Pulverizer Failure Cause Analysis

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ABSTRACT

Large coal pulverizers have been identified by EEI surveys as one of the main systems responsible for lost steam generation capacity of large coal fired utility boilers. This report contains the results of a 16 month study to examine the problem of pulverizer outages and to identify root cause failure modes for the major mill types currently in service.

A data base of 469 pulverizers, the majority larger than 40 tons/hr coal capacity, was compiled by surveying the utilities with coal fired boilers in this country. The analysis of this data base combined with telephone interviews and seven field site visits to utilities identified both design and operational problem areas in all of the mill types studied.

Five specific problem areas were established and evaluated in this study: (1) drive components, (2) grinding zone, (3) air system, (4) mill fires and explosions, and (5) boiler problems associated with the pulverizer.

The root causes of these problems were identified and documented. Recommendations for solutions to some of the more common problems were given after discussion of the findings with the manufacturers.

EPRI PERSPECTIVE

PROJECT DESCRIPTION

This final report is one of several surveys being conducted by the Fossil Fuel Power Plants Department to define more clearly the major generic equipment and/or operating problems responsible for utility power plant outages. This survey includes input from 21 U.S. utilities, with 69 generating units, 469 coal mills and an average size over 600 MW.

PROJECT OBJECTIVES

The main objective of this 16-month investigation was to determine the underlying causes of coal pulverizer failures. Other objectives were to identify design changes to reduce failure frequency, to quantify the relative importance and contribution of each problem to pulverizer reliability, and to identify those problems whose solutions require developments in current technology.

PROJECT RESULTS

Data analysis resulting from this survey clearly demonstrates problems with pulverized coal systems and their components, problems contributing to the unavailability of generating units. Recommendations are made to improve the reliability of existing coal pulverizers, and generic problems requiring future research and application of existing technologies are identified. It is also recommended that users place less emphasis on the initial costs of pulverizers and more emphasis on those design features that improve reliability to encourage manufacturers to accelerate their efforts to improve the technology and correct critical problems. Implementation of the recommendations included in this report by users and manufacturers can substantially improve the availability of pulverizers.

Further information regarding utility contacts and plants associated with this survey may be made available through EPRI.

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Section 1

INTRODUCTION AND SUMMARY

BACKGROUND AND JUSTIFICATION

According to a recent EEI survey (1), coal pulverizer operation has a major impact on the availability of large coal fired steam generators. The significance of lost generation due to the pulverizer has been cited by Southern Company System (2). The pulverizer was ranked sixth in terms of lost generation causes in 1976 for the 78 units in the System. Four percent of the total generation losses were pulverizer related. Since the EEI data bank does not include outage causes of pulverizer failures, there existed a definite need for detailed information about the major causes of pulverizer outages and the limitations imposed on a boiler by poor performance. It was the goal of this study to provide this information and to identify the major problems of coal pulverization.

PROGRAM OBJECTIVES AND TECHNICAL APPROACH

The primary objective of this study was to document the major reasons for poor coal pulverizer performance. Problems with mills of a capacity greater than forty tons/hour were the primary focus of the study. Coal type, design, maintenance and operations were investigated for potential causes of the failures. A second objective of the study was to document field modifications made by the manufacturer and/or the utility which may have improved the reliability or the performance of the pulverizer. Conclusions from the findings and recommendations for future research based on these findings have been made.

The initial phase of the program was dedicated to the gathering of performance data for a number of mill configurations. A representative sample was obtained. The data was obtained primarily through the use of a questionnaire which was sent to the participating utilities. A data base of 469 mills was formed and represents the designs from the four major manufacturers, Babcock and Wilcox, Combustion Engineering, Foster Wheeler and Riley Stoker. Bowl mills, roll-race mills, planetizing roll mills, ball-race mills and ball/tube mills were the configurations evaluated.

The questionnaires served the primary purpose of identifying the major problems, however additional information on root causes and field modificiations was obtained by field visits. Subsequent telephone conversations with maintenance and operations plant personnel as well as the field visits to several utilities supplied most of the latter information. Field visits were made to stations with pressurized bowl mills, roll-race mills and planetizing roll mills. These case studies have been included in Appendixes B through H.

DATA SUMMARY

Five specific problem areas were identified and evaluated in this study: (1) drive components, (2) grinding zone, (3) air system, (4) mill fires and explosions, and (5) boiler problems associated with the pulverizer. Drive components included gearbox, bearings and shafts. The grinding zone consisted of grinding elements (rolls, rings, balls, etc.). The air system included the circulation, classification and transportation of the pulverized coal. The origin of mill fires and explosions was documented and methods of prevention were suggested. Boiler and furnace related problems that were identified included slagging and carbon carryover.

The specific problem areas associated with each mill configuration have been summarized in Table 1-1. Included in the table are: (1) data base of mills for each mill configuration; (2) the percentage of units having problems in one of the five specific areas; (3) utility and manufacturer efforts to cope with these problems. Additional detail on the problem areas, root causes and modification for each particular mill configuration are presented in Sections 4-8.

A summary of the findings for the five mill configurations is presented below. The discussion includes a description of the manufacturer's effort to improve pulverizer performance.

BOWL MILLS

Most of the drive component problems are associated with either improper spring compression settings and/or contamination of the lube oil. Utilities have made operational changes (e.g. resetting journal spring compression) and have added preventive maintenance procedures (e.g. oil checks) to improve performance of pulverizer drive components. At one plant, periodic oil analyses (every two months) have succeeded in predicting two pulverizer failures. This preventative

Table 1-1. Summary Table

	BOWL MILLS		ROLL-RACE		PLANETIZING ROLL		BALL-RACE		BALL/TUBE	
# Units	40		7		9		7		6	
#Mills	276		58		52		56		18	
	Problem Area	Modifications	Problem Area	Modifications	Problem Area	Modifications	Problem Area	Modifications	Problem Area	Modifications
DRIVE TRAIN	(54%)* Oil Contamination --low seal air --burned seals Excessive Shaft Breakage --improper roll adjustment --bearings	seal air capacity (M/U)** frequent oil analysis (every two months) filtration (M/U) lube oil system (M) spring compression (M) reduced reset rolls (M/U) larger bearings (U)	(14%) Gearbox --O-ring problems --thrust bearings lost	No details--gearbox no longer a problem	(67%) Oil Contamination --low seal air --cooler supply water in oil Excessive Wear and Breakage --low speed shafts --gears --undersized drive train	increased seal in air capacity (U) extra large lube oil filters (U) synthetic oil (U) lubricant new design (M/U) larger gear system (M/U) larger bearings (M/U)	(57%) Oil Contaminatior --low seal air	increased seal air capacity (U)	(67%) Oil Contamination --no details	No details
GRINDING AREA	(35%) Excessive Wear --rolls/rings --liners	Hard faced rolls (M/U) NiHard 20% chrome surfaced larger liners (M)	(29%) Rolls Cracking	new material (M)	(100%) Excessive Wear --grinding elements Excessive Breakage --thrustring failure Mill Skids	no details high carbon steel (U) (higher tensile strength than NI hard) no details	(14%) Excessive Wear --ball/ring	wear material on balls increased for better grind (U)	(33%) No details	No details
AIR SYSTEM	(13%) Excessive Wear --classifier --multiport outlet	ceramic lining (U) vanes reset (M/U)	(29%) Excessive Wear (coal type) --pulverizer housing --throat inserts --slope plates --classifier --swing valves	ceramic lining added (M/U) different throat designs (M/U) Tapco overlay (U) ceramic brick (M/U) modified valve seal and plate (M/U)	(67%) Excessive Wear --classifier system	ceramic lining (M/U)	(0%)		(33%) No details	No details
MILL FIRES AND EXPLOSIONS	(33%) Liners --coal accumulation	liners removed (U) flat surfaces eliminated (U)	(70%) Bowl Area Pyrite Plow Breakage	lowered mill outlet temp (U) larger stainless steel springs used (M)	(11%) No details	No details	(0%)		No details	No details
ASSOCIATED BOILER PROBLEMS	(13%) Slagging --oversized particles	frequent fineness testing (M/U)	(29%) Slagging --oversized particles		(33%) Slagging --oversized particles due to excessive classifier wear and vanes sizing	No details	(86%) Slagging --oversized particles	monitoring furace exit temperature (U)	(0%)	

*( ) - denotes % units which have had associated problem areas
**M - manufacturer suggested modification
U - Utility modification

maintenance measure, suggested by the manufacturer, will be included in the maintenance procedures of the utility.

Excess wear problems have been associated primarily with the rolls and liners. The manufacturers do have a hard surfaced roll available to the utilities. A NiHard surface is typically used by the utilities to increase roll life. Several stations have the mill rolls hardened on-site or by an independent vendor.

Excessive wear of the liners coupled with coal accumulation has been identified as a major cause of mill fires and explosions. Some utilities have either removed the body liner cover plates and separator body liners completely or have installed new liner cover plates to reduce the "lay out" or accumulation of coal in the mill. The manufacturer is making design changes to the separator body liners to reduce the number of dead air pockets where coal may accumulate and hot spots may occur. As a result of this study, the manufacturer has initiated a project to investigate the inclusion of incipient mill fire detectors on their new installations.

The manufacturer has recently begun putting together an availability data report in the form of a questionnaire to enable utilities with their mills to share solutions to similar problems. Any pulverizer malfunctions which might derate the unit have also been included.

ROLL-RACE MILLS

The data collected in this study indicate problem areas with roll-race mills have existed primarily with mill fires and explosions. Seventy percent of the units questioned using this mill reported fires and explosions as a problem area. Pyrite plow failure at two units had been responsible for several fires, but the frequency of fires decreased dramatically with the replacement of the springs on these units. The manufacturer is investigating incipient mill fires detectors for the roll-race mills. Mill inerting systems are strongly recommended by the manufacturer. Also, clearing systems to combat mill puffs are required on mills grinding the high moisture, highly volatile western coals.

While many of the mills in the study may not be "seasoned" in terms of extensive operating history, the roll-race configuration appears to be relatively problem free regarding drive components, grinding zone elements, and air system. Excessive breakage was not reported by any of the stations, and excessive wear problems were confined to only two units. These wear problems were associated with the abrasive nature of the coal being ground at this station. Utility modifications were made to specifically reduce wear in the housing liners, throat inserts, classifier, swing valves and burnerline piping.

The manufacturer has tried to minimize excessive wear in the grinding zone and the circulating and classifying regions of the mill. The roll-race tires are reversible and can tolerate up to five inches of wear before replacement. In addition, the classifier cones of all mills have segmented ceramic lining, regardless of coal type and properties in use.

PLANETIZING ROLL MILLS

Excessive wear and breakage has been experienced with the drive components and grinding elements of the planetizing roll mills. The gears and bearing drive worm shaft have been particularly prone to wear with oil contamination being responsible for part of these problems. Extra large lube oil filters were installed at two units to improve filtration and reduce the contamination problem.

Grinding element problems were evident at all the stations. Thrust ring breakage has been particularly severe. High carbon steel is being tried as a thrust ring material at one plant as a substitute for NiHard. Although the wear quality of the high carbon steel is not as good as the NiHard, it is thought that the tensile properties of the high carbon steel will reduce cracking.

The classifier system (cones, vanes) has also been susceptible to extreme wear. Rapid wear of the classifier blades has contributed to oversized coal entering the furnace. Ceramic lining of the classifier cone has been successful in reducing cone wear, but vane wear is still a problem.

Data has been gathered for the planetizing roll mill, however this mill type is no longer being manufactured. A new series mill is now being manufactured which has eliminated the thrust ring breakage problem. This mill has three stationary spring rolls the tension on which are individually controllable. The grinding rollers have been designed with replaceable tires which can be reversed to increase life before complete replacement. This feature is similar to the roll-race mill. Also, the gearbox is a self-contained unit which can be removed without dismantling the upper mill body. A prototype of this mill has been in operation only 9,300 hours at this writing.

BALL-RACE MILLS

Similar to the planetizing roller mill, the counter-rotating ball-race mill is no longer being manufactured. Problems with excessive wear, vibration, teardown complexity and poor seals lead to a high maintenance characteristics with a poor reliability record. Many utilities which had the ball-race mills at their stations have replaced them with the roll-race mill.

BALL-TUBE MILLS

Data on the ball/tube mill was limited. Correlations of problem areas and root causes for these mills was not possible. The ball/tube mill did however experience problems similar to those of other mill configurations.

CONCLUSIONS AND RECOMMENDATIONS

Based on the findings of this study, the following conclusions have been made. These conclusions are grouped into the major problem areas.

DRIVE COMPONENTS

- All of the pressurized mill configurations surveyed in the study had problems with either oil seals or air seals. The seal problem is a serious one, leading to possible bearing and shaft failures. Utilities as well as manufacturers are aware of the problems (inadequate seal air capacity, burned oil seals, inadequate oil filtration) and are working toward solutions.

- Monitoring lube oil at frequent intervals should be investigated by the utilities as a preventative maintenance practice. Such analyses will allow prediction of impending pulverizer failures (bearing and/or subsequent shaft failure) or permit the scheduling of maintenance (e.g. oil changes, seal replacements).

GRINDING ZONE AND AIR SYSTEM

- Experimentation by the utilities with various hardened surfaced rolls, chromium carbide liners, ceramic lined housing and classifier cones indicates that unsatisfactory wear life of key components is a problem with many of the mills in service today. Longer life materials that maximize the wear cycles of the mill are available and can be incorporated in yet-to-be built mills. These high performance factors should be requested when calling for equipment bids.

MILL FIRES AND EXPLOSIONS

- A better means of isolating fires from the furnace and the coal bunker needs to be developed for preventing the spread of fires. Excessive wear in the multiport outlet of the mills have rendered the isolation valves less than effective.

While the above discussion is related to upgrading pulverizer performance, other findings from the study indicate a need for additional information concerning associated boiler problems that originate with the pulverizers.

ASSOCIATED BOILER PROBLEM AREAS

- Future work is recommended to measure and document coal loading distribution in the coal pipes leading to the burner from the pulverizer and relate that to furnace side operational problems such as slagging, fouling and corrosion due to poor air/fuel control at the burner.

MAINTENANCE COSTS

- More information needs to be gathered on maintenance. Specific maintenance costs should include manhours (labor) and parts for a specific list of components. Such data can be shared by the utilities and is particularly valuable when the effectiveness of mill modifications regarding reduced maintenance costs is assessed.

A final conclusion and recommendation is based on a need to systematically quantify mill performance with coal type, maintenance and operations. It is recommended to select a new pulverizer installation of a current design and monitor mill performance and related fireside problems that are mill performance related. The impact of cleaned coal on mill performance should also be evaluated.

Some data was gathered to assess the relative importance and contribution of pulverizer system problems to reliability. Ranking of pulverizer problem areas on a lost generation cause basis could be done for only the pressurized bowl and planetizing roll mills. Mechanical failures and coal were the most significant problem areas in terms of megawatt hours lost due to forced outages (see Appendix I).

SECTION 2

PULVERIZER SYSTEM FUNCTIONS AND DESIGN PARAMETERS

A brief review of pulverizer system functions and important design parameters is appropriate before initiating a detailed discussion of different design configurations and criteria for specific performance and reliability objectives. These system functions and design parameters formed the basis for assessing major pulverizer problem areas.

PULVERIZER SYSTEM FUNCTIONS

The pulverizer system obviously must be designed in a manner that is consistent with the steam generation capacity, load changes, and coal types available. Important functions that a pulverizer system must be designed to perform properly and reliably include (3):

- Feeding--supplying raw coal to mill
- Drying--using preheated primary air to remove moisture from coal
- Grinding--pulverizing coal by crushing, impact or attrition
- Circulating--removing coal from grinding zone, rejecting foreign material (tramp iron, etc.)
- Classifying--returning oversized particles to the grinding zone while delivering sized particles to mill outlet.
- Transporting--delivering pulverized coal/air mixture to burners

Relative to these functions and the associated pulverizer system design criteria, the importance of coal type and properties and coal fineness will be emphasized. With this background, later sections of the report will examine the problem areas which have been encountered with different types of pulverizer mills.

PULVERIZER DESIGN PARAMETERS

Coal Type and Properties

Coal characteristics are integral to pulverizer system design, sizing, and performance. In particular, the heating value, moisture content, grindability, and abrasiveness of the coal are of interest (4). If the coal burned has a lower heating value than design, there may be problems meeting load requirements. Not enough pulverized coal of the proper size can be delivered to the burners without overloading the mills. The load requirements of the boiler cannot be met.

Coal moisture is an important parameter when designing mill capacity. Preheated primary air must be able to dry the coal sufficiently during grinding. Surface moisture of the coal can diminish the capacity of the grinding elements by hindering particle separation during crushing. An extremely wet coal is usually hard to grind. Furnace problems can result from a high moisture coal. Insufficient drying of a high moisture coal can influence flame stability as well as causing high superheat temperatures.

The grindability of a coal is particularly important for pulverizer sizing. The most widely accepted method developed to describe the ability of a solid to be pulverized is the Hardgrove grindability index (HgI). The HgI has been utilized to accurately predict a pulverizer's ability to grind eastern coals. Overestimated values of grindability, however, have occurred with the subbituminous and lignitic coals. Subsequently, a continuous grindability index (CGI) was developed to estimate the grindability of these coals (5).

Abrasiveness, like a low grind coal, will reduce the lifetime of wear elements and liners and will also cause wear problems in the circulating, classifying, and transporting sections of the pulverizer system. Some indicators of coal abrasiveness are the relative amounts of silica (SiO_2) and alumina (Al_2O_3) in the coal's ash, the weight percent ash in the coal, and the weight percent sulfur in the coal. A coal with a silica/alumina ratio greater than two is considered abrasive. Also an eastern bituminous coal with a sulfur content greater than 3% is also considered abrasive. This abrasiveness is due to the high pyrite (FeS) content of the coal.

One of the objectives of this program was to study the effect of the fuel properties (heating value, moisture content, grindability and abrasiveness) on pulverizer performance and specifically look at the eastern versus western coals in terms of wear and performance. For the coal properties listed above, there are certain fundamental difference between the two coals.(6) Western coal typically has an ash-free higher heating value of 19 to 24 MJ/Kg (8200 to 10,500 moist Btu/lb) and a high moisture content of 20 to 30%. The ash content of a western coal is approximately 10% by weight. The western subbituminous coal usually exhibits a high volatile content. Eastern coal typically has a higher ash-free value of 25 to 30 MJ/Kg (11,000 to 13,000 moist Btu/lb) and a moisture content of 4 to 10%. The ash content and sulfur content of the eastern coal is typically higher than the western coal. The eastern coals also typically have a lower volatile matter content.

