXD =	2700	FOUL INDEX =	0.06
SULFUR =	1.33	1.40	MAGNESIA =	0.79	ST OXD =	2700	SILICA % =	73.32
CARBON =	73.66	77.33	POTASSIUM =	1.6	HT OXD =	2700	Fe:Ca =	3.81
HYDROGEN =	5.17	5.43	SODIUM =	0.24	FT OXD =	2700	Fe:Ca+Mg =	3.06
NITROGEN =	1.51	1.59	SULFUR TRI =	2.9			DOLOMITE % =	22.14
CHLORINE =	0.14	0.15	PHOS PENT =	0.1	HGI =	45	ALKALI-COAL =	0.08
OXYGEN =	7.32	7.68	UNDETER =	0.45				
PROX SUM =	100.00	100.00						
ULTIM SUM =	100.00	100.00	TYPE SLAGGING = LOW		TYPE FOULING = LOW		TYPE ASH = BIT.	

FIGURE 8. COAL ANALYSIS AND CALCULATED INDICES FROM SPREADSHEET.

BOILER PARAMETERS

UNIT =		DULONG BTU =	13409	FLUE GAS:		PULVERIZER DESIGN SPECS	
AH AIR IN =	100	B-W T250 =	2614	% H2O =	8.42	CAPACITY FACTOR OF 1:	
AH AIR OUT =	500	W-F T250 =	2531	% CO2 =	13.95	HGI =	50
GAS OUT (UNC) =	300	N-R T250 =	2599	% SO2 =	0.09	GRIND =	70%
GAS OUT (COR) =	300	N-R T500 =	2503	% N2 =		BTU/lb. =	11000
% O2 =	3.2	N-R T1000 =	2417	% O2 =	3.08		
% CARBON-ASH =	5	N-R T5000 =	2251	ADIAB FLAME =	3643	ACTUAL SPECS.	
% CARRYOVER =	80	N-R T10000 =	2192	THEO AIR =	10.01	HGI =	45
% RAD LOSS =	0.4	Tcv =	2643			GRIND =	70%
		FUSION FT-IT =				BTU/lb. =	13127
		% QUARTZ(DRY) =	-0.31	BOILER EFF =	89.15	CAP. FACTOR =	1.10

FIGURE 9. BOILER PARAMETER SECTION OF SPREADSHEET INCLUDING BIOLER EFFICIENCY AND MILL CAPACITY.

REFERENCES

1. Folsom, B.A., Heap, M.P. and Pohl, J.H., "Effects of Coal Quality on Power Plant Performance and Costs", EPRI CS-4283 Vol. 1-4, Project 2256-1 February 1986.

2. Galluzzo, N.G., Stallard, G.S. and Mehta, A.K., "EPRI Coal Quality Impact Model", Project 2256-2. Presented at: Impact of Coal Quality on the Economics of Thermal Power Seminar, Halifax, Nova Scotia, June 15-16, 1987.

3. Raask, E. "Mineral Impurities in Coal Combustion", Hemisphere Publishing Corp., Washington, D.C., 1985.

4. Nurick, W., "An Engineering Approach to Prediction of Fuel Impacts on Utility Boiler Systems". Presented at: EPRI seminar on Reducing Electricity Generating Costs by Improving Coal Quality, Indiana, PA, November 5-6, 1986.

5. Miemiec, L.S., Lexa, G.F., LeVasseur, A.A. and Mehta, A.K., "Effects of Coal Cleaning on Boiler Performance" ASME Paper No. 87-JPGC-FACT-7, October 1987.

6. Doherty, M.B. and Stogran, H.K., "American Electric Power's Approach in Evaluating Steam Generator Fuels", EEI Prime Movers Committee Meeting No. 167, Detroit, MI, September 1982.

7. American Society of Mechanical Engineers, ASME Test Form for Abbreviated Efficiency Test. ASME PTC 4.1 New York, NY, 1974

COAL QUALITY EVALUATION PROGRAM

OWNER:	UTILITY
PLANT:	
UNIT:	1
MW NET:	
MW GROSS:	500
CAPACITY FACTOR:	
HEAT RATE	10000
PURCHASE KTN/YR:	1000
INVENTORY-KTONS:	200

PRESENT COAL — AVERAGE QUALITY

COAL COST /T:	$41.50
TRNSPRT.COST /T:	
AT 11,900 BTU/LB	

PROPOSED COAL: HIGH QUALITY

COAL COST /T:	$46.50
TRNSPRT.COST /T:	
AT 13,300 BTU/LB	

INTEREST RATE: 10.0

ASH REMOVAL COSTS

F.A.REMOVE $/T:	$5.00
B.A.REMOVE $/T:	$5.00
COAL HDLNG $/T:	$2.00

PRESENT COAL		PROPOSED COAL		CHANGE	
DELIVERED $/TON:	$41.50	DELIVERED $/TON	$46.50	($5.00)	
DELIVERED $/MBTU	$1.74	DELIVERED $/MBTU	$1.74	$0.00	
FUEL COST MIL/KW	17.44	FUEL COST MIL/KW	17.25	0.19	
HEAT RATE:	10000	HEAT RATE:	9890	110	
BOILER EFF:	88.17	BOILER EFF:	89.15	-0.98	
PURCHASE KTN/YR:	1000	PURCHASE KTN/YR:	883	108	BTU
				10	B-EFF
INVENTORY-KTONS:	200	INVENTORY-KTONS:	177	23	
ASH TONS/YR:	99,992	ASH TONS/YR:	53,980	46,012	
FLY ASH TONS/YR:	79,993	FLY ASH TONS/YR:	43,184	36,810	
BOT.ASH TONS/YR:	19,998	BOT.ASH TONS/YR:	10,796	9,202	
DISPOSAL COST $/YR		DISPOSAL COST $/YR			
FLY ASH:	$399,967	FLY ASH:	$215,919	$184,048	
BOTTOM ASH:	$99,992	BOTTOM ASH:	$53,980	$46,012	
SULFUR TONS/YR:	26,258	SULFUR TONS/YR:	11,771	14,487	
SO2 LBS/MBTU:	4.19	SO2 LBS/MBTU:	1.90	2.29	
SO3 PPM:	17	SO3 PPM:	8	9	
ACID DEW POINT:	277	ACID DEW POINT:	267	10	

COAL COST SAVINGS $/YR

DUE TO BTU:	$0
DUE TO B-EFF:	$449,786
DUE TO COAL HANDLING:	$234,716

INVENTORY SAVINGS $/YR

DIFFERENTIAL VALUE:	$90,954
INTRST RT COMPD CNTNLY:	10.52
CARRYING COST:	$9,566

ASH DISPSL SAVINGS $/YR

FLY ASH AND BOTTOM ASH:	$230,060

POTENT B-EFF SAVES $/YR

DUE TO LOWER E.G.TEMP:	$116,290

ACTUAL SAVINGS PER YEAR:	$924,129
POTENTIAL SAVINGS PER YEAR:	$116,290
TOTAL:	$1,040,419

FIGURE 10. COMPARISON OF QUALITY IMPACT COST FROM COALS WITH SAME DELIVERED COST.