Technical Publication

Design for High Availability - Firing Equipment

by

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Presented to
Association of Edison Illuminating Companies
Birmingham, Alabama
September 15, 1976

DESIGN FOR HIGH AVAILABILITY-FIRING EQUIPMENT

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In this paper, I will specify the historical causes of problems affecting the availability of fuel burning equipment and enumerate the statistically more important areas that cause outages. The following discussion of Riley Stoker Corporation's current programs addresses these problems. Finally, the value of new ABMA Coal Specification guideline to the manufacturer is reported.

PARTIAL OUTAGE CAUSES

To ascertain the relative importance of each component in the fuel preparation, conveying, and combustion concern, Riley Stoker evaluates the very important feedback information we receive from the Equipment Availability Task Force of the Prime Movers Committee, Edison Electric Institute (see Table 1).

The report encapsulates the equipment availability record and summarizes the average number of occurances, average equivalent hours per outage, and average equivalent outage hours per unit year. Since fuel burning equipment normally appears in multiple and independently operating systems, complete forced outages due to failures of its component are very remote; therefore, we chose to present the statistical data referencing forced *partial* outages.

It is interesting to note that although the occurrence rate per unit year of forced pulverizer outage averages only twice annually, the average downtime per outage is so long that it results in a relatively high average equivalent hours per unit year of forced partial outage when compared to other fuel burning equipment. The column labeled "Factor of Importance" is the ratio of average equipment hours per unit year of each component compared to slagging, which is fifth among fuels and fuel burning equipment-related outage causes.

The report indicates that although causing an average outage time of less than one hour per occurrence, wet coal happens frequently enough throughout the year to result in its being ranked second in order of importance. The remainder of the top five are similarly evaluated.

AVAILABILITY IMPROVEMENT PROGRAMS

Pulverizer. The Riley ball tube mill has historically enjoyed the reputation of being the most reliable pulverizer on the market today. Our design engineers conduct continuing programs to further improve this product line to insure that we continue to earn our reputation. We are currently completing extensive testing of our product improvement ideas on our full-size 13′ diameter by 16′ long ball tube mill (Figure 1). The prospects look excellent for improvements in the mill's lubrication system made possible by eliminating the need for high pressure oil pumping requirements. Pulverizing component failures that result in immediate shutdown of the unit are few for Riley ball tube mills; however, our testing has verified our ability to eliminate the hardened steel pinion gears from the drive train, thus assuring that we will not encounter an overstressed pinion tooth failure with the latest mill model.

FACTOR OF IMPORTANCE	AVG. NO. OCCUR. PER UNIT YEAR	AVG. EQUIV. HRS. PER OUTAGE	AVG. EQ. HRS. PER UNIT YEAR	COMPONENT CAUSING OUTAGE
20	2.36	8.83	20.88	PULVERIZER
3	4.16	0.81	3.37	WET COAL
2	0.50	4.58	2.31	FUEL HANDLING
1	0.52	2.78	1.45	POOR QUALITY COAL
1	0.25	4.08	1.04	SLAG

Table 1 Forced Partial Outages of Fuel Burning Equipment
10-Year Summary 1965-1974 (EEI)

Wet Coal. The Riley ball tube mill pulverizing system is particularly suited to handling wet coal, since it incorporates the Riley crusher dryer (Figure 2) immediately upstream of the pulverizer. The crusher-dryer provides adequate coal-size reduction and flash drying to properly prepare even extremely wet coal for handling, pulverizing, conveying, and combustion. We installed crusher-dryers on an existing ball tube mill in the southeastern United States. Shortly after installation, it was reported that after a typical torrential rainstorm, the steam generator that was not equipped with Riley crusher-dryers began losing