Coal Fineness

Coal fineness will depend primarily on classifier setting, mill capacity air flow, and coal type. Key factors in establishing coal fineness variability are the means of grinding, circulating, and classifying. Grinding elements reduce the coal either by crushing, impact, or attrition to a certain size which is picked up by the circulating air and swept to the classifier. The classifier returns oversized particles to the grinding zone while permitting the proper sized particles to enter the transport lines to the burners. If a certain percentage of oversized particles passes through the classifier and into the burner lines, some serious problems such as burnerline pluggage, slagging, fouling, smoking, and excessive carbon carryover in the furnace may result. Typically, requirements for the pulverizer system will require 98% through 50 mesh and 70% through 200 mesh. If more than 2% is retained on the 50 mesh, slagging and carbon carryover may be expected in the furnace. A poor coal grind will also increase burnout time resulting in reduced heat transfer in the near flame zone (radiant) and increased heat transfer in the far flame zone (convective). Poor grind at high loads may cause excessive superheat steam temperatures.

The operating coal feed rates and air flow rates will influence the coal fineness product. A mill operating at lower coal feed rates will respond with a finer coal. High air flow will increase classifier wear but will limit grinding element work. The result will be a decrease in the fineness of the mill output. Low air flow may result in excessive grinding element wear. Subsequent wear in the grinding zone will further influence the coal fineness product.

The degree to which a coal needs to be pulverized for fineness requirements will depend on coal type and rank. Eastern coking coals, when exposed to furnace temperatures, will swell and form lightweight porous coke particles. Carbon carryover can be high unless pulverization is very fine. Free burning (western) coals do not require the same degree of fineness because the swelling characteristic is absent.

Section 3

DATA BASE PREPARATION AND STUDY FOCUS

This study involved the acquisition and screening of performance data for various mill configurations to achieve a representative sample for problem area analysis. Most of this data was acquired by the use of questionnaires sent to utilities, supplemented by plant visits. Included in this section is a discussion of how the questionnaire was devised, the content of the data base established for study, and problem area focus with associated causes and solutions.

THE QUESTIONNAIRE

The questionnaire sought information in several categories concerned with general boiler data, problem areas associated with the pulverizer, coal history information and outage data for individual pulverizers. Appendix A is a copy of the questionnaire.

The areas of interest in terms of pulverizer problem areas were the drive component (gearbox, shafts, bearings), grinding elements, air systems, fires and explosions and boiler problems associated with the mill. Trash separators and crushers were included as associated pulverizer equipment to assess the impact of coal preparation and handling difficulties on mill performance. When analyzing and reviewing problem areas, it is important to keep in mind that the items noted as problem areas may have been so at one time but have since been solved by some modifications made by the manufacturer and/or utility.

Coal history information was sought to document the design coal for the pulverizer as well as deviations from the design coal and to determine how pulverizer outages, maintenance and operations were affected by coal changes. Coal properties may vary considerably over time due to the numerous coal sources a unit may have. Also, a utility may be forced by environmental regulations to use blended or low sulfur coals to meet SO_2 regulations.

Important coal properties considered were: Hardgrove grindability index, moisture content, ash, sulfur, heating value and coal particle size.

The intent of the third page of the questionnaire was to document availability based on the type and number of pulverizer outages. Information on the frequency and severity of scheduled and forced mill outages was requested for a three year period. Records in this area were not always available from the utilities or were limited based on the unit startup date. Forced outages were also minimal for some units where one or two spare mills are available. Appendix I is dedicated to pulverizer availability data and the relative amount of megawatt hours lost due to various components associated with a pulverizer system.

Two other items of interest were scheduled maintenance and maintenance cost data to determine the frequency of overhauls (minor or major), grinding element replacement, and labor and material costs associated with pulverizer repair.

DATA BASE

A data base from 469 pulverizer mills was established for the study. Mill types include bowl, roll-race, planetizing roll, ball-race and ball/tube mills. The mills studied include those of all four major pulverizer manufacturers, Babcock and Wilcox (B&W), Combustion Engineering (CE), Foster Wheeler (FW) and Riley Stoker (RS). The numbers of mills by type and size are listed in Table 3-1. The study emphasis was placed on pulverizers with capacities greater than 40 tons/hr. However, approximately 15% of total mills in the data base are of capacities between 20 and 40 tons/hr.

Data was gathered for a number of "seasoned" pulverizers to achieve a more complete picture of operating availability, reliability, and performance as a function of complete picture of operating availability, reliability, and performance with coals, mill type, etc. Seasoned pulverizers are defined as those having sufficient service time to receive routine maintenance such as ball replacement, grinding zone rebuilds or even complete overhauls. Data has also been gathered on the mill types with respect to operation on eastern and western coals. It should be noted that the data base also includes mills on line for only a year or two. Summary tables of data gathered for the bowl mills, roll-race, planetizing roll, ball-race and ball mills are presented in subsequent sections.

Table 3-1

Data Base -- Mill Type and Pulverizer Size Distribution

Manufacturer	Mill Type	Size (tons/hr) 20-29	30-39	40-49	50-59	60-69	≥ 70	Mill Total	% Total
I	Bowl Mill								
	Pressurized				12	99	35	146	31.2
	Pressurized/Suction	20	8	10	44			82	17.4
	Suction			12	6	22		40	8.5
	Deep Bowl	8						8	1.7
II	Roll and Race					58		58	12.6
	Ball and Race	10		18	28			56	11.9
III	Roll and Table		16	6	30			52	11.1
	Ball Mill				18			18	3.8
IV	Ball Tube Mill		6	3				9	1.8
Total Mills of Capacity Range		38	30	49	138	179	35	469	
Pulverizer Size Distribution (% Basis)		8.1	6.4	10.5	29.4	38.1	7.5		100.0

PULVERIZER PROBLEM AREAS AND FOCUS

Table 3-2 summarizes pulverizer problem areas by stations and mill configurations. This table and those unnamed plants having problems are presented in each subsequent section of the report by mill type. The plant names have not been given in this study, since the primary objective is to document generic problem areas associated with a mill and not a plant. It should be noted that the tabulation of problems have been done on a unit basis and not on a mill basis. In some cases, a problem area may be associated with only one or two mills at that unit.

The focus of the pulverizer problem areas for this study was centered on the drive mechanisms, grinding zone, circulating and classifying section of the mill, mill fires and explosions, and boiler problems originating in the mill. Drive components included were gearbox, bearings, shafts and seals associated with these components. The major elements of concern in the grinding area were rolls, rings, liners, journals, thrust rings, etc. Items included in the air system were the primary air plenum chamber (primary air inlet, pyrite chamber, pyrite sweepers) and areas in the mill exposed to the circulating and classifying process such as mill housing, classifier vanes, and the multiport outlet. Excessive wear or breakage with mill components have been noted. Fires and explosions were another focal point; in particular, the sources of the fires, whether it was the bunker, the mill, or in the burnerlines, and methods used to prevent fires and explosions. Boiler problems associated with the mill, such as slagging, fouling, smoking, and carbon carryover are also presented.

In addition to documenting utility-wide pulverizer problem areas, solutions that have been devised to cope with these problems have been included as well. Seven field visits were conducted to investigate the modifications made to improve pulverizer performance. The problem areas along with the underlying cost causes and the field "fixes" are documented in the following sections.

Table 3-2

Summary of Pulverizer Problem Areas on a Station Basis

	Press. Bowl	Press/Suction Bowl	Suction Bowl	Deep Bowl	Roll-Race	Planetizing Roll	Ball-Race	Ball	Ball/Tube
Number of Stations	22	10	7	1	7	9	7	3	3
Number of Mills	146	82	40	8	58	52	56	18	9

Problem Areas Associated with Mills (Station Basis)

Problem Area	Press. Bowl	Press/Suction Bowl	Suction Bowl	Deep Bowl	Roll-Race	Planetizing Roll	Ball-Race	Ball	Ball/Tube
Gearbox	12	8	2	0	1	8	6	0	2
Bearings	11	8	3	0	0	6	6	3	2
Shafts	14	6	2	1	0	4	0	3	0
Seals	10	6	2	0	3	4	7	3	2
Grinding Elements	8	4	2	0	2	9	1	0	1
Motor	2	0	0	0	0	1	2	0	1
Classifier	1	0	0	0	0	6	0	0	1
Pyrite System	3	0	1	0	2	0	0	0	0
Excess Wear	8	3	1	0	2	7	3	3	1
Excess Breakage	4	3	4	1	0	7	0	0	1
Mill Fires	6	5	2	0	5	1	0	3	1
Mill Explosions	0	0	2	0	3	0	0	3	1
Slagging	3	2	0	0	2	3	6	0	0
*Trash Separators	4	4	2	0	4	3	0	0	0
*Crushers	4	2	1	0	2	0	0	0	0

* Ancillary equipment associated with the mill

Section 4

BOWL MILLS

The most extensive data base for any one mill configuration was gathered for the bowl mills. Pressurized, pressurized/suction and suction mills are all included in this study.

MILL CONFIGURATION AND OPERATION

A bowl mill (Figure 4-1) consists of a segmented rotating grinding ring, three spring loaded tapered rolls, an automatically controlled feeder, a classifier and a main drive. Coal is forced from the center of the grinding ring to the bowl perimeter by centrifugal force where the coal then comes between the rolls and the grinding ring. The rolls are held in stationary journals. The classifier is an internal cone type, housed in a high-sided chamber, and provided with adjustable vanes.

The majority of bowl mills being manufactured today are pressurized. The pressurized mill uses a cold side primary air fan, located on the inlet side of the pulverizer, that forces the cold primary air through the air preheater and into the pulverizer where it picks up the pulverized coal and delivers the proper coal-air mixture to the burners. The suction mill draws hot primary air and entrained coal from the pulverizer under negative pressure by an exhauster located on the outlet side of the pulverizer. The exhauster at the outlet side of the pulverizer is subject to severe erosion from the pulverized coal/air mixture. Some mills are a combination of the pressurized/suction mill. While data have been accumulated for all three mill types, the emphasis will be on the pressurized mills since this is the preferred design on new installations.

DATA BASE

A data base of 276 bowl mills was established for the study. Included in this number are pressurized bowl, pressurized/suction bowl, suction bowl, and deep bowl mills. Table 4-1 presents a list of the plant's startup date, nominal capacity, number of mills, problem areas, coal type used and maintenance data.

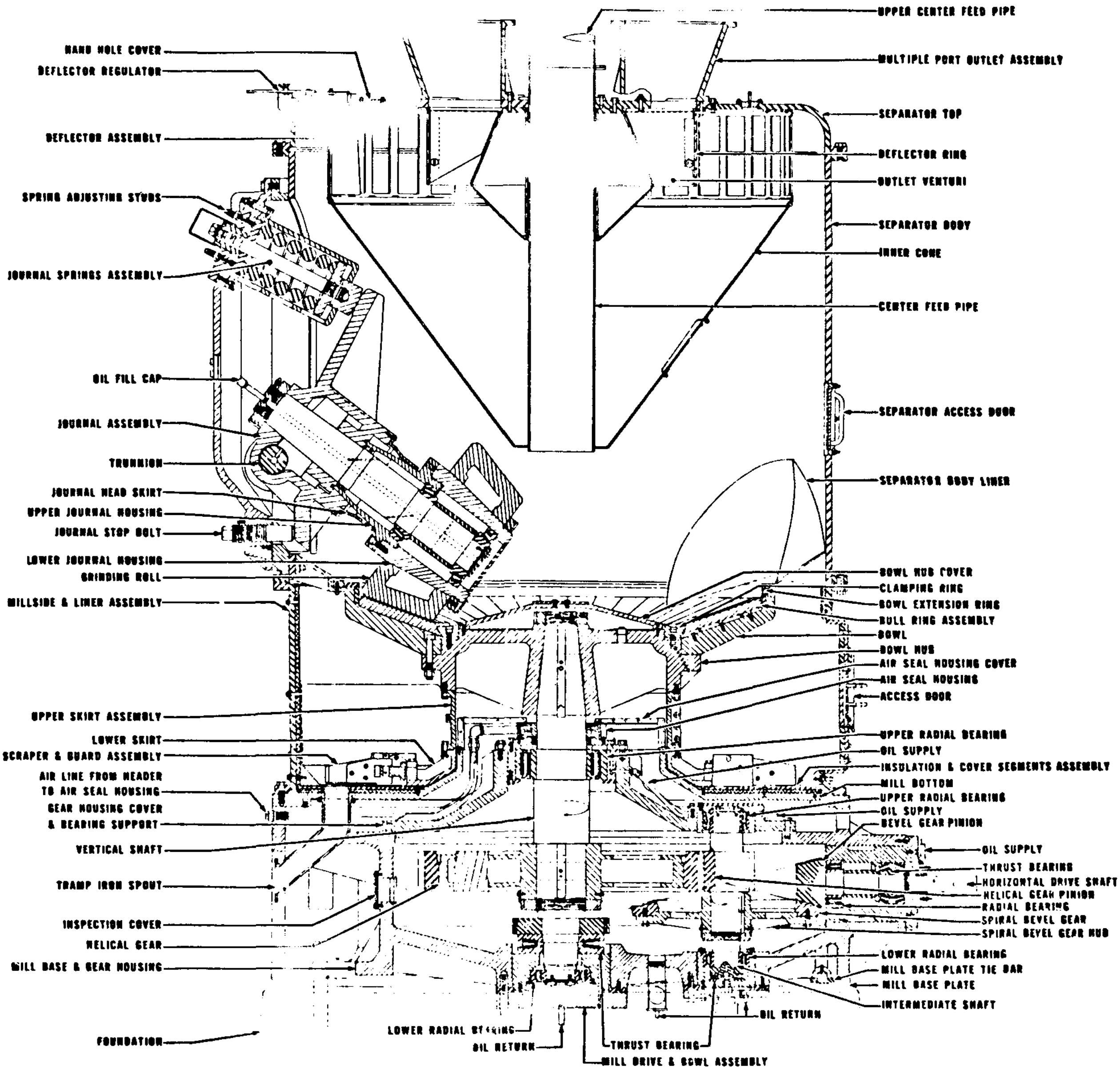

Figure 4-1. Pressurized Bowl Mill (Part Location Drawing).

Source: Manufacturer's Operation Manual

Table 4-1. Data Base--Bowl Mills

Plant	Unit	Startup Date	Nom. Capacity (MWe)	#Mills/each Unit	#Mills @ full load	Pulverizer Size (tons/hr)	Problem Areas: Gearbox	Bearings	Shafts	Seals	Grinding Elements	Motors	Classifier	Pyrite System	Excessive Wear	Excessive Break	Mill Fires	Mill Explosions	Slagging	Trash Separators	Crushers
Pressurized																					
ID 1	A,B	3/76,2/77	700	7	6	72	x	x	x	x	x				x						
ID 2	A,B	8/71,7/72	665	8	7	66	x	x		x	x			x					x	x	x
ID 3	A	5/75	527	6	5	67				x	x				x				x		
	B	3/78	527	6	5													x			
ID 4	A,B,C	6/73,4/75,3/36	750	7	6	66	x	x	x												
ID 5	A,B	6/71,7/72	700	6	5	66	x		x								x				
	C,D	7/74.7/75	880	7	6	66			x						x		x				
ID 6	A,B	8/76,1/78	865	7	6	72															
ID 7	A	10/72	700	6	6	69		x	x	x						x	x				
ID 8	A	10/71	700	6	5	69	x							x							
ID 9	A	8/74	884	7	7	72	x		x												
ID 10	A	4/77	511	6	6	60				x	x									x	x
ID 11	A	5/69	690	6	6	53		x	x	x	x		x		x	x	x			x	
ID 12	A	12/73	597	6	6	53		x	x	x		x			x	x					
ID 13	A	6/76	600	6	5	66	x	x	x	x	x	x			x	x					
Pressure Suction Mills																					
ID 14	A	'66	950	10	10	43															
ID 15	A,B	'61,'65	550	10	10	28	x	x	x								x		x		
ID 16	A,B	'70,'71	900	8	7	50	x	x	x	x	x						x		x		
ID 17	A,B	6/67,6/68	900	8	7	50	x	x		x	x				x						x
ID 12	B,C	9/65,7/66	583	6	6	50	x	x	x	x	x					x					x
ID 18	A	6/63	542	8		39									x	x	x				
Suction Mills																					
ID 18	B	6/57	278	8[3]		21			x							x					
ID 19	A,B	5/69,5/70	580	6	6	60	x	x	x	x	x					x	x	x			
ID 20	A,B	10/71,10/71	575	5	5	60							x		x				x		
ID 10	B	11/73	511	6	6	50	x											x	x		
ID 21	A	4/69	500	6		46									x						
ID 22	A	1/68	500	6		46															

Plant	Unit	Coal Type[1]	Typical Coal Properties: Heating Valve (BTU/lb)	HgI	%Moisture	%Ash	% Sulfur	Abrasiveness (silica/alumina)	Maintenance Data[2]: Scheduled Maintenance Tonnage Throughput(x1000)	Major Overhaul Tonnage Throughput (x1000)	¢/Ton Coal Ground
Pressurized											
ID 1	A,B	W-Mont.	8400	52	26	10.0	0.8	2.3	200	500	
ID 2	A,B	W-Wash.	7800	34	24	15.0	0.8	2.3	100	400	16-20
ID 3	A	W-Mont.	8420	52	26.5	10.1	0.6	2.3	100	500-700	
	B	W-Mont.	8420	52	28.7	55.0	0.3		100	500-700	
ID 4	A,B,C	W-Ariz.	10725	42	10.3	10.4	0.5	2.1	250		
ID 5	A,B	E-Ky.	12000	55	8.5	14.0	1.6		100	600	
	C,D	E-Ky	12000	55	8.5	14.0	1.6		100		
ID 6	A,B	E-Ind.	11000	55	8.5	14.0				450	6
ID 7	A	E-Ala.	11500	53	7.0	15.0	1.5				
ID 8	A	E	11500		8.2	14.1	0.9		100		
ID 9	A	E-Ala.	11800		6.9	13.5	1.7		300		
ID 10	A	E-Ind.	12530	38	7.0	8.9	0.6	2.0			
ID 11	A	E-Ky.	13000	45	5.0	9.0	1.0				
ID 12	A	E-W.V.	11500	60	8.0	18.0	3.0				
ID 13	A	E-Ill.	10473		13.7	11.6	2.9			250	
Pressure Suction Mills											
ID 14	A	E-Ky	12035	43	8.0	17.0	0.9				
ID 15	A,B	E-Ky	11170	60	7.4	16.4	3.1				
ID 16	A,B	E-Pa.	11600	65	4.0	17.0	2.4		125	275	39
ID 17	A,B	E-Pa.	11600	65	4.0	17.0	2.4		225	350	26
ID 12	B,C	E.W.V.	11500	60	5.0	18.0	3.0				
ID 18	A	E-									
Suction Mills											
ID 18	B	W-	9538		24.1	4.4	0.4	1.3			
ID 19	A,B	E-Ky.	11850	34-60	7.0	13.5	1.1	1.7			6.5
ID 20	A,B	E	12800	80-110	4.3	13.7	1-2.3		80-120	200-300	
ID 10	B	E-Ind.	10680	55	13.1	10.5	3.2	2.2	200	460-700	
ID 21	A	E-Oh.	9960	45	19.3	7.4	0.7	1.2		250	
ID 22	A	E-Oh.	11990	48	7.2	10.9	0.7	1.9		250	

1) Coal Type
   W-Western Coal
   E-Eastern Coal
2) Maintenance
   a) Scheduled maintenance will include work where applicable on replacing exhauster blades, resurfacing rolls, replacing separate body liners, etc.
   b) Major overhauls will include work where applicable on replacing grinding ring segments and rolls, liners, cones, discharge valves, etc.
3) Deep bowl mills.