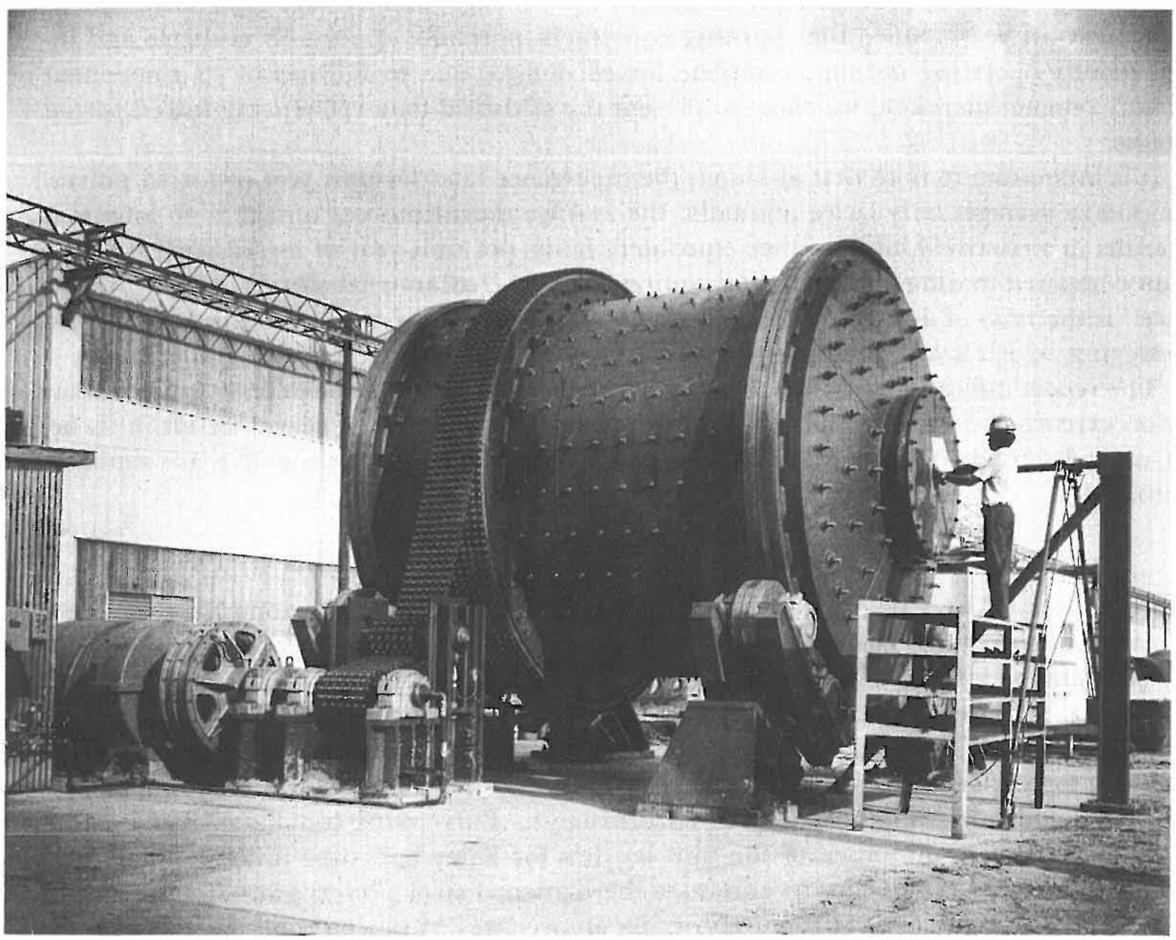

Figure 1 Ball Tube Mill Pulverizer Undergoing Test

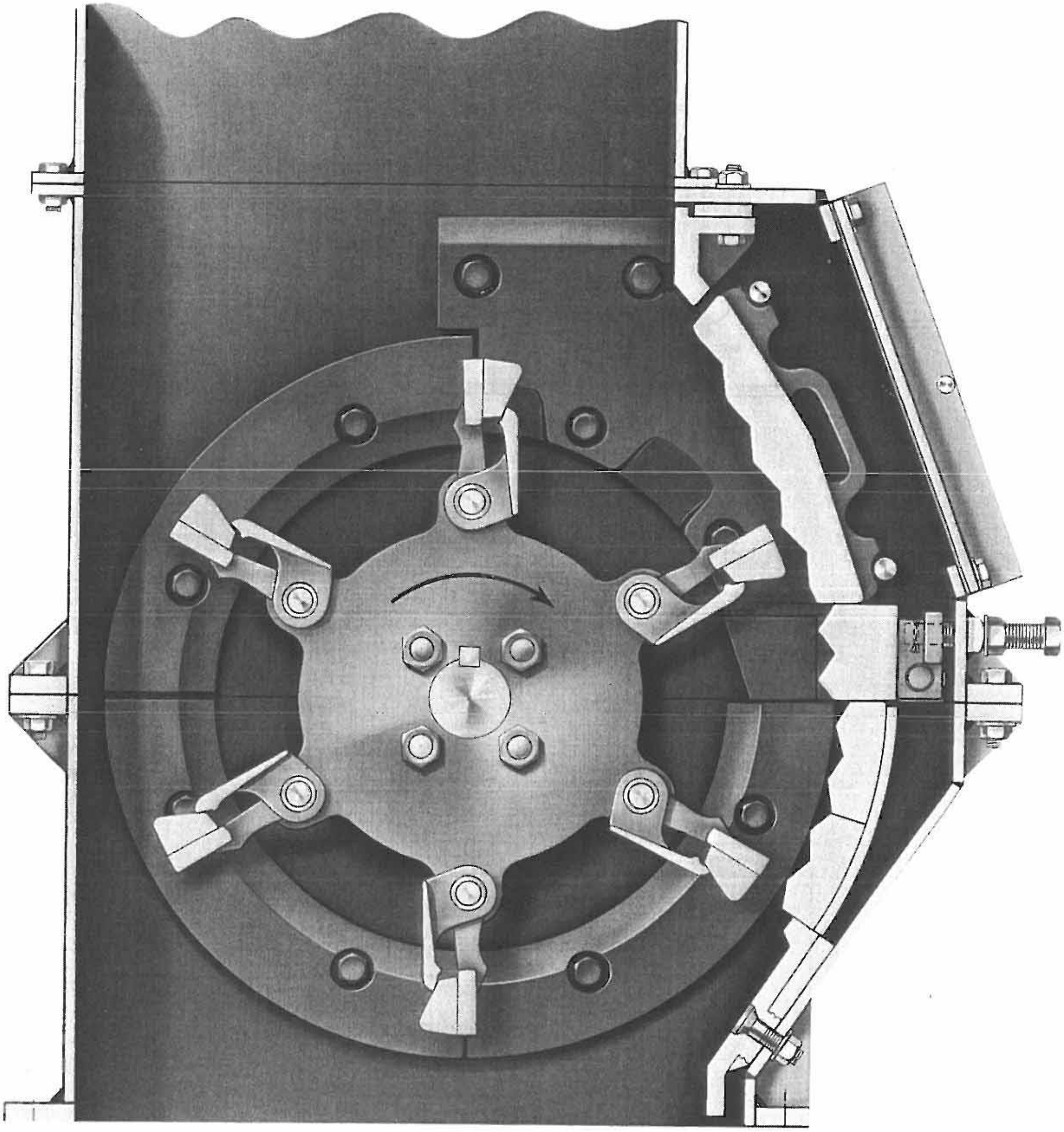

Figure 2 Riley Crusher-Dryer

steaming capacity due to wet coal, while its adjacent twin unit equipped with crusher-dryers continued at its normal generating capacity. Recent testing at a mid-western plant utilizing high moisture sub-bituminous coal indicates that the crusher-dryers were able to remove all of the surface moisture and a significant portion of the equilibrium moisture from the coal, such that the pulverization process in the mill and the combustion at the burners were both satisfactory.

Fuel Handling. Experience tells us that the best way to handle coal is to utilize inclines for chutes and hoppers that are as close to vertical as is practicable (Figure 3). The use of stainless steel in this area has helped to prevent coal accumulations and corrosion.