From the data base, 40 units and 276 bowl mills, three plants with pressurized bowl mills were selected for field visits. The case studies for these three sites (Plant ID 2 A,B; Plant ID 3 A,B and Plant ID 7 A) are included in Appendices B-D respectively.

PROBLEM AREAS/CAUSES/MODIFICATIONS

Figures 4-2, 4-3, and 4-4 show the percentage of units having problem areas associated with the pressurized bowl, pressurized/suction bowl, and suction bowl mills. The following discussion examines some of the more prevalent problem areas associated with the bowl mill.

Drive Components

Table 4-2 presents data on those stations experiencing problems with the drive components. A underlying cause for the problem(s) is identified where applicable along with modifications, whether successful or unsuccessful, that were made to cope with the root cause of the problem.

Most of the drive component problems can be associated with improper spring compression settings and/or contamination of the lube oil. Excessive breakage of the vertical shaft was reported at eight units. Such breakages result from excessive roller journal bearing wear and loading on the vertical shaft seal created by improperly adjusted roller journal springs. Spring compressions as well as roll positions are critical items for maintenance inspection to insure that shaft failures do not occur. Mill fires may also draw the temper from the springs; thus maintenance and spring checks should be made following mill fires to insure that proper spring adjustment is maintained.

Solutions to the vertical shaft breakage problem have included journal spring adjustment and frequent spring checks. At one plant, the journal spring compression was reduced from twenty to fifteen tons and straps were welded on the spring adjusting and jam nuts to the spring stud to prevent loss of spring loading during operation. Units C,D of Plant ID 5 have instituted spring checks at three month intervals to insure proper spring adjustment and have not experienced problems with shaft breakage since this maintenance check was instituted.

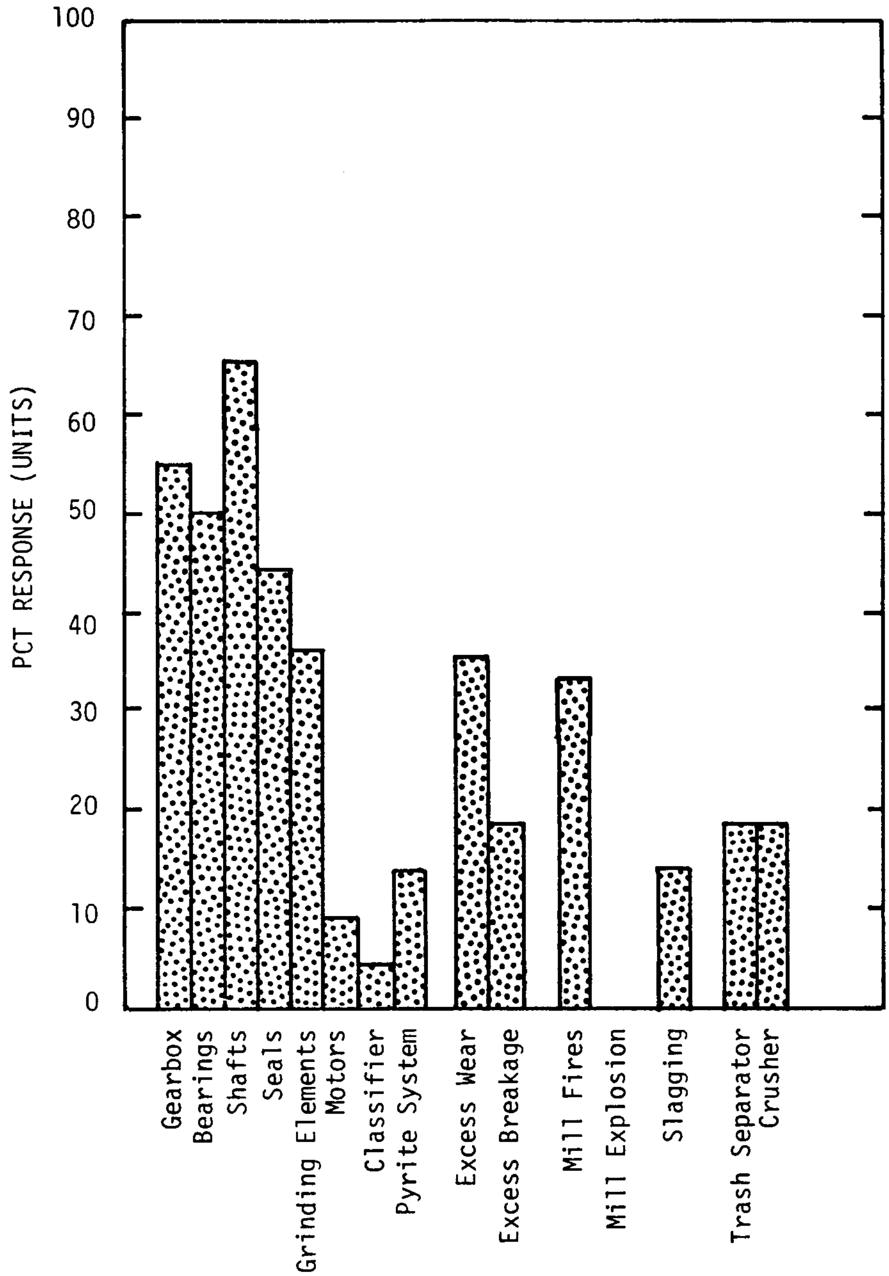

Figure 4-2. Pressurized Bowl Mills--Problem Areas.

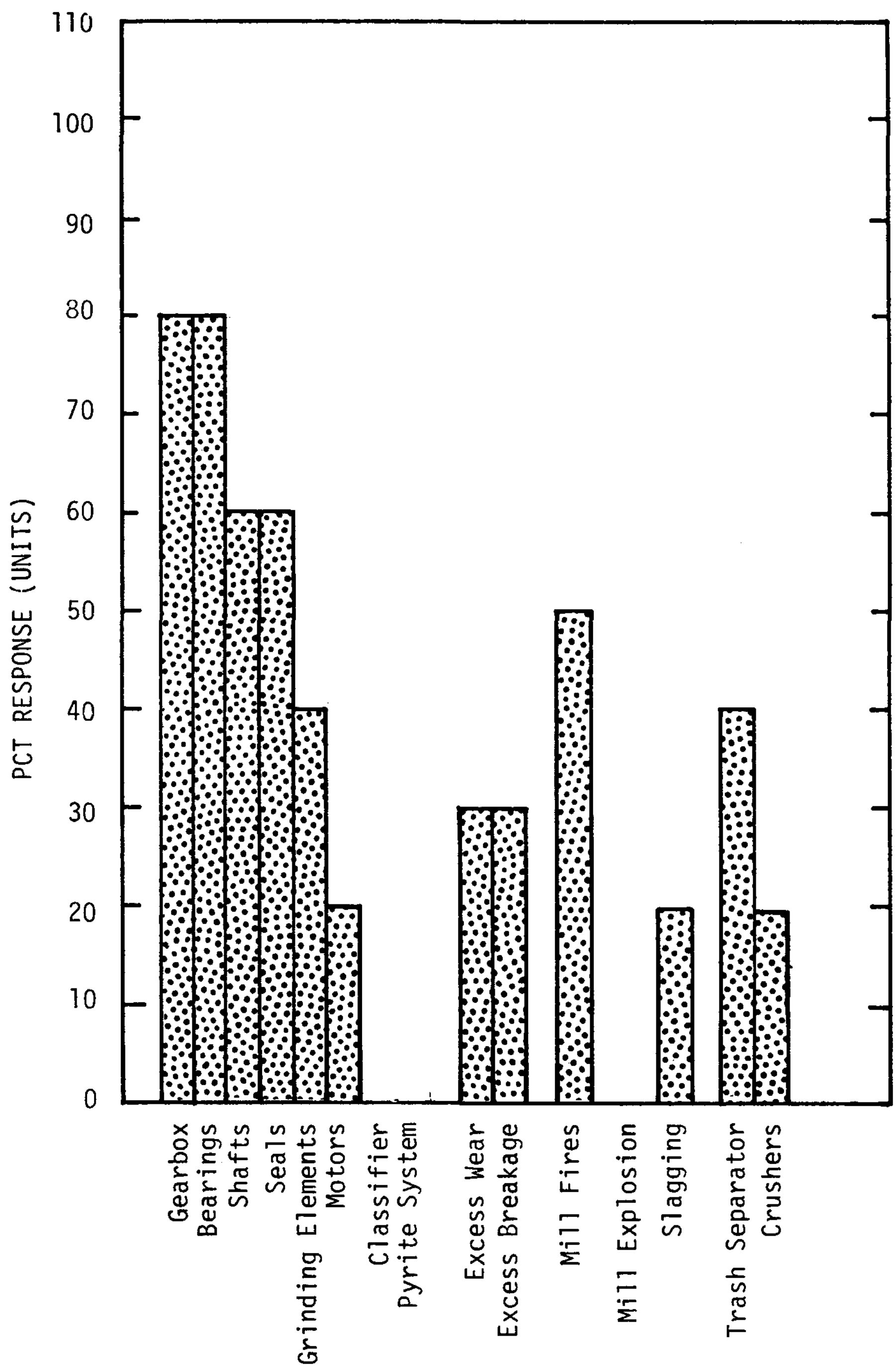

Figure 4-3. Pressurized/Suction Bowl Mills--Problem Areas.

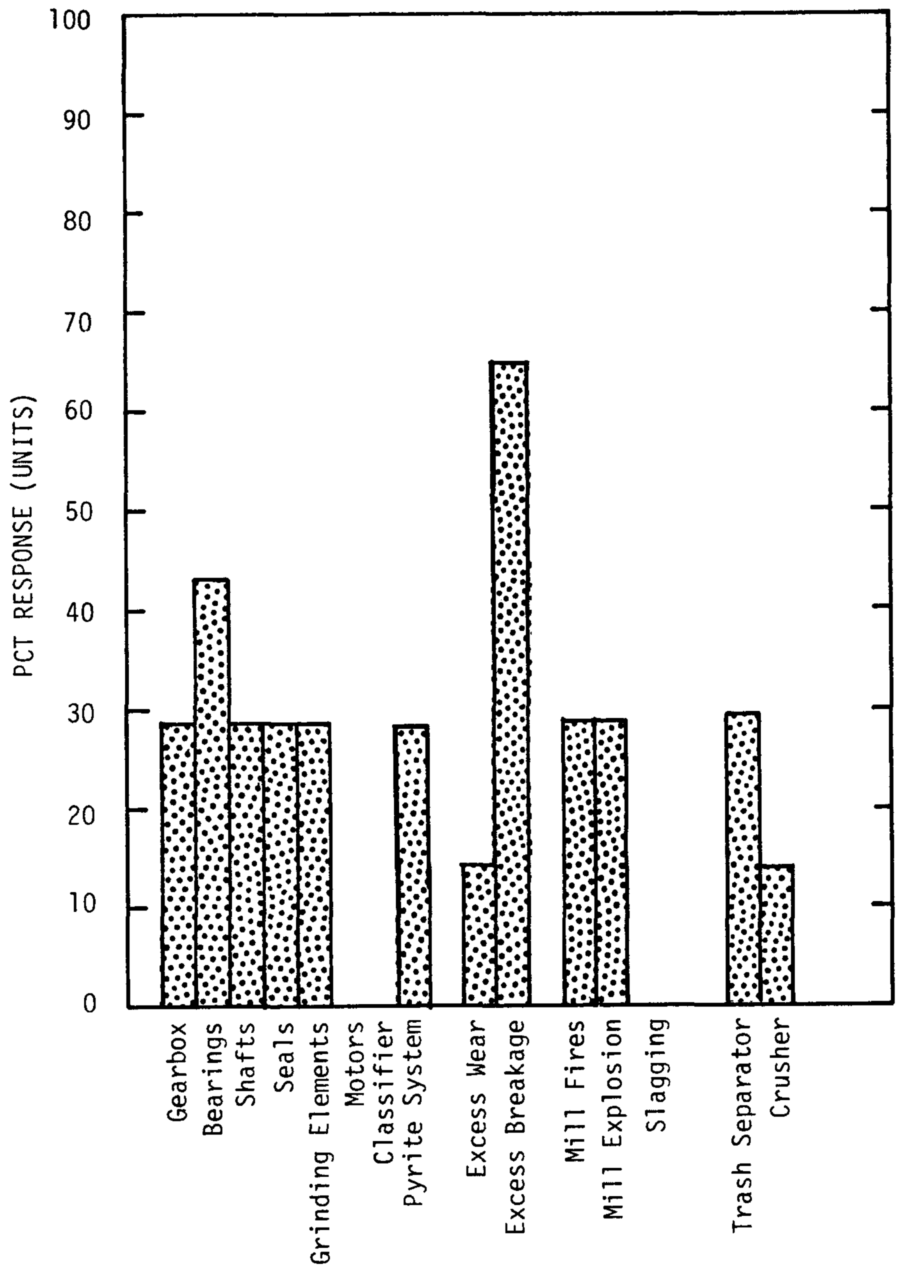

Figure 4-4. Suction Bowl Mills--Problem Areas.

TABLE 4-2

BOWL MILLS-DRIVE COMPONENT PROBLEM AREAS

Unit	Problem Area: Gearbox	Bearings	Shafts	Seals	Problem Area Specifics/Causes	Modification	Successful
					PRESSURIZED		
ID 1/A,B	X	X	X	X	Contaminated oil--seals	Testing oil--ongoing	--
ID 2/A,B	X	X	X	X	Contaminated oil; burned seals main drive bearing failure	Internal lube system New seal material to be tried	--
ID 3/A				X	Blowby past oil seals-not serious		--
ID 4/A,B,C	X	X	X		Too great a startup torque--gear teeth breakage	Larger, stronger gears	Yes
ID 5/A,B ID 5/C,D	X		X X		Vertical shaft breaks due to incorrect spring compression	Reduced spring compression; springs checked every 90 days	Yes
ID 7/A		X	X	X	Low seal air--oil contamination	Increase seal air capacity--yet to do	--
					Mechanical seal on pump	Alternate packing material	--
					Shaft breakage (4) due to high spring compression and locking nut not holding	Journal spring compression reduced from 20 to 15 tons and strap welded nut	Yes
ID 8/A	X				Absence of oil spray lubrication --oil bath	Gears renewed	--
ID 10/A				X	Not reported	Not reported	
ID 12/A		X	X	X	Vertical shaft breaks-improper roll setting; worm shaft breaks-bad bearings, seals	Reset spring compression. New bearings	Yes
ID 13/A		X	X	X	Shaft locking nut not holding	Not reported	
					PRESSURIZED/SUCTION		
ID 15/A,B	X	X	X		Shaft breakage-roll settings misoriented	Reset rolls	Yes
					Oil contamination	Not reported	
ID 16/A,B	X	X	X	X	Maintenance practice part of problem	Improving maintenance	
ID 17/A,B	X	X	X	X	Oil contamination	Filtering oil with external filter preventative maintenance	Yes
ID 12/B,C	X	X	X	X	Vertical shaft breaks--improper roll adj Worm shaft breaks--bad bearings, seals	Reset spring compression New bearings	Yes
ID 18/A			X		Undersized shaft	Larger Diameter Shafts	Yes
					SUCTION		
ID 10/B		X			Bearings too small	Larger bearings	Yes

The lubrication system is another root cause of problems encountered with the drive mechanism. The lubrication problems have been associated more with mill bearings and the gearbox than the roller journal assembly. Oil contamination has occurred from either oil seal or air seal failure. If proper air seal pressure is not maintained or not available, coal dust will contaminate oil in the main drive shaft area. Oil seals may be lost due to high mill temperatures, especially from mill fires. At Plant ID 2 A,B one vertical shaft failure had resulted from an oil seal failure and subsequent main drive bearing failure.

Pulverizer outages associated with the lube oil system may be avoided by performing a periodic oil analysis. At Plant ID 10 A, an oil analysis has been conducted every two months and these analyses have predicted two potential pulverizer failures. This preventative maintenance measure, as suggested by the manufacturer, may help avoid some drive mechanism difficulties.

Filtration systems have also been employed to limit the impact of oil contamination on the drive components. An external filter has been installed on the mills at Plant ID 17 A,B for this purpose. A centrifuge to separate the dirt, grit and foreign material from the oil will be tried with the lube oil pump at Plant ID 2.

Grinding Zone

Table 4-3 presents those stations experiencing grinding element problems and the work that has been done to increase the life of the elements. Excessive wear in the grinding area can lead to reduced capacity and increased spillage. The manufacturer specifies that a roll having 1 1/4 inch wear off the radius is worn and should be replaced, and that the grinding ring segments with one inch worn off the surface should be replaced.

Most of the wear problems were associated with the grinding ring and rolls and separator body liners. Hard surfacing the rolls is a common practice to increase life. Several stations have rolls hardened on-site or hardened by an independent vendor due to economics, delivery, and longer life. The manufacturer does have a hard surfaced roll available to the utilities. A NiHard surface is typically used by the utilities to increase roll life. One plant is trying a set of 20% chrome surfaced rolls from an independent vendor for increased roll life.