Poor Quality Coal. This cause of partial outage can occur in several areas of a steam generating facility. High emissions due to poor quality coal can result in capacity limitations. High levels of quartz, feldspar, and other abrasive substances occurring in coal ash

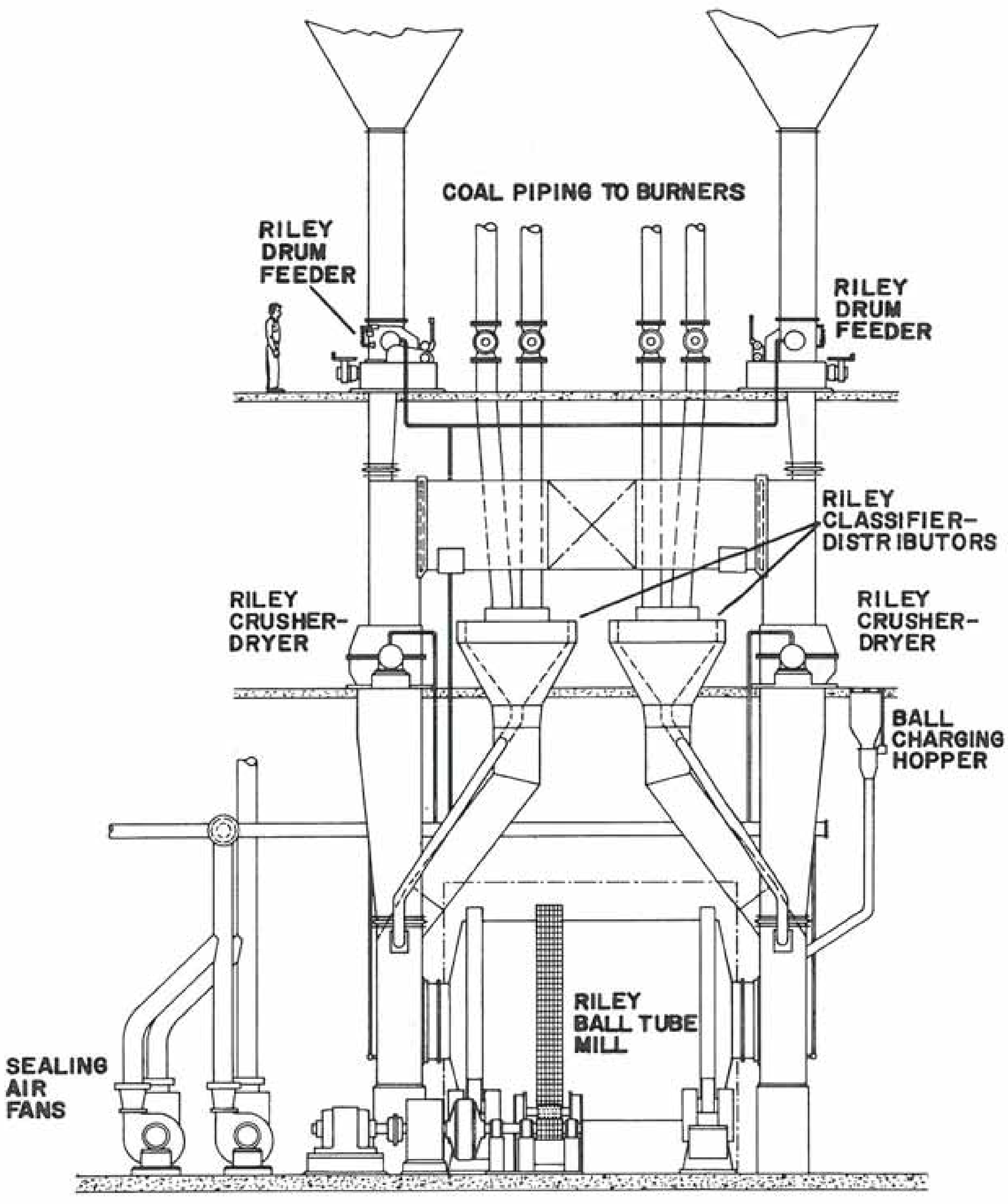

Figure 3 Typical Coal Pulverizing System

can contribute to rapid deterioration through abrasion of many coal preparation components. Our evaluations of pneumatic ash reinjection piping have shown that the "Nihard" types of materials are best suited for this application, followed closely by ceramic lining. Our testing of silicon carbide ceramic coal spreaders leads us to believe that the application of this material may result in as much as an order of magnitude increases in wear life.

Our recent application of silicon carbide-lined burner heads, turning vanes, nozzles, ignition tube protective sleeves, and coal spreaders to an entire compliment of burners on an opposed-fired flare type burner installation (Figure 4) has shown marked improvements

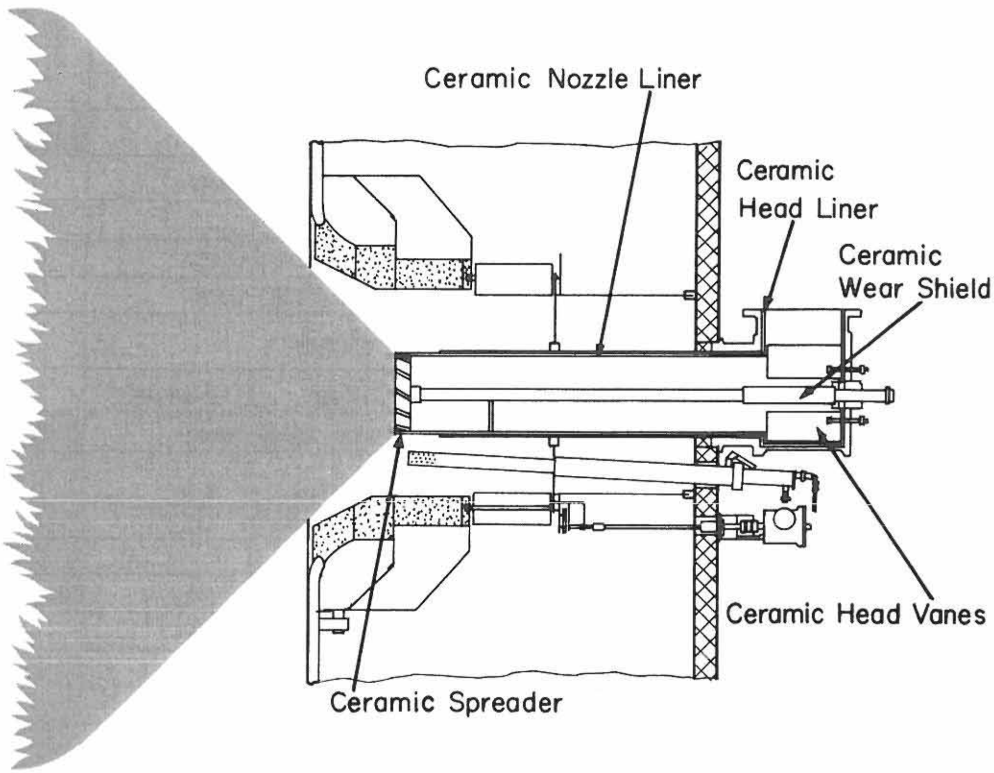

Figure 4 Riley Flare Type Burner

in the overall performance of the unit. It has been reported that the combustion efficiency has improved, resulting in the ability to operate with lower excess air. Since the unit had been partially curtailed by particulate emission limitations, the combined effect of lower carbon loss and lower excess air resulted in an increase in precipitator efficiency, allowing the unit to operate at a significantly higher megawatt output than had been the case prior to the installation of the new burners.

Slag. It is extremely important that the designer understand the slagging potential of the fuel that the customer intends to burn in the steam generator prior to finalizing the furnace design. Since the slagging tendency of the coal can affect the requirement for furnace plan area heat release by as much as 50% in order to control the accumulation of deposits in the furnace, there have been and continue to be numerous investigations into the chemical constituents within the flyash in an attempt to determine the fuel's slagging tendency beforehand so that the unit can be properly proportioned. The attached Table 2 lists some of the more popular indicators.

ABMA FUEL SPECIFICATION

It is certainly appropriate that we discuss the newly developed ABMA fuel specification sheet (Table 3), since it addresses each of the aforementioned outage-causing components.

It incorporates most of the items and analyses that are commonly recognized as necessary to the proper design of steam generating plants. In addition, it identifies and lists other significant information that is sometimes overlooked while setting unit design specifications:

The proximate analysis is very important in determining combustion equipment design.

Grindability and feed size are necessary to determine proper pulverizer, feeder, and duct sizing.

Sulfur is important to the corrosion specialist to determine the slagging potential of the flyash of the flyash as well as to determine pollutant emission levels of SO_2.