Table 4-3

Bowl Mills--Grinding Zone Problem Areas

Plant/Unit	Component	Reason for Wear	Modification	Successful
		PRESSURIZED		
ID1/A,B	Separator body	Inadequate size	Trying larger separator body	--
ID2/A,B	Rolls, liners	Low grind, high moisture western coal (HgI ∿ 34; 25% moisture; silica/alumina=2.3	Trying 20% chrome surface on rolls	--
ID3/A,B	Liners	Western coal (silica/alumina=2.3)		
ID5/C,D	Grinding elements	Grinding material	Have hard faced rolls	Yes
ID10/A	Grinding elements	Indiana coal HgI ∿ 38; 7.0% moisture	Resurfacing rolls	Yes
ID11	Rolls, liners	Kentucky coal HgI ∿ 45; 5.0% moisture (low grind)	Hardened surface being tried	Yes
ID13	Rolls	Illinois coal (HgI unavailable; 14% moisture)	Not Reported	
		PRESSURIZED/SUCTION		
ID16/A,B	Rolls	Grinding material	Hardened surface being tried	--
ID17/A,B	Rolls	Grinding material	Hardened surface helped	--
		SUCTION		
ID19/A,B	Grinding elements	Grinding material	Not Reported	

As expected, grinding elements were a problem area where western subbituminous coal was used. The low grindability, high moisture properties of some western coals are expected to limit the wear cycle of the rolls, rings, etc. Maintenance work has to be scheduled at 100,000 tons coal throughput to patch and replace separator body liners at Plants ID 2 and 3 and at 200,000 tons at Plant ID 1. Worn separator body liners will allow hot air to mix with fines, leading to mill fires. Roll life varied in the survey from 200,000 tons throughput (western coal, no resurfacing) up to 700,000 tons throughput (Indiana coal, resurfacing).

If excess grinding wear is experienced, coal fineness records should be checked to make sure that excess fineness is not occurring. Low primary air flow will also accelerate grinding element wear.

Air System

Table 4-4 presents data from those stations experiencing problems with the circulating, classifying and transporting of the coal/air mixture. The classifier system would be expected to be a high wear item due to the abrasive nature of the coal/air mixture in the cyclonic flow patterns created by the externally adjusted classifier vanes. Of the mills investigated, classifier vane and cone wear was a problem area with those mills utilizing the western coal. Classifier patching is a frequent maintenance item at Plant ID 3 due to the Montana Colstrip coal used. Ceramic lining on the cones and a change in cone design have been tried but have been ineffective solutions. Plant ID 2 tried angle iron bars to reduce cone wear by deflecting the flow away from the cone surface but mill capacity was reduced substantially. Subsequently, the angle iron bars were removed in favor of increased mill capacity. Ceramic lined cones have been recently installed at Plant ID 2.

Wear problems were reported with the butterfly valves (discharge gates) at the multiport outlet. This problem has been evident with both the western and eastern coals. The coal/air mixture wears the valve. When the worn valve is closed to shut off any backflow to the mill from the burners, the seal is ineffective.

Table 4-4

Bowl Mills--Air System

Plant/Unit	Component	Problem Area Specifics/Causes	Modification	Successful
		PRESSURIZED		
ID2/A,B	Cones, discharge valve	Abrasive coal/air mixture (western coal)	Contoured air inlet vane opening covers Ceramic liners	See Text
ID3/A	Cones, discharge piping	Abrasive coal/air mixture (western coal)	Deflector bars in cone helped Ceramic liners, changed cone design, altered air flow patterns	Yes No
ID5/C,D	Cones	Coal/air mixture	Not reported	--
ID7	Discharge valve and piping	Coal/air mixture	Not reported	--
ID8	Multiport outlet	Coal/air mixture	Not reported	--
ID9	Multiport outlet	Coal/air mixture	Resin material applied at outlet	Yes
ID11	Classifier wear	Coal/air mixture	Reset classifier	Yes
ID13	Discharge valve	Coal/air mixture	Not reported	--
		PRESSURIZED/SUCTION		
ID15/A,B	Exhauster blades	Coal/air mixture	Install longer blades	Yes
ID16/A,B	Classifier vanes	Coal/air mixture	Reset vanes	Yes
ID17/A,B	Discharge piping	Pyrites buildup on exhauster inlet	Install deflectors and fenders to prevent buildup	Yes
ID18/A	Exhauster blades, liners	Abrasive coal/air mixture	Hardened surface being tried	--
		SUCTION		
ID21	Exhauster blades	Abrasive coal/air mixture	Hardened surface	No
ID22	Exhauster blades	Abrasive coal/air mixture	Hardened surface	No

Burnerline pluggage was also mentioned as a problem area. This would result from inadequately pulverized coal or low coal/air velocities. Coal transport line pluggage at Plant ID 2 was reduced with improved coal fineness.

The pressurized-suction and suction mills have an exhauster at the mill outlet and these exhausters wear rapidly due to the abrasiveness of the coal/air mixture. At Plant ID 20 A,B, the fan wheels are replaced after every 80,000 to 120,000 tons of coal because of worn blades while casing liners are replaced after every 240,000 to 260,000 tons of coal. Wear of fan wheel blades causes running unbalance resulting in failures of exhauster pedestals, pedestal bearings and shafts. At Plant ID 10 A, the exhuaster blades are replaced after 225,000 tons. Harder surface blades have been tried with some success. The material used for hard surfacing was not reported.

Mill Fires and Explosions

The manufacturer has noted that mill fires may be caused by the following improper operating conditions:

- Excessive mill temperatures.
- Foreign matter collecting in the inner cone.
- Accumulation of pyrites or coal on mill bottom cover plates or in the hot air inlet to the mill.
- Coal accumulations in areas above the bowl.

While most plants have experienced fires at one time or another, only fifteen units identified fires as a problem area. Table 4-5 presents those stations having both major and minor fire problems and the steps that have been taken to remedy the fires/explosions problem. The fires, in most cases, have been associated with liner wear and coal accumulation. At Plant ID 1, two major mill fires have occurred in a six month time period due to an inadequately sized separator. Excessive wear is experienced with the separator body liners allowing hot air to mix with fine western coal. A larger separator size is being tried to eliminate this problem. At Plant ID 2, the liner cover plates for the separator body liners were removed to eliminate areas of likely coal accumulation. It was found that the separator body bottom liners wore rapidly at the air inlet openings.

Table 4-5

Bowl Mills--Mill Fires and Explosions

Plant/Unit	Location/Causes	Modifications to Reduce Fires	Successful
		PRESSURIZED	
ID1/A,B	Separator liner/small size causes excessive wear-hot air mixes with fine coal	Larger separator liner	--
ID3/B	Primary air inlet, temperature monitor may be problem	Lowered mill outlet temperatures	To be determined
ID7/A	Burner line pluggage-low velocity (primary air limited)	Increased primary air	--
ID11/A	Coal accumulation on flat surfaces ignited	Eliminated flat surfaces	Yes
ID12/A	Coal accumulation on separator body liners.	Liners removed, reduced fire occurrences	Yes
		PRESSURIZED/SUCTION	
ID15/A,B	Coal accumulation on pyrite chamber, low primary air flow	Increased exhauster draft	Yes
ID16/A,B	Accumulation of pyrites and coal in pyrite chamber, maintenance practice	Improved preventive maintenance	Yes
ID18/A	Coal accumulation on separator body liners.	Liners removed, reduced fires	Yes

A new liner cover plate was adapted to eliminate coal accumulation. At Plant ID 12, the separator body liners were removed entirely thus substantially reducing the number of fires. Fires and explosions at Plant ID 18 A,B have also been attributed to the separator body liners.

The introduction of hot primary air into the mill which ignites accumulated coal in the mill has been observed with other mills. This problem of coal accumulation in the pulverizer is called "lay out" and is something all manufacturers try to avoid by designing the mill so that no places exist where coal can accumulate. At Plant ID 11 A, mill fires were ascribed to the presence of flat surfaces in the bowl area where coal lay out occurred. The flat surfaces have been modified causing a noticeable reduction in the number of fires. At Plant ID 3 B, five mill fires have occurred on one mill alone in the span of about one year. A faulty temperature monitor has been associated with the fire problem. The problem may also have been associated with the hot primary air igniting the coal which has accumulated. The manufacturer is making modifications on the separator body liner to reduce the number of air pockets where accumulations and hot spots occur.

Some fires have occurred at the exhauster inlet duct due to pyrite buildup. Deflectors and fenders to prevent buildup have been tried at Plant ID 16 A,B. Longer exhauster blades were installed at Plant ID 15 A,B to reduce wear.

Localized hot spots which develop due to poor primary air distribution also increase the mill's susceptibility to fires. Low primary air has been associated with several mill fires.

Boiler Problems Associated With the Pulverizer

The only boiler problem associated with pulverizers was slagging. Of the three plants that did report a slagging problem, two burn western coal. Slagging potential has been documented as being a more severe problem with a western subbituminous coal than an eastern bituminous coal. Ash constituents (base/acid ratio and sulfur content), ash fusion temperature, and ash viscosity are important fuel properties used to predict slagging potential (7).

While ash characteristics are important for predicting slag potential, oversized coal particles leaving the classifier are associated with the slagging problems at Plants ID 2 and ID 3. Longer burnout due to larger size particles may create locally reducing atmospheres which will affect the ash fusion temperature and viscosity of the ash.

Coal fineness at Plant ID 2 is monitored at each mill every two weeks to help maintain proper coal size. One modification made at the plant was to elongate the inlet air openings to the journal opening centerlines. The purpose of this modification was to relieve the classifier load by promoting preliminary segregation in the grinding area. These air inlet vane covers improved fineness. However, extreme wear of the external cone and body liners results from this modification. These covers were eventually removed.

Classifier vanes have been adjusted to minimize the carryover of coarse coal at Plant ID 3. Even with the improved grind, slagging still is a problem.

Section 5

ROLL-RACE MILLS

Roll-race mills have been on-line in large U.S. coal-fired utility boilers since 1972. These mills have essentially replaced the ball-race mills, discussed in Section 7.

MILL CONFIGURATION AND OPERATION

A roll-race pulverizer (Figure 5-1) consists of a segmented rotating grinding table, three pivotally supported roll wheel assemblies, automatically controlled feeder, classifier, and a main drive. Coal is fed through a feed spout and drops between the rolls and onto the grinding table. The pulverized coal is separated by the classifier, returning oversized coal to the grinding zone while the properly sized coal is transported to the burners. Heavy foreign material falls through the throat into the pyrites box. The roll-race mill, similar to the bowl mill, operates under positive air pressure. The primary air enters through the pulverizer throat to produce centrifugal turbulence which prevents coal from falling through the throat and into the pyrites hopper.

A major difference between the bowl mill and roll-race mill is the roll mounting and its shape. Three pivotally supported, spring loaded rolls are mounted with roller bearings on shafts rigidly fixed in brackets. The pivoted system allows the rolls to "step" on the irregularities in the grinding zone thus avoiding the mill skid problem that occurs with the planetizing roller mills. Brackets are attached to the pressure frame allowing the three rolls to follow the ring. The spring adjustment on the tires is done externally via a hydraulic tension cyliner.

DATA BASE

A data base of 58 roll-race mills was established. Table 5-1 presents a list of the plants, startup dates, number of mills, problem areas, coal properties and maintenance data. From the data base of seven units and 58 roll-race mills, two plants with the roll-race mills were selected for field visits. The case studies for these two sites (Plant ID 23 A and Plant ID 25) are included in Appendices E and F respectively.

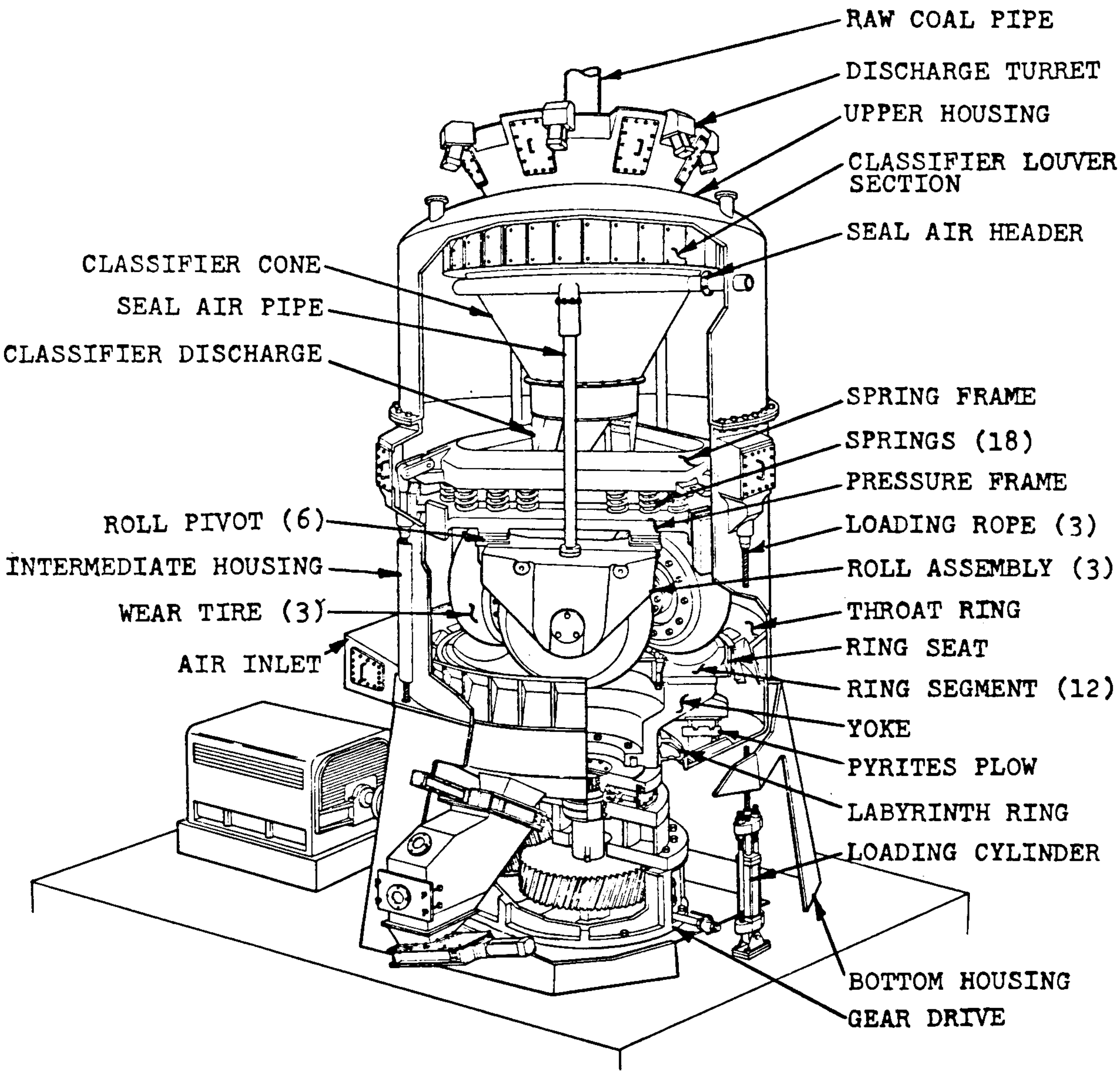

Figure 5-1. Roll-Race Mill (Part Location Drawing)

Source: Manufacturer's Operation Manual

Table 5-1. Roll-Race Mills

Plant	Unit	Startup Date	Nom. Capacity (MWe)	#Mills/each Unit	#Mills @ full load	Pulverizer Size (tons/hr)	Gearbox	Bearings	Shafts	Seals	Grinding Elements	Motors	Classifier	Pyrite System	Excessive Wear	Excessive Break	Mill Fires	Mill Explosions	Slagging	Trash Separators	Crushers	Coal Type[1]	Heating Valve (BTU/lb)	Hgl	%Moisture	%Ash	% Sulfur	Abrasiveness (silica/alumina)	Scheduled Maintenance Tonnage Throughput(x1000)	Major Overhaul Tonnage Throughput (x1000)	¢/Ton Coal Ground
							Problem Areas																Typical Coal Properties						Maintenance Data[2]		
Table 5-1. Roll-Race Mills																															
ID 23	A	5/77	650	7	6	62				x												W-Wyo.	8.25	61	30	5.8	0.3				
ID 24	A,B	8/74,12/75	1140	10	8	62				x	x						x			x		E-Ky.	11850	34-60	7	13.5	1.1	1.5-1.9			
ID 25	A,B	3/73,11/73	1300	11	11	62								x	x		x	x	x	x	x	E-Ky.	10550	57	10.1	16.3	3.5	2.9	135	1000	34
ID 26	A	12/75	350	4	4	62	x										x	x				W-Wyo.	8250	55	29.0	5.2	0.3				
ID 27	A	6/78	450	5		62																E-Ky.	13000		5.5	6-7	0.7				
Planetizing Roll Mills																															
ID 28	A,B,C	3/76,3/75,2/78	650	6	6	50	x				x		x		x	x			x	x		E-Ill.	11700	63	12.4	6.5	1.5	2.5	525		23
ID 29	A,B	7/69,12/69	660	6	5	50	x	x			x		x									E-Pa.	11500	80	2.8	25.0			500		45
ID 30	A	5/70	325	4	4	38	x	x	x	x	x		x		x	x						E-	11777	50	7.5	11.6	2.5				
	B	8/73	500	6	6	45	x	x	x	x	x				x	x						E-	11777	50	7.5	11.6	2.5				
ID 31	A	12/70	500	6	6	38	x	x	x	x	x				x	x	x					E-Inc.	12000	55	5.5	8.5	3.7				
ID 32	A	5/73	500	6	4	39	x	x	x	x	x	x			x	x						E-Ky.	12000	55	8.5	8.5	3.7				67.5
Ball-Race Mills																															
ID 33	A,B	7/69,7/70	795	9	8	48	x	x		x		x			x				x			W-	8800		10.5	22.2	0.6				54
ID 34	A,B,C	6/71,5/73,5/74	750	7		50	x	x		x									x			E-W.V.	12690	60	4.0	11.0	2.8	2.3			
	D	3/73	730	7		50	x	x		x									x			E-W.V.	12690	60	4.0	11.0	2.8	2.3			
ID 35	A	'65	500	10	10	21				x	x				x							E-Ky.	11200	50	7.7	15.0	4.0				85.4
Ball/Tube Mills																															
ID 36	A,B,C	12/72,10/73, 11/74	640	6	6	55		x	x	x					x	x	x	x	x			E-		50							
ID 37	A	'65	250	3	3			x		x												E-									
ID 33	C	'64	225	3	3	40	x											x	x			W-	8800		10.5	22.2	0.6				
ID 32	B	7/68	250	3	3	32	x	x		x	x	x	x		x	x						E-Ky.	12000	55	8.5	8.5	3.9				

1) Coal Type
W-Western Coal
E-Eastern Coal

2) Maintenance
a) Scheduled maintenance will include work where applicable on replacing exhauster blades, resurfacing rolls, replacing separate body liners, etc.
b) Major overhauls will include work where applicable on replacing grinding ring segments and rolls, liners, cones, discharge valves, etc.