	SLAGGING TENDENCY				Lignite	Western	Eastern
	LOW	MEDIUM	HIGH	SEVERE			
B/A X S (DRY)	0 - 0.6	0.6 - 2.0	2.0 - 2.6	2.6 -			
T250, °F.	- 2550	2550 - 2260	2260 - 2200	2200 -			
% ALKALI IN ASH	0 -	- 2.0	2.0 -	-			
B/A	- 0.5	0.5 - 0.9	1.0 - 1.75	1.75 -			
ASH FUSION, °F, H=W REDUCING	- 2330	2330 - 2130	2130 - 2025	2025 -			
	FOULING TENDENCY						
	LOW	MEDIUM	HIGH	SEVERE			
STRENGTH OF SINTERED ASH, PSI	- 1000	1000 - 5000	5000 - 16000	16000 -			
B/A X Na_2O (WATER-SOLUBLE IN LOW TEMP. ASH)	0 - 0.1	0.1 - 0.25	0.25 - 0.7	0.7 -			
B/A X Na_2O (IN HIGH TEMP. ASH)	0 - 0.2	0.2 - 0.50	0.50 - 1.0	1.0 -			
% Na_2O IN ASH	- 1.0	- 3.0	-	-			
% Na_2O IN ASTM COAL ASH	- 1.0	1.0 - 2.0	2.0 - 3.0	3.0 -			
% Na_2O IN ASTM COAL ASH	- 3.0	3.0 - 6.0	6.0 - 8.0	8.0 -			
% Na_2O IN DRY COAL	-	-	- 0.30	0.30 -			
% ALKALI AS Na_2O IN DRY COAL	-	-	- 0.60	0.60 -			
% ALKALI IN ASH	- 3.0	3.0 -	- 5.0	5.0 -			
% ALKALI IN DRY COAL	- 0.3	0.3 - 0.4	0.4 - 0.5	0.5 -			
CHLORINE/ASH	- 0.1	0.1 - 1.7	1.7 - 2.5	2.5 -			
% CHLORINE IN COAL	- 0.3	0.3 -	- 0.5	0.5 -			

Table 2 Prediction of Slagging and Fouling Tendency

Heating value is, of course, used in determining fuel handling and ash handling requirements, mill sizing, and dollar value to the user.

Ultimate analysis is necessary for the determination of flue gas constituents, overall unit efficiency, certain forms of corrosion, and the degree of generation of oxides of nitrogen.

The float sink fraction aides in predicting the abrasiveness of a coal.

Ash fusion temperatures are used in the determination of slagging tendencies of the fly-ash.

Ash analysis is another very important method of analyzing the inorganic constituents in coal to determine both slagging tendency in the furnace and fouling tendency in the convection banks.

Burning profiles are used in the study of the combustion process, particularly when the fuel constituents vary significantly from previous industry experience.

Bulk density is utilized by the designer in sizing his fuel handling equipment.

Free swelling index is used as an indication of caking characterstics of coal and is important in gasification and fluidized bed reactors.

Reactivity index aides in determining the fire and explosion potential of coals within fuel preparation and conveying systems.

Please note the request that each coal be analyzed individually, since it has been found that listing coal properties by ranges of constituents leads to gross misunderstanding of the true properties anticipated and very often results in combinations of properties that cannot exist in nature and for which reliable predictions of steam generator performance can therefore not be determined.

The user must attempt to specify the single design fuel analysis per ABMA form such

RECOMMENDED ABMA
COAL GUIDE SPECIFICATION FORM

SOURCE (STATE/COUNTY/COMPANY/MINE/SEAM) ______________

____

CLASSIFICATION BY RANK ______________

Proximate Analysis—as received (percent by weight)
- Volatile Matter ______________
- Fixed Carbon ______________
- Ash ______________
- Moisture (Total) ______________
- Equilibrium Moisture ______________
- ______________

Grindability—Hardgrove[b] ______________
- Feed Size (Sieve Analysis)

Sulfur
- Forms of Sulfur
  - Pyritic ______________
  - Organic ______________
  - Sulfates ______________