3) Deep bowl mills

PROBLEM AREAS/CAUSES/MODIFICATIONS

Figure 5-2 presents graphically those stations reporting problems with drive components, grinding zone, air system, fires and explosions, and any boiler problems related to the mills.

Drive Components

Table 5-2 presents problem areas associated with the drive components. Only two plants reported drive mechanism difficulties. Plant ID 26 A reported thrust bearing wear in the gearbox which was subsequently eliminated by some manufacturer modifications. At Plant ID 23 A an oil leakage problem between the initial and secondary gear reduction junction was curbed by altering the lube oil pattern. The problem was not an outage producing problem, but just a nuisance. Other than that, the utilities participating in the study felt that the bearings and shafts were not problem areas. No excessive wear or breakage problems with the drive components have been reported. These mills, however, have not accumulated the large number of service hours that some of the other designs have.

Grinding Zone

Table 5-3 presents problem areas associated with the grinding elements. The only problem has been the cracking of rolls. The manufacturer tried a different roll material; however, the rolls have not been on line a sufficient time to make a proper evaluation. These mills with the roll cracking problem were some of the earlier mills of this design. Roll cracking has not occurred on newer mills at other stations.

The long grinding life of the roll-race tires is attributed to the volume of wear metal (Elverite) used with the roll-race tires and the ability to reverse the tires. Wear life of the rolls is projected to be approximately one million tons or more at Plant ID 25. The rolls were expected to grind about 850,000 tons of coal but the wear rate has actually decreased with use. This decrease in wear is due to the flattening of the roll wear contour.

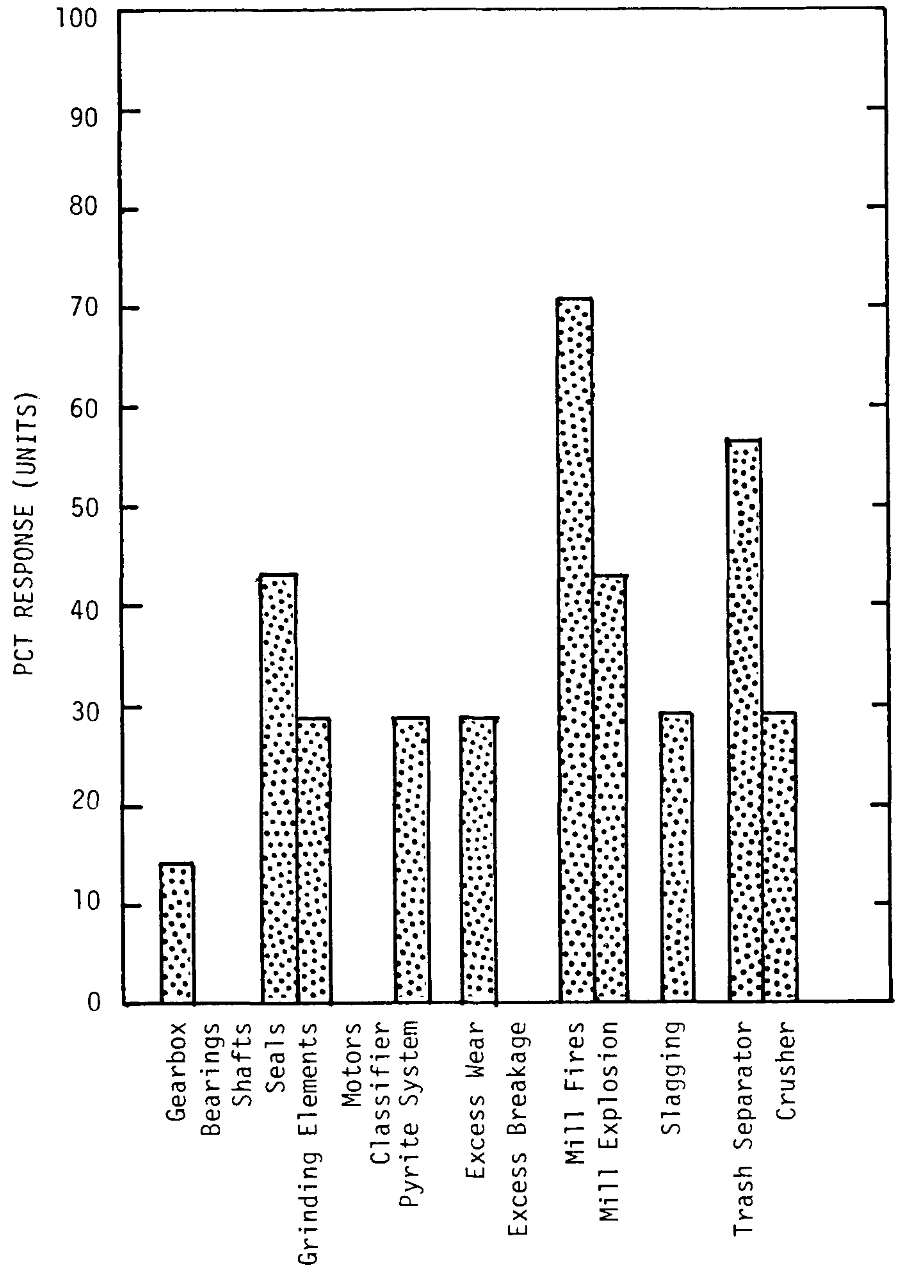

Figure 5-2. Roll-Race Mills-Problem Areas

Table 5-2

Roll-Race Mill--Drive Component Problem Areas

	Problem Areas						
Plant/Unit	Gearbox	Bearings	Shafts	Seals	Problem Area Specifics/Causes	Modification	Successful
ID23/A				X	Oil leakage between initial and secondary gear reduction junction	Lube spray pattern	Yes
ID26/A	X				O-ring problems in two gear-boxes. Lost some thrust bearings	Specifics unavailable	Yes

Table 5-3

Roll-Race Mill--Grinding Zone Problem Areas

Plant/Unit	Component	Problem Area Specifics/Causes	Modification	Successful
ID24/A,B	Rolls	Cracking	Manufacturer changed tires to different material	--

Air System

Table 5-4 presents data from those stations experiencing problems with the circulating, classifying and transporting of the coal/air mixture. Wear problems associated with the coal have been documented for Plant ID 25. Specifically, the pulverizer housing, throat inserts, slope plates, classifier and swing valves have all been subject to erosion resulting from the abrasive action of the coal used at the plant. In order to reduce the rate of system failures for the mills due to wear, the following specific modifications have been implemented at this plant.

Pulverizer Housing. Originally, the manufacturer had partially lined the housing with ceramic, but additional sections of the housing were sustaining high wear. Ceramic housing liners have now been added to the pulverizer housing to prevent erosion. Ceramic lining adhesive in the grinding zone had failed, especially after exposure to high temperatures as a result of mill fires. This ceramic lining is now welded and glued on.

Throat Inserts. Throat inserts are welded to the top and front edges of the air inlet vanes to prevent wear. Throat insert erosion has been a nagging problem. The throat air inlet vane area, like the classifier blades, is subject to high erosion rates. The pipe insert type throat, a manufacturer fix to create radial flow, lasted about 135,000 tons before being pad welded and then lasted an additional 63,000 tons. Hard surfacing of the pipe inserts increased the wear life up to 365,000 tons. The manufacturer has now designed flat throats for better air distribution which reduces throat erosion at the pipe insert. Also, turning vanes have been installed in the primary air duct for better air distribution into the pulverizer windbox.

Slope Plates. Slope plates have been the greatest source of wear on these mills. The plates were redesigned to reduce surface area and their angle in relationship to coal flow. Ceramic brick has been tried as well as chromium carbide overlay (Tapco plate). Foreign objects such as tramp iron tend to break out the ceramic.

Table 5-4

Roll-Race Mills--Air System Problem Areas

Plant/Unit	Component	Problem Area Specifics/Causes	Modification	Successful
ID23/A	Throat liners	Coal/air mixing	Fabricated steel to be tried	--
	Seals	Air leakage around yoke area	New packing material to be tried	--
ID25/A,B	Pulverizer housing	Coal type--Kentucky coal (16.3% ash, 3.5% sulfur, silica/alumina abrasiveness equals 2.9)	Ceramic lining added	See text
	Throat inserts		Different throat designs	
	Slope plates		Redesigned; chromium carbide overlay	
	Classifier		Ceramic brick	
	Swing valves		Modified valve seat and plate	
	Burner piping		Ceramic lined piping	
	Pyrite plows	Spring failure due to metal fatigue	Heavier springs	Yes

Table 5-5

Roll-Race Mills--Mill Fires and Explosions

Plant/Unit	Location/Causes	Modifications to Reduce Fires	Successful
ID24/A,B	Bowl area	Operational change--lowered mill outlet temperature 10 °F	Yet to be determined
ID25/A,B	Pyrite plow breakage	Replaced deficient springs on plows	Yes

The chromium carbide is very wear resistant, and based on material cost and outage time, chromium carbide material is more economic than ceramic or conventional plate material.

Classifier. Problems with the classifier have included erosion in the classifier skirt and over the top of the classifier blades, leading to decreased fineness. A solution was to cover the classifier skirt surface with ceramic brick and to weld a 1/4" x 2" x 2" angle in the top of the classifier against each blade to prevent cross flow of coal eroding the skirt. The classifier blades had been extended to 19" to improve the percent fineness through 200 mesh. The extension of classifier blades was also made at Plant ID 23 A.

Swing Valves. Swing valves were a source of erosion wear at Plant ID 25 A,B. The situation is dangerous with respect to mill fires and explosions because if the valves begin to leak, furnace pressure can cause a flash back if primary air pressure is lost on any pulverizer. Wear resistant valve seats and plates have been installed on the mills. The success of these modified valve seats and plates cannot be documented at this time. The danger of swing valve erosion and flashback is a serious problem with pressurized furnaces, not with the balanced draft furnaces.

Some difficulties have been reported with the pyrite plows and pyrite chamber at Plant ID 25 A,B, and Plant ID 23 A. The pyrite plow is attached to the yoke to sweep pyrites and other reject material to the pyrite hopper. Brackets are bolted to the plow to support the yoke. The original design called for counterweighted plows but these plans were ineffective. These counterweighted plows were changed out in Plant ID 23 A after approximately six months service. The spring loaded plows now in use have been more successful; however, spring failure due to metal fatigue did occur twice at Plant ID 25. Heavier springs were then installed with no further difficulties. The replacement and repair of pyrite plows and pyrite gates had at one time required most of the unscheduled maintenance for Plant ID 25.

Mill Fires and Explosions

Fires have been reported with some of the mills in the data base. This information is summarized in Table 5-5. Pyrite plows have been a major source of fires at Plant ID 25. Since plow failures have decreased with replacement of the deficient springs, the fire frequency has decreased dramatically. A plow failure in the pyrite chamber could result in an accumulation of coal dust or heavy foreign matter (i.e., tramp iron) in a crevice, dead space, etc. Mill fires have occurred in the bowl area at Plant ID 24. The mill outlet temperature was lowered 10°F (160°F to 150°F) to reduce the fire frequency. While no fires have occurred since that operational change, there is some question about the effect of this modification on fires.

Boiler Problems Associated With the Pulverizer

Carbon loss has been attributed to the pulverizers at Plant ID 24 and slagging has been attributed partially to the pulverizers at Plant ID 25. While the coal fineness has been approximately 68% through 200 mesh at Plant ID 24, carbon loss persisted. Burner impeller checks are a frequent preventative maintenance check on the plant to insure that high wear has not resulted in a flame with poor combustion characteristics and superheater fouling potenial. It is difficult to say whether the excessive carbon carryover is the result of a high percentage of coal retained on the 50 mesh, worn burner impellers, or the swelling characteristics of this particular eastern coal. Further investigation of the problem would be needed to determine whether the root cause is associated with the mill or burner.

The slagging problem at Plant ID 25 is the result of several factors including burner arrangement and insufficient combustion air. Due to the burner arrangement, a firing imbalance results when certain mills are taken off line.

Section 6

PLANETIZING ROLL MILLS

The planetizing roll mill has been a mill beset by several problems during its history. Although the mill is no longer being offered for sale, the problems encountered with the mills have been documented along with modifications made to improve performance.

MILL CONFIGURATION AND OPERATION

A planetizing roll (roll-table) mill (Figure 6-1) consists primarily of a segmented rotating grinding table, three equally-spaced hollow toroidal spring loaded rolls, automatically controlled feeder, classifier, and a main drive. As in the bowl mill and roll-race mill, coal is fed through the feed inlet between the grinding rollers and grinding ring. A classifier retains oversized coal in the grinding zone while sending the finer coal to the burner. A major distinction which can be made between this and the other roller mills is the method by which the force is applied to the grinding rollers. That force is applied by a uniformly loaded thrust ring fitting smoothly into each roll neck. Rolls not only revolve about their own axes, but also rotate about the mill axis, distinguishing them from the bowl mill and other roller mills. The planetizing roller mills also operate under pressure. The pressurized primary air is distributed under the table and directed through the air ports. Mixing of the coal and air is promoted by the design of the air port ring which creates circumferential mixing.

DATA BASE

A data base of 52 planetizing roll mills was established. Table 6-1 presents a list of the plants, startup dates, nominal capacity, number of mills, problem areas, coal properties and maintenance.

From the data base of nine units and 52 planetizing roll mills, two plants with the planetizing roll mills were selected for field visits. The case studies for these two sites (Plant ID 30 A,B and Plant ID 31 A) are included in Appendixes G and H respectively.

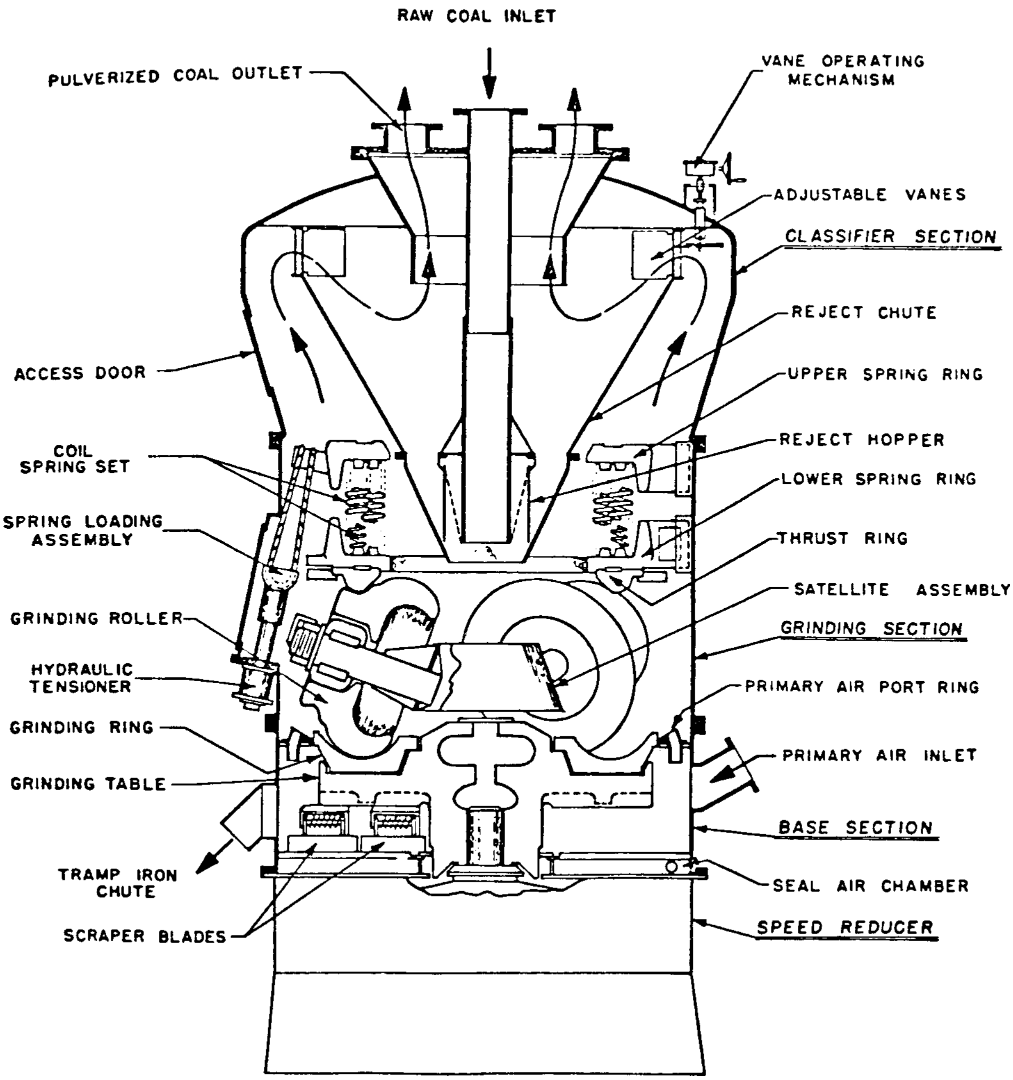

Figure 6-1. Planetizing Roll (Part Location Drawing)

Source: Manufacturer's Operational Manual

Table 6-1. Planetizing Roll Mills

Plant	Unit	Startup Date	Nom. Capacity (MWe)	#Mills/each Unit	#Mills @ full load	Pulverizer Size (tons/hr)	Gearbox	Bearings	Shafts	Seals	Grinding Elements	Motors	Classifier	Pyrite System	Excessive Wear	Excessive Break	Mill Fires	Mill Explosions	Slagging	Trash Separators	Crushers	Coal Type[1]	Heating Value (BTU/lb)	Hgi	%Moisture	%Ash	% Sulfur	Abrasiveness (silica/alumina)	Scheduled Maintenance Tonnage Throughput (x1000)	Major Overhaul Tonnage Throughput (x1000)	¢/Ton Coal Ground
							Problem Areas															Typical Coal Properties							Maintenance Data[2]		
Roll-Race Mills																															
ID 23	A	5/77	650	7	6	62				x												W-Wyo.	8.25	61	30	5.8	0.3				
ID 24	A,B	8/74,12/75	1140	10	8	62				x	x						x			x		E-Ky.	11850	34-60	7	13.5	1.1	1.5-1.9			
ID 25	A,B	3/73,11/73	1300	11	11	62								x	x		x	x	x	x	x	E-Ky.	10550	57	10.1	16.3	3.5	2.9	135	1000	34
ID 26	A	12/75	350	4	4	62	x										x	x				W-Wyo.	8250	55	29.0	5.2	0.3				
ID 27	A	6/78	450	5		62																E-Ky.	13000		5.5	6-7	0.7				
Table 6-1. Planetizing Roll Mills																															
ID 28	A,B,C	3/76,3/75,2/78	650	6	6	50	x				x		x		x	x			x	x		E-Ill.	11700	63	12.4	6.5	1.5	2.5	525		23
ID 29	A,B	7/69,12/69	660	6	5	50	x	x			x		x									E-Pa.	11500	80	2.8	25.0			500		45
ID 30	A	5/70	325	4	4	38	x	x	x	x	x		x		x	x						E-	11777	50	7.5	11.6	2.5				
	B	8/73	500	6	6	45	x	x	x	x	x				x	x						E-	11777	50	7.5	11.6	2.5				
ID 31	A	12/70	500	6	6	38	x	x	x	x	x				x	x	x					E-Inc.	12000	55	5.5	8.5	3.7				
ID 32	A	5/73	500	6	4	39	x	x	x	x	x	x			x	x						E-Ky.	12000	55	8.5	8.5	3.7				67.5
Ball-Race Mills																															
ID 33	A,B	7/69,7/70	795	9	8	48	x	x		x		x			x				x			W-	8800		10.5	22.2	0.6				54
ID 34	A,B,C	6/71,5/73,5/74	750	7		50	x	x		x									x			E-W.V.	12690	60	4.0	11.0	2.8	2.3			
	D	3/73	730	7		50	x	x		x									x			E-W.V.	12690	60	4.0	11.0	2.8	2.3			
ID 35	A	'65	500	10	10	21				x	x				x							E-Ky.	11200	50	7.7	15.0	4.0				85.4
Ball/Tube Mills																															
ID 36	A,B,C	12/72,10/73, 11/74	640	6	6	55		x	x	x					x	x	x	x	x			E-		50							
ID 37	A	'65	250	3	3			x		x												E-									
ID 33	C	'64	225	3	3	40	x											x	x			W-	8800		10.5	22.2	0.6				
ID 32	B	7/68	250	3	3	32	x	x		x	x	x	x		x	x						E-Ky.	12000	55	8.5	8.5	3.9				

1) Coal Type
W-Western Coal
E-Eastern Coal

2) Maintenance
a) Scheduled maintenance will include work where applicable on replacing exhauster blades, resurfacing rolls, replacing separate body liners, etc.
b) Major overhauls will include work where applicable on replacing grinding ring segments and rolls, liners, cones, discharge valves, etc.

3) Deep bowl mills

PROBLEM AREAS/CAUSES/MODIFICATIONS

Figure 6-2 presents graphically those units having problems with drive components, grinding zone, air system, fires and explosions, and any boiler problems related to the mills.

The reports on the planetizing roll mills from the participating utilities indicate that this mill configuration has severe problems with its drive components, grinding system and air system. The discussion of these problem areas follows.

Drive Components

Table 6-2 presents problem areas associated with the drive components. Utilities reported that the drive mechanism of the planetizing roll was subject to considerable problems. All of the plants but one use an integral gearbox. Excessive wear was reported in the integral gearbox at three of the stations while excessive breakage of the bearing drive worm shaft was reported for three stations as well. At Plant ID 29 A,B, the gearing and bearings were undersized for the design mill capacity. The station is now looking to an independent engineering firm to increase the size of the bearings and shafts.

The manufacturer had designed a self-contained gearbox for the newer roll table mills (Series C) which is removable for maintenance and repair. A number of mills with this modified gearbox have been on line at Plant ID 28 C for about a year and a half without problems.

Grinding Zone

Table 6-3 presents problem areas associated with the grinding zone. Thrust ring failure has been a recurrent problem with nearly all mills in the survey. Thrust ring replacement has been as frequent as once every month for three consecutive months at one plant. The frequency of such failures has spurred work to improve thrust ring lifetime. At one plant, a high carbon steel is being tried as the thrust ring material rather than the normal NiHard material. The material is expected to wear faster than the NiHard, but the carbon steel tensile properties should enable it to eliminate the thrust ring cracking problem. At Plant ID 29 A,B, the NiHard thrust ring material has been changed and this has seemed to solve the breakage problem. Information concerning the thrust ring material at this plant was not reported.

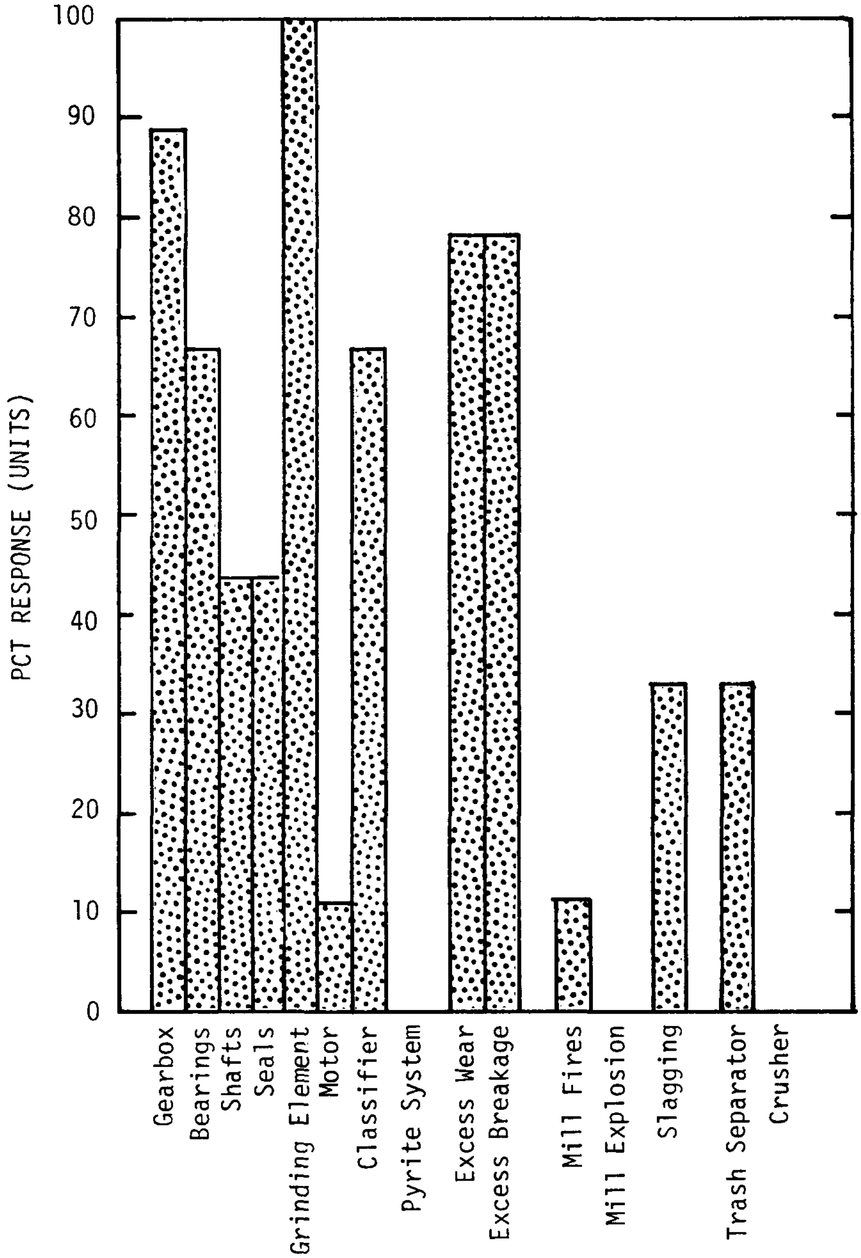

Figure 6-2. Planetizing Roll Mills--Problem Areas.

Table 6-2

Planetizing Roll Mill--Drive Component Problem Areas

Plant/Unit	Problem Area: Gearbox	Bearings	Shafts	Seals	Problem Area Specifics/Causes	Modification	Successful
ID28 A,B	X		X		Oil contamination in gearbox due to cooler supply; intermediate pinion shaft breaking	Not reported	
ID29 A,B	X	X			Failures due to undersized system	Converting to larger gearing system	
ID30 A,B	X	X	X	X	Insufficient seal air leading to lube oil contamination	Extra large lube oil filters placed on speed reducer	Yes
					Premature gearbox failure		
					Bearings badly pitted and galled (thrust, radial, worm shaft). Severe wear and cracking--bull gear shaft.	See text	
					Worm shaft seals badly worn. Low speed shaft breakage	Design change made	Yes
ID31 A	X	X	X	X	Oil contamination--worm gears pitted and galled	Trying new synthetic oil	
ID32 A	X	X	X	X	Not reported	Not reported	

Table 6-3

Planetizing Roll Mill--Grinding Zone Problem Areas

Plant/Unit	Component	Problem Area	Modification	Successful
ID28 A,B	Rolls	Chipping	Manufacturer rolls tried	No
	Thrust ring	Breakage	New material being tried	--
ID29 A,B	Spacer assembly	Wear	NiHard surface; smaller donut	Yes
	Thrust ring	Wear	Harder material	Yes
ID30 A,B	Thrust ring	Breakage	Trying a high carbon steel material	--
ID31 A	Thrust ring	Breakage	Not reported	--
ID32 A	Unavailable	Not reported	Not reported	--

Table 6-4

Planetizing Roll Mill--Air System Problem Areas

Plant/Unit	Component	Problem Area	Modification	Successful
ID28 A,B,C	Cone liners	Coal/air mixture	Ceramic lining	Yes
	Classifier blades	Coal/air mixture	Patching/replacing blades	--
ID29 A,B	Classifier	Clogged linkages	Converting to external linkage system	--
ID30 B	Classifier	Vane seizing		Yes

Some work has been done in the area of improving the satellite spacer assembly life time. Plant ID 30 A,B has redesigned the assembly with a NiHard surface spherical block to improve wear. Stainless steel spherical wear blocks were replaced by paraboloy blocks on one mill. These blocks operated for three years service with approximately 3/8 inch wear. Some experimentation with NiHard spherical blocks is continuing.

Excessive roll wear has been reported by Plant ID 28. The abnormal wear was due to chipping of the rolls. Normal wear has been experienced on only a few of the rolls. All grinding elements last about 14,000 hours of service (approximately 450,000 tons) on Unit A. Maximum wear on the roll is typically three and one half inches.

Roll skidding in the planetizing roller mills is an inherent design problem, which was evident at several stations. Irregular sized coal fed to the grinding zone as well as debris and foreign material promote the skidding.

<u>Air System</u>

Table 6-4 presents problem areas associated with the air system. The classifier was identified as a problem area at both Plants ID 28 A,B and ID 29 A,B. The difficulty at Plant ID 28 has been rapid wear of the classifier blades. Patching and replacement of the blades are usually necessary at 13 week intervals. At Plant ID 29, the classifier linkages were clogging and thus affected coal fineness. The classifier vanes were modified to facilitate external control, and the trouble was eliminated.

<u>Mill Fires and Explosions</u>

The units with the roll-table mills reported that mill fires and explosions did occur with some frequency but were not considered a major problem area.

<u>Boiler Problems Associated with the Pulverizer</u>

Slagging has been associated with the classifier allowing oversized coal to enter the burner. Excessive wear of the classifier vanes contributed to the poor grind.

Section 7

BALL-RACE MILLS

Another pulverizer mill configuration no longer being built but still presented in this discussion because of the data gathered is the counter rotating ball-race mill. Many of the ball-race mills have been or are being replaced by the roll-race mills. These mills have been plagued by poor reliability.

MILL CONFIGURATION AND OPERATION

The ball-race pulverizer (Figure 7-1) operates on the ball bearing principle. The grinding elements are the balls and races. One race rotates in one direction above the balls while a second ring rotates in the other direction below the balls.

DATA BASE

A data base of 56 ball-race mills was established. Table 7-1 presents a list of the plants, startup dates, nominal capacity, the number of mills, coal type and maintenance data.

PROBLEM AREAS/CAUSES/MODIFICATIONS

Figure 7-2 presents graphically those units having problems with drive components, grinding zone, air system, mill fires and explosions and boiler related problems. The main problem areas of the ball-race mills are those involving the drive components, high wear, and boiler slagging due to poor coal grind. None of the ball-race mills studied has abnormal problems with the air system and fires/explosions. Table 7-2 lists the main problem areas.

Drive Components

Drive component failures have originated primarily with seal failures and/or oil contamination. Dirt in the lubricating oil caused bearing failure. One plant did increase its seal air fan capacity to curtail air seal problems. Bearing and gearbox failures decreased. Although this modification did not completely eliminate these failures, a majority of the problems were solved.

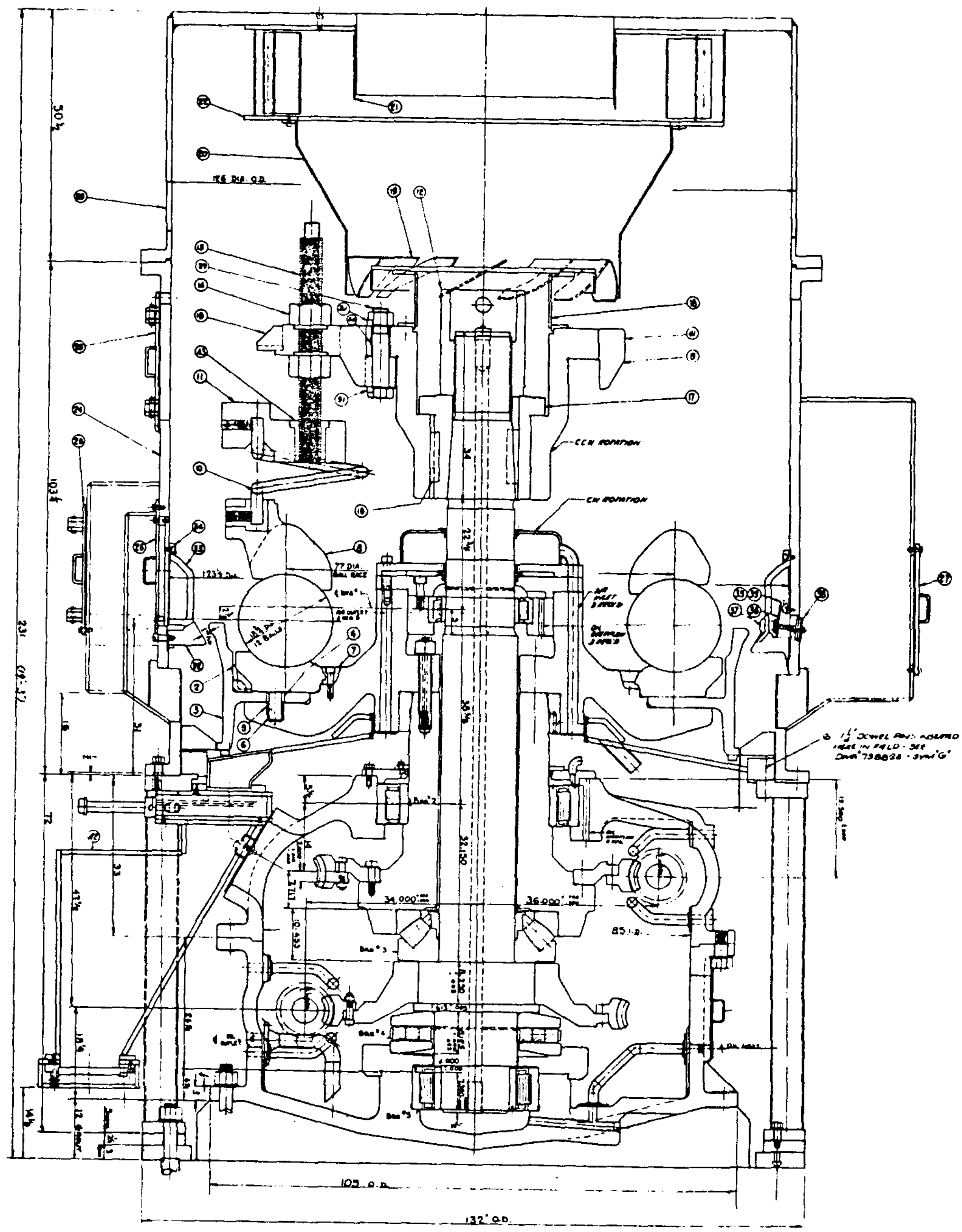

Figure 7-1. Ball-Race Mill (Part Location Drawing)

Table 7-1. Ball-Race Mills

							Problem Areas																Typical Coal Properties						Maintenance Data[2]		
Plant	Unit	Startup Date	Nom. Capacity (MWe)	#Mills/each Unit	#Mills @ full load	Pulverizer Size (tons/hr)	Gearbox	Bearings	Shafts	Seals	Grinding Elements	Motors	Classifier	Pyrite System	Excessive Wear	Excessive Break	Mill Fires	Mill Explosions	Slagging	Trash Separators	Crushers	Coal Type[1]	Heating Value (BTU/lb)	Hgl	%Moisture	%Ash	% Sulfur	Abrasiveness (silica/alumina)	Scheduled Maintenance Tonnage Throughput (x1000)	Major Overhaul Tonnage Throughput (x1000)	¢/Ton Coal Ground
Roll-Race Mills																															
ID 23	A	5/77	650	7	6	62				x												W-Wyo.	8.25	61	30	5.8	0.3				
ID 24	A,B	8/74,12/75	1140	10	8	62				x	x						x			x		E-Ky.	11850	34-60	7	13.5	1.1	1.5-1.9			
ID 25	A,B	3/73,11/73	1300	11	11	62								x	x		x	x	x	x	x	E-Ky.	10550	57	10.1	16.3	3.5	2.9	135	1000	34
ID 26	A	12/75	350	4	4	62	x										x	x				W-Wyo.	8250	55	29.0	5.2	0.3				
ID 27	A	6/78	450	5		62																E-Ky.	13000		5.5	6-7	0.7				
Planetizing Roll Mills																															
ID 28	A,B,C	3/76,3/75,2/78	650	6	6	50	x				x		x		x	x			x	x		E-Ill.	11700	63	12.4	6.5	1.5	2.5	525		23
ID 29	A,B	7/69,12/59	660	6	5	50	x	x			x		x									E-Pa.	11500	80	2.8	25.0			500		45
ID 30	A	5/70	325	4	4	38	x	x	x	x	x		x		x	x						E-	11777	50	7.5	11.6	2.5				
	B	8/73	500	6	6	45	x	x	x	x	x				x	x						E-	11777	50	7.5	11.6	2.5				
ID 31	A	12/70	500	6	6	38	x	x	x	x	x				x	x	x					E-Inc.	12000	55	5.5	8.5	3.7				
ID 32	A	5/73	500	6	4	39	x	x	x	x	x	x			x	x						E-Ky.	12000	55	8.5	8.5	3.7				67.5
Table 7-1. Ball-Race Mills																															
ID 33	A,B	7/69,7/70	795	9	8	48	x	x		x		x			x				x			W-	8800		10.5	22.2	0.6				54
ID 34	A,B,C	6/71,5/73,5/74	750	7		50	x	x		x									x			E-W.V.	12690	60	4.0	11.0	2.8	2.3			
	D	3/73	730	7		50	x	x		x									x			E-W.V.	12690	60	4.0	11.0	2.8	2.3			
ID 35	A	'65	500	10	10	21				x	x				x							E-Ky.	11200	50	7.7	15.0	4.0				85.4
Ball/Tube Mills																															
ID 36	A,B,C	12/72,10/73, 11/74	640	6	6	55		x	x	x					x	x	x	x	x			E-		50							
ID 37	A	'65	250	3	3			x		x												E-									
ID 33	C	'64	225	3	3	40	x											x	x			W-	8800		10.5	22.2	0.6				
ID 32	B	7/68	250	3	3	32	x	x		x	x	x	x		x	x						E-Ky.	12000	55	8.5	8.5	3.9				

1) Coal Type
W-Western Coal
E-Eastern Coal

2) Maintenance
a) Scheduled maintenance will include work where applicable on replacing exhauster blades, resurfacing rolls, replacing separate body liners, etc.
b) Major overhauls will include work where applicable on replacing grinding ring segments and rolls, liners, cones, discharge valves, etc.