Heating Value—BTU/lb. as received ______________

Ultimate Analysis—as received (percent by weight)
- Moisture ______________
- Carbon ______________
- Chlorine ______________
- Hydrogen ______________
- Nitrogen ______________
- Oxygen ______________
- Sulfur ______________
- Ash ______________

Float Sink Fraction (1.6 sp.gr.) ______________

Ash Fusion Temperatures (°F)

	Reducing	Oxidizing
Initial deformation	______________	______________
Softening (H=w)	______________	______________
Hemispherical (H=½w)	______________	______________
Fluid	______________	______________

Ash Analysis (percent by weight)
- SiO_2 ______________
- Fe_2O_3 ______________
- Al_2O_3 ______________
- CaO ______________
- MgO ______________
- P_2O_5 ______________
- Na_2O ______________
- K_2O ______________
- TiO_2 ______________
- SO_3 ______________
- NAF[c] ______________
- Viscosity[d] ______________

Burning Profiles[e] ______________

Bulk Density (as delivered) ______________

Free Swelling Index ______________

Reactivity Index[f] ______________

ASTM TEST METHODS

1. Proximate Analysis—D3172,D3173,D3174,D3175,D3177,D2013
2. Ultimate Analysis—D3173,D3174,D3176,D3177,D3178,D3179, D2361
3. Heating Valve (BTU)—D2015,D3286
4. Grindability—D409
5. Moisture—D2013,D3173,D3302
6. Bulk Density—D291
7. Free Swelling—D720
8. Ash Analysis—D2795
9. Ash Fusion Characteristics—D1857
10. Classification by Rank—D388
11. Sampling Methods—D2234
12. Sampling Preparation—D2013
13. Chlorine—D2361
14. Forms of Sulfur—D2492
15. A Test for Sieve Analysis of Crushed Bituminous Coal—311-30

[b] Note: Grindability for at least three moisture levels should be determined when low rank coals are analyzed (e.g. Sub—C or Lignite).

[c] Not accounted for.

[d] Corey, Richard C., "Measurement and Significance of the Flow Properties of Coal Ash Slag," Bur. Mines Bull, Vol. 618, 1964.

* Please use one form for *each* coal specification; do not list property ranges or composite properties.

[d] Moore, G. F. and Ehrler, R. F., Western Coals—Laboratory Characterization and Field Evaluations of Cleaning Requirements, ASME paper No. 73-WA/FU-1 Detroit, Mich., November 1973.

[e] Wagoner, C. L. & Winegartner, E. C., "Further Developments of the Burning Profile," Journal of Engineering for Power, Trans ASME, Series A, Vol. 95, No. 2, April 1973.

[e] Moore, G. F. and Ehrler, R. F., Western Coals—Laboratory Characterization and Field Evaluations of Cleaning Requirements, ASME Paper No. 73-WA/FU-1 Detroit, Mich., November 1973.

[f] See *Reactivity of Solid Fuels* by A. A. Orning, "Industrial and Engineering," Pages 813, Vol. 36 (1944).

Table 3 Recommended ABMA Coal Guide Specification Form that the manufacturer can accurately determine steam generator performance conditions and guarantees. He should also specify other individual real analysis such that the manufacturer can predict variations in unit performance germane to each alternate fuel specified. In implementing the ABMA form, the user assures himself that all currently accepted coal effects criteria are being considered by the steam generator manufacturers.

Also shown on the recommended ABMA specification is a complete listing of ASTM test methods and other references.

CONCLUSION

In this presentation we have identified the most important fuel and fuel preparation outage causes. We have also discussed Riley Stoker Corporation's present efforts to further improve:

1. Pulverizer Reliability—Improvements to research pulverizer
2. Wet Coal Handling—Utilization of Riley crusher drier
3. Fuel Handling—Design vertical stainless steel chutes
4. Poor Quality Coal—Use of abrasion resistant materials
5. Slag—Accurately predict slagging tendency

And finally, we have presented and explained the newly developed ABMA coal specification criteria.

The problems of fuel burning equipment availability are being addressed and identified, and product-line developmental programs are continuing and being successfully implemented. Continued cooperation between the user and the manufacturer, such as is evidenced by the fuel specification guidelines, enable us to be optimistic that we can meet the challenge of deteriorating fuel quality head on and come out successfully.