3) Deep bowl mills

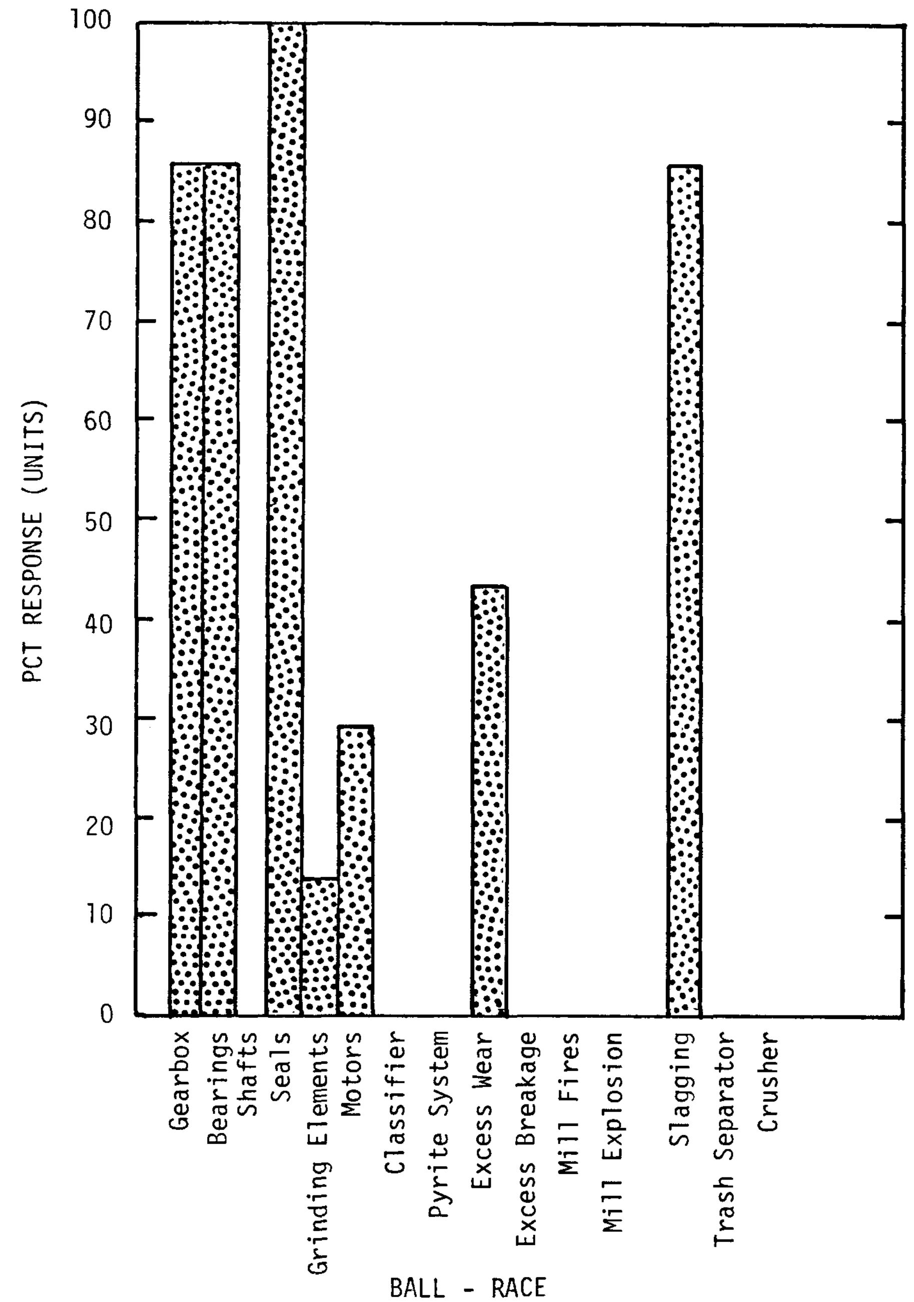

Figure 7-2. Ball-Race Mills--Problem Areas.

Table 7-2

Ball Race--Problem Areas

Plant/Unit	Problem Area: Gearbox	Bearings	Shafts	Seals	Motors	Slagging	Excess Wear	Grinding Element	Problem Area Specifics/Causes	Modification	Successful
ID33/A,B	X	X		X	X	X	X	X	. Coal dust in the gearbox/seals	Increasing air capacity to seals	Partially
									. Dirt in lub. oil ruining bearings/seal		
ID34/ A,B,C,D	X	X		X		X			. Slagging	Monitor furnace exit temperature	Yes
									. Hydraulic loaders-leaks	--	--
ID35/A				X			X		. Ball cracking	Increasing size of the ball	Yes

Filtering of the lubicating oil may be a means by which failures due to oil contamination may be avoided. However, several units reported that the system did not lend itself to the addition of a filter.

Problems with the motors on these mills have also been an area of concern. A majority of the stations experienced problems of overheating, although a large percentage of these overheating problems were cited as a result of too many consecutive starts without enough cool-off time and of breaker trips because of current overloading.

Grinding Zone

Grinding element problems were not severe, though the mills studied had some problems of excess wear and cracking. To alleviate the problem, Plant ID 33 A, B increased the wear material thickness from 18.75 inches to 26.00 inches and altered the ring speed. Since these adjustments were made, the balls and ring now last approximately 500,000 tons. It was also noted that fires which started inside the mill also caused the balls to break at a later date.

At Plant ID 35, the balls and rings last only 90,000 tons of coal per set. The expected tonnage throughput was 150,000 tons.

Air System

The only problem in this area resulted from the use of an undersized air fan. One unit did experience classifier problems, such as vane erosion, though it was felt by the plant personnel that the high abrasion of the coal being utilized at that time was responsible.

Mill Fires and Explosions

One area in which the ball-race mills have not experienced any abnormal problems is that of fires and explosions. Though some ball cracking resulted from fires, these incidents were not of great concern to the utilities, and they did not consider the minimal amount of fires as a major problem.

Boiler Problems Associated with the Pulverizer

Ninety percent of the boilers utilizing ball and race mills experienced slagging problems. One utility reported that slagging was suspected to be a pulverizer associated problem but had never proven this. Other utilities reported oversized pulverized coal reaching the burners as being responsible for slagging.

Section 8

BALL/BALL TUBE MILLS

BALL (TUBE) MILLS

The ball mill or tube mill (Figure 8-1) is a horizontally supported grinding cylinder in which a charge of mixed-size forged steel balls act as the grinding media. Gravity causes the balls to descend on the coal, pulverizing the coal by attrition and impact. Air acts as a carrier to transport the pulverized coal to the classifiers. Gravity returns oversized particles for further grinding.

DATA BASE

A data base of 18 ball mills and nine ball tube mills was established. Table 8-1 presents a list of the plants, startup dates, nominal capacity, number of mills, problem areas, coal properties and maintenance data. The data base includes mills from the two manufacturers.

PROBLEM AREAS/CAUSES/MODIFICATIONS

Table 8-2 is a summary of the problems associated with the ball mills. Figures 8-2 and 8-3 graphically show problem areas associated with drive components, grinding zone, air system, fires and explosions, and any boiler problems related to the mill.

Drive Components

The ball mills have experienced various problems with the gearbox, seals, shafts, and bearings. Oil contamination was increased due to seal failures which later caused excess bearing wear along with excess shaft wear and breakage. The underlying causes for such failures were poor sealing ability resulting in oil contamination. There have been limited attempts to correct these problems.

Grinding Zone

Grinding element and related subcomponent problems were minimal. Problems noted include excess liner and ball wear and ball cracking (a result of mill fires).

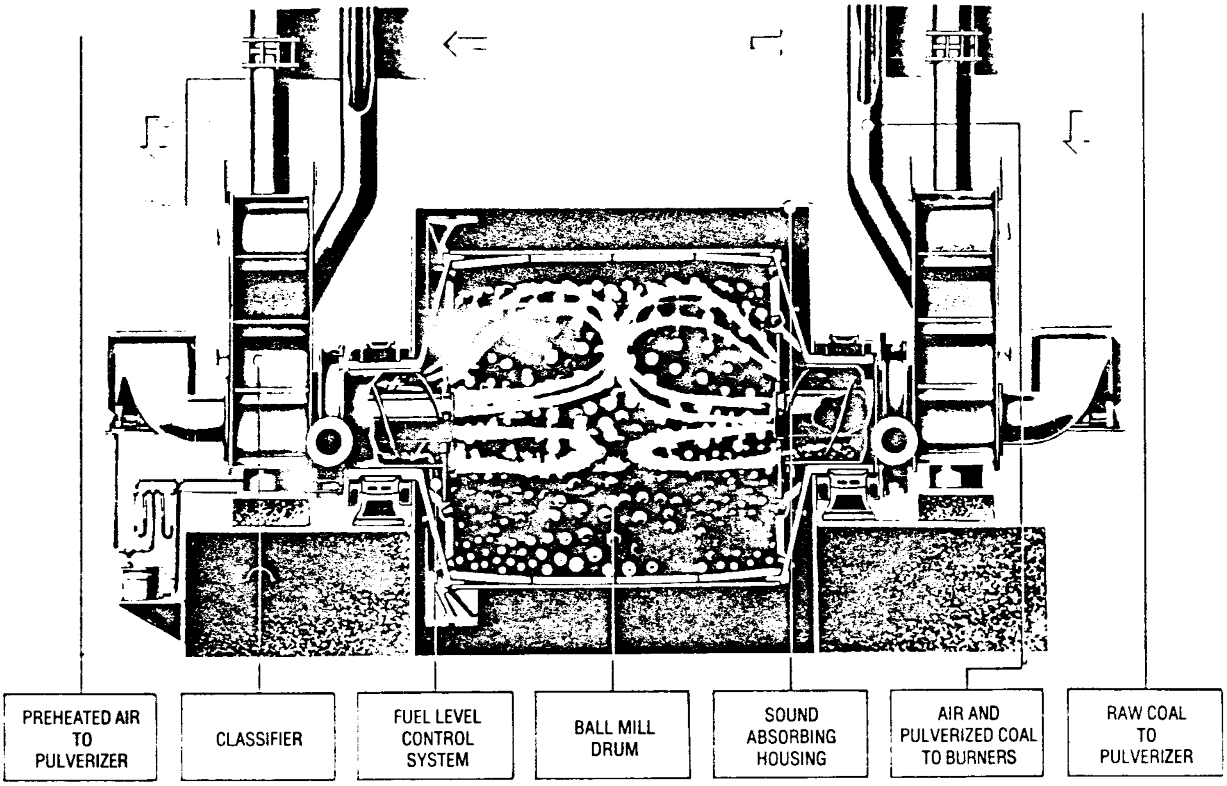

Figure 8-1. Ball Mill Design.

Source: Manufacturer's Brochure on Ball Mills

Table 8-1. Ball/Tube Mills

Plant	Unit	Startup Date	Nom. Capacity (MWe)	#Mills/each Unit	#Mills @ full load	Pulverizer Size (tons/hr)	Problem Areas															Typical Coal Properties							Maintenance Data[2]		
							Gearbox	Bearings	Shafts	Seals	Grinding Elements	Motors	Classifier	Pyrite System	Excessive Wear	Excessive Break	Mill Fires	Mill Explosions	Slagging	Trash Separators	Crushers	Coal Type[1]	Heating Valve (BTU/lb)	Hgi	%Moisture	%Ash	% Sulfur	Abrasiveness (silica/alumina)	Scheduled Maintenance Tonnage Throughput(x1000)	Major Overhaul Tonnage Throughput (x1000)	¢/Ton Coal Ground
																						Roll-Race Mills									
ID 23	A	5/77	650	7	6	62				x												W-Wyo.	8.25	61	30	5.8	0.3				
ID 24	A,B	8/74,12/75	1140	10	8	62				x	x						x			x		E-Ky.	11850	34-60	7	13.5	1.1	1.5-1.9			
ID 25	A,B	3/73,11/73	1300	11	11	62								x	x		x	x	x	x	x	E-Ky.	10550	57	10.1	16.3	3.5	2.9	135	1000	34
ID 26	A	12/75	350	4	4	62	x										x	x				W-Wyo.	8250	55	29.0	5.2	0.3				
ID 27	A	6/78	450	5		62																E-Ky.	13000		5.5	6-7	0.7				
																						Planetizing Roll Mills									
ID 28	A,B,C	3/76,3/75,2/78	650	6	6	50	x				x		x		x	x			x	x		E-Ill.	11700	63	12.4	6.5	1.5	2.5	525		23
ID 29	A,B	7/69,12/69	660	6	5	50	x	x			x		x									E-Pa.	11500	80	2.8	25.0			500		45
ID 30	A	5/70	325	4	4	38	x	x	x	x	x		x		x	x						E-	11777	50	7.5	11.6	2.5				
	B	8/73	500	6	6	45	x	x	x	x	x				x	x						E-	11777	50	7.5	11.6	2.5				
ID 31	A	12/70	500	6	6	38	x	x	x	x	x				x	x	x					E-Inc.	12000	55	5.5	8.5	3.7				
ID 32	A	5/73	500	6	4	39	x	x	x	x	x	x			x	x						E-Ky.	12000	55	8.5	8.5	3.7				67.5
																						Ball-Race Mills									
ID 33	A,B	7/69,7/70	795	9	8	48	x	x		x		x			x				x			W-	8800		10.5	22.2	0.6				54
ID 34	A,B,C	6/71,5/73,5/74	750	7		50	x	x		x									x			E-W.V.	12690	60	4.0	11.0	2.8	2.3			
	D	3/73	730	7		50	x	x		x									x			E-W.V.	12690	60	4.0	11.0	2.8	2.3			
ID 35	A	'65	500	10	10	21				x	x				x							E-Ky.	11200	50	7.7	15.0	4.0				85.4
												Table 8-1. Ball/Tube Mills										Ball/Tube Mills									
ID 36	A,B,C	12/72,10/73, 11/74	640	6	6	55		x	x	x					x	x	x	x	x			E-		50							
ID 37	A	'65	250	3	3			x		x												E-									
ID 33	C	'64	225	3	3	40	x											x	x			W-	8800		10.5	22.2	0.6				
ID 32	B	7/68	250	3	3	32	x	x		x	x	x	x		x	x						E-Ky.	12000	55	8.5	8.5	3.9				

1) Coal Type
W-Western Coal
E-Eastern Coal

2) Maintenance
a) Scheduled maintenance will include work where applicable on replacing exhauster blades, resurfacing rolls, replacing separate body liners, etc.
b) Major overhauls will include work where applicable on replacing grinding ring segments and rolls, liners, cones, discharge valves, etc.

3) Deep bowl mills

Table 8-2

Ball and Ball Tube Problem Areas

Plant/Unit	Problem Area: Gear Box	Bearings	Shafts	Seals	Motors	Slagging	Excess Wear/ Breakage	Grinding Elements	Mill Fires/ Explosions	Classifier	Problem Area Specifics/Causes	Modifications	Successful
ID32/B	X	X		X	X		X	X	X	X	Not reported	Not reported	--
ID36/A,B,C		X	X	X			X		X		Oil contamination	Not reported	--
ID33/C		X		X		X					Poor quality coal	Not reported	--
ID38/A	X								X		Gearbox-speed reducer/ continuous settlement causes bearing and seal wear	Not reported	--

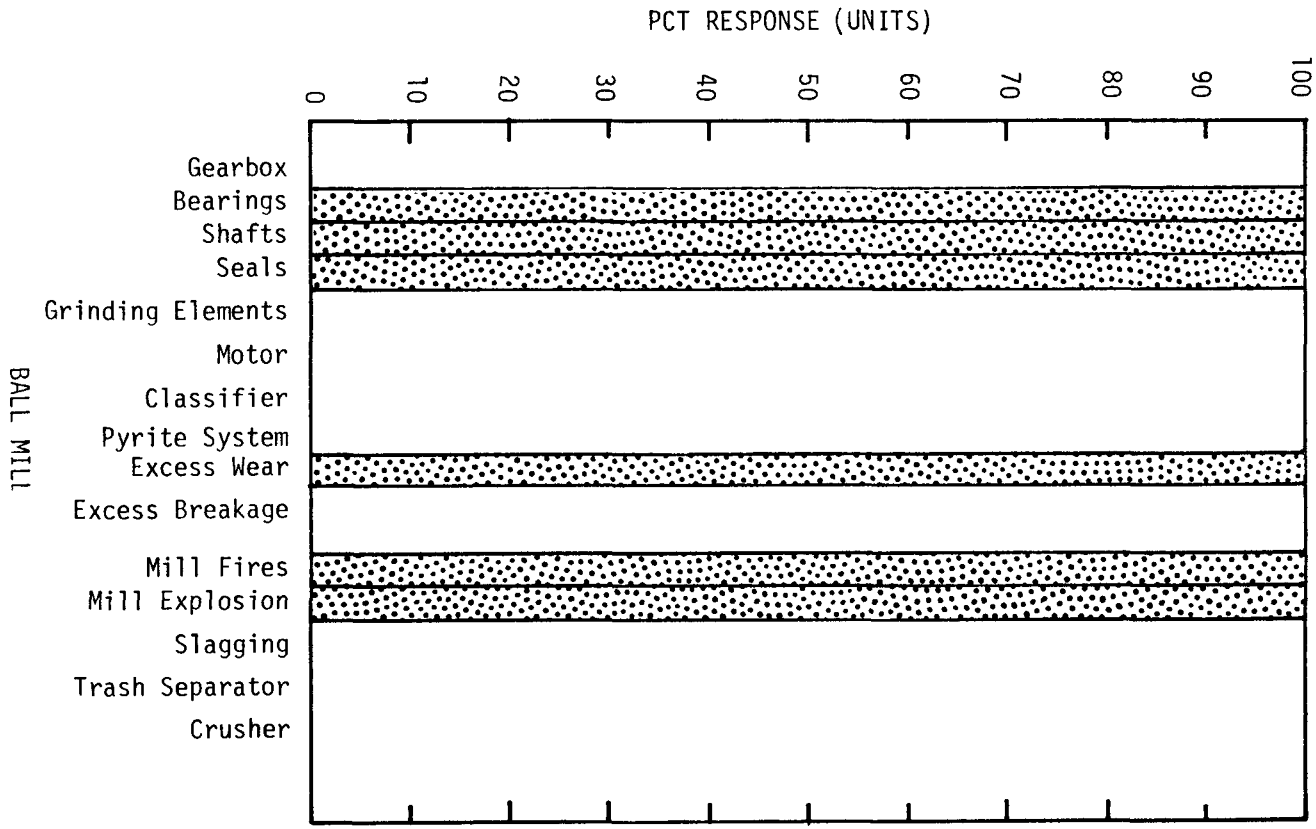

Figure 8-2. Problem Areas - Ball Mills.

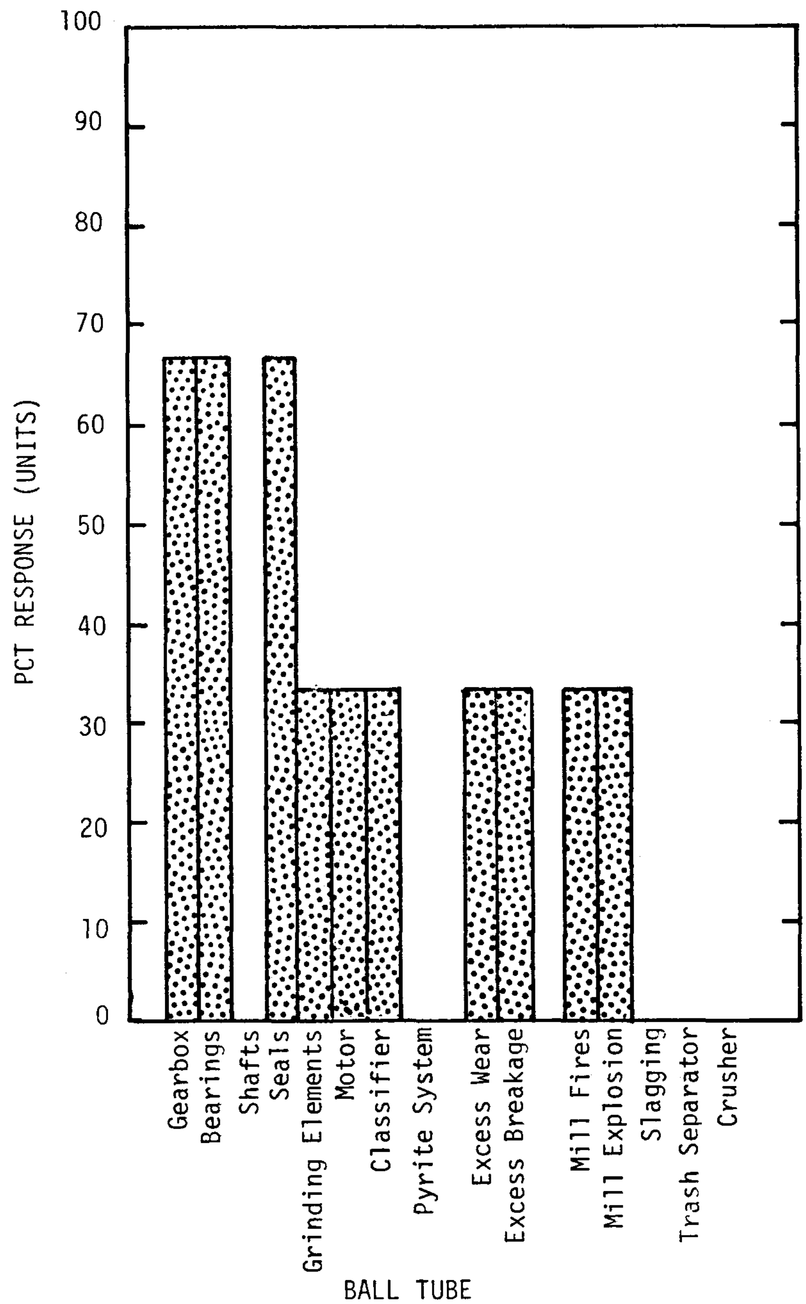

Figure 8-3. Problems Areas - Ball Tube Mills.

Air System

The air system includes those mill components involved with the circulation, classification, and transportation of the coal prior to and after pulverization. Such components were not a source of serious concern, although operation of the classifier in one station resulted in problems. The specific nature of this problem and possible solutions was unspecified.

Mill Fires and Explosions

Fires and explosions plagued many of the mills investigated. Coal characteristics, coal settlement, and extremely high temperatures were credited as chief causes of these occurrences. Fires resulted in ball breakage and shortened life. Solution to these problems have not been found.

Boiler Problems Associated With the Pulverizer

Boiler associated problems involving the ball and ball tube type mills were associated with slagging in a few cases. The magnitude and occurrences of these problems were limited and were not considered to be a major concern.

SECTION 9

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2. Robin, T. T. and Brickell, M. C., "Reliability of Operating Power Plants-A Utility Viewpoint," Combustion, September 1978.

3. Babcock & Wilcox, Steam/Its Generation and Use, 1972.

4. Kitchen, W. A., "How to Choose a Pulverizer System," reprinted from April 15, 1977 issue of Electrical World, McGraw-Hill.

5. Vecci, S. J. and Moore, G. F.," Determine Coal Grindability," Power, March 1978.

6. Maloney, K. L., et al, "Systems Evaluation of the Use of Low-Sulfur Western Coal in Existing Small and Intermediate-Sized Boilers," EPA Contract No. 68-02-1863, July 1978.

7. Vecci, S. J., Wagner, C. L., and Olson, G. B., "Fuel and Ash Characterization and Its Effect on the Design of Industrial Boilers," Vol. 40, Proceedings of the American Power Conference, 1978.

APPENDIX A

QUESTIONNAIRE

PULVERIZER RELIABILITY DATA SHEETS

KVB

PULVERIZER RELIABILITY DATA SHEET

Utility ______________________________

Plant Location ____________________ Unit No. __________

Plant Personnel to be Contacted for Further Information __________

____

Title ______________________________

Phone ______________________________

GENERAL DATA

Boiler Size ____ MW Number of Burners ____ Firing Rate ____ lb/hr

Number of Pulverizers/Boiler ________ Startup Date ______________

Number of Pulverizers Required for Full Load _______ Type Pulverizers _______

______________ Pulverizer Make ______________

Pulverizer Size _____ ton/hr Approx. Accumulated Hours ______________

Power Requirements: Design Current, _____ amps Typical Full Load, ____ amps

Mill Outlet Temperature____°F Is Pulverizer Top ____ or Side ____ Loaded?

Are there any boiler problems which can be attributed to the pulverizers such as slagging, fouling, smoking, etc.? Yes____ No ____ Describe: __________

____

Have any of the following components been a source of problem?

Item	Yes	No
Gearbox	___	___
Bearings	___	___
Seals	___	___
Motor	___	___
Grinding Elements	___	___
Shafts	___	___
Other __________	___	___
______________	___	___

Do you feel that you experience excessive wear problems? Yes ____ No _____

Explain ______________________________

____

Do you feel that you experience excessive breakage problems? Yes ____ No ____

Explain: ______________________________

____

Have problems with the following ancillary equipment influenced pulverizer problems?

Item	Yes	No
Trash Separators	___	___
Screw Feeders	___	___
Crushers	___	___
Other __________	___	___
______________	___	___

6940-2

KVB

PULVERIZER RELIABILITY DATA SHEET (Continued)

COAL HISTORY

Do you fire a blended coal on this unit? Yes____ No ____

If so, please explain the types of coals used: ______________________________

____

	Design Specs.	Changes in Coal Type Year Change Was Made		
Coal Source: State				
Mine				
Seam				
Hardgrove Grindability Index				
% Moisture				
% Ash (As Fired)				
% Sulfur (As Fired)				
Btu (As Fired)				
Mineral Analysis % Wt* Silica SiO_2				
Alumina Al_2O_3				
Titania TiO_2				
Ferric Oxide Fe_2O_3				
Coal Particle Size				

*If Available

6940-3

KVB

PULVERIZER RELIABILITY DATA SHEET (Continued)

UNIT AVAILABILITY DATA

NOTE: In order to make it as convenient as possible, the data can be provided in one of three ways: (1) data of each pulverizer outage; (2) yearly totals - e.g., # outages, total outage hours, etc.; (3) your own data sheets containing the required information. Please provide the data for the last three (3) years.

Outage Date/ Year (Totals)	Unit Hours of Operation	Type of Outage Forced or Scheduled	Outage Duration Hours	MWH Lost	# of Outages (Totals)

If possible, please estimate:

Hours Between Scheduled Maintenance Design ____________ Practice ________

Cost of Pulverizer Maintenance __________¢/lb Coal Ground

6940-4

APPENDIX B

CASE STUDY 1: PLANT ID 2, UNITS A,B

Units A and B of Plant ID 2 are 665 megawatt rated coal fired utility boilers. Unit A went on line August 1971 while Unit B went on line July 1972. Both units have eight pressurized bowl mills rated at 66 tons/hr, but only seven mills are required for full load requirements. Since both units have been on line several years, the mills are definitely seasoned. The typical coal burned at the Plant is very low grind (HgI$\sim$35), high moisture (24%), low Btu (7800) western subbituminous coal.

The biggest problems encountered with the pressurized bowl mills at the Plant have been the lube oil system and cone wear. Associated problems with the lube oil system have been oil seal deterioration resulting in contaminated lubrication and orifice plugging. Oil seals have burned up primarily from high ambient temperatures as a result of air seal failure. These failures have led to vertical shaft wear and vertical shaft failure in one instance. Contaminated lubrication has been associated with the main drive shaft bearing failures and orifice pluggage.

Solutions to the lube oil problems at the Plant have come from at least two sources. An internal lube oil system (manufacturer recommendation) installed a few years ago on one of the mills proved successful in terms of adequate lubrication. This same system is now available on the latest pressurized bowl mill designs. The oil pump is driven by the intermediate shaft and supplies oil to all points except the bevel gears. A centrifuge to separate the dirt, grit and foreign material from the oil will be tried with the lube oil pump on one of the mills.

Plant 2 has also experienced excessive cone wear problems. Four angle iron bars were situated in the classifier to reduce wear but compromised mill capacity substantially. Thus, these angle iron bars were subsequently removed. Ceramic lined classifier cones are currently being tried to reduce wear in this area.

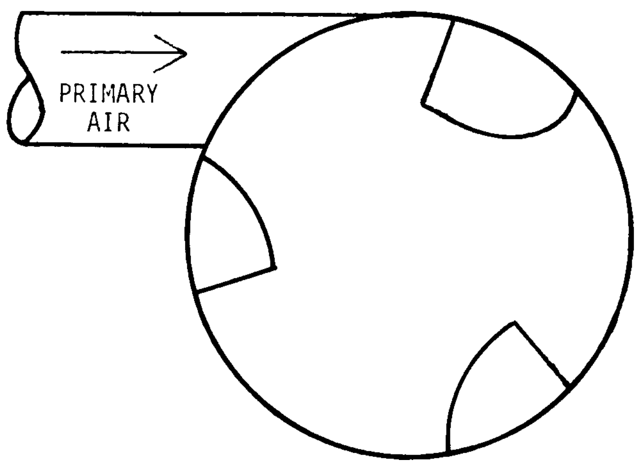
Fineness has been another area of concern at the Plant. Coal fineness is now monitored on a biweekly basis for each mill due to the slagging problem which is partially due to oversized pulverized coal. One method which has been used to improve fineness is the elongation of inlet air openings to the journal opening centerlines. The purpose of this contoured air inlet vane opening cover modification was to relieve the load on the classifier by promoting preliminary segregation in the grinding area. These air inlet vane covers improved fineness by reducing the 50 mesh carryover but caused extreme wear of the external cone and body liners. The covers were eventually removed because of the wear problems in other areas of the mill.

Mill fires are not a problem at this Plant. The fires that have occurred are either mill or burnerline related. It was noted that the liner cover plates for the separator body liners had been removed, eliminating areas of likely coal accumulation. These liners wear excessively at the air inlet openings (Figure B-1). A new 3/8 inch wear resistant cover plate for the back of the separator body liners has been tried with all the mills without incident or signs of coal accumulation.

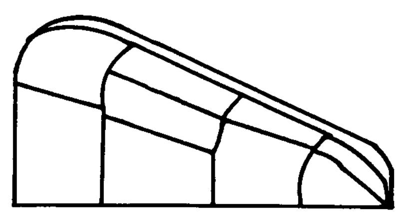
In terms of maintenance practice, three minor overhauls and a major overhaul will be typically performed on a mill during a year's time (about 400,000 tons coal throughput). Liners are typically removed and replaced at 100,000 tons coal throughput intervals, rolls at 200,000 ton intervals. Rolls are being resurfaced by an independent vendor, but future plans are for an on-site facility. The plant personnel are experimenting with 20% chrome surfaced rolls.

Current maintenance costs for the pulverizer system are 14-20¢/ton coal ground. These high costs are attributed, in part, to the coal quality. The high clay content of the coal has been responsible for coal spillage and bad grind. The coal is now washed to remove some of the clay and upgrade coal quality.

Operating procedures call for each journal to be loaded at 30 tons spring compression. The spring compression is checked during each major outage. The eccentric reading has been set at one since startup (no trunnion adjustment) and based on experience, the classifier setting is four. If the classifier setting is higher, the grind is finer but the load capacity drops significantly.



TOP VIEW: Primary Air Admission and Three Separator Body Liners.



Segmented Separator Body Liner.

Figure B-1.

APPENDIX C

CASE STUDY 2: PLANT ID 3, UNITS A,B

Unit A of Plant ID 3 is a 527 megawatt rated coal fired utility boiler. This generating unit went on line in May 1975. The unit has six pressurized bowl mills rated at 67 tons/hr with one spare mill available. As of December 1978, the unit has been on line approximately 27,000 hours. Unit B of Plant ID 3 also has six pressurized bowl mills with one spare mill available. This unit, however, has been on line only a year and a half.

From discussions with the plant personnel, the most important problem area at Unit A is wear. Excessive wear problems at Unit A are associated with the internals of the mill and discharge piping and are related to the type of coal pulverized. The coal pulverized at Unit A is a Montana Colstrip coal with the following characteristics:

Hardgrove Grindability Index:	52
% Moisture:	26
% Ash:	7.2
% Sulfur:	0.6
Btu as Fired:	8,750
SiO_2:	39.8
Al_2O_3:	17.0

This western subbituminous coal has a high abrasive potential based on the relative amount of silica and alumina in the coal's mineral inorganics.

Wear problems have been particularly excessive with the liners, cones and multiport outlet. Maintenance work must be done on these components in intervals of approximately 100,000 tons coal throughput. Normal maintenance includes patching the classifier cone, changing out wear plates and side liner plates at the separator body liners, and patching the side of the mill below the roller door where hot air enters. Wear problems have also occurred at the butterfly valves of the multiport outlet.

Deflector bars in the cone area have been placed in front of the discharge gates to help cut down wear in the multiport outlet region. The manufacturer and the utility have tried ceramic liners, modified the cone design and altered the coal/air flow patters in the mills, but these changes have not been successful in reducing wear.

Slagging has been a problem at Unit A and has been associated with the coarse coal leaving the pulverizer. It should be noted that the classifier vanes were adjusted to minimize the percent carryover on the 50 mesh screen. While the grind problem has been minimized, slagging remains a problem. Other factors such as ash constituents, ash fusion temperatures, and ash viscosity of the coal must be considered along with the firing conditions of the furnace in order to minimize this problem.

Another problem area identified from the questionnaire was the mill base. The gearbox metal had cracked due to thermal stress in the region underneath the primary air entrance. The metal was repaired by "metal stitching" by the manufacturer. The manufacturer noted the problem was due to casting. This problem with the mill base has not been observed at other units and mills.

No serious problems have been encountered with the lubricating system or seals. Some leaks have occurred in the oil piping network, but nothing serious enough to cause a forced outage. The hoses used to monitor oil pressure in the roller journals had been a problem and were subsequently removed. Coal would flow into the roller journals due to the hoses.

No problems with seal air or coal dust entering the lubricating oil have been encountered. Slight problems with blowby past the oil seals have occurred.

Mill fires have been a major problem on Unit B. Since startup, five fires have occurred on one mill. A faulty temperature probe may have been the cause of the problem. Discoloration of the mill skin exterior on the side of the mill where the primary air enters was noted.

In terms of maintenance and mill work records, the following items will be monitored based on a tonnage throughput basis for the two units:

- Rolls
- Rings
- Liners
- Cones
- Spring compression

Spring compression in the roller journals will be checked at about 200,000 tons coal throughput. Rolls are typically arc gouged with lifetimes of 500,000 to 700,000 tons per set rolls. All three rolls will be replaced at one time. These rolls are tapered and cannot be reversed.

APPENDIX D

CASE STUDY 3: PLANT ID 7, UNIT A

Unit A of Plant ID 7 is a rated 700 megawatt coal fired utility boiler. The unit has six pressurized bowl mills rated at 69 tons/hr, and all six are needed for full load. Originally, the unit had been designed to operate at full load with one spare mill. Unit A's startup date was October 1972 and these mills had each accumulated about 37,000 hours as of the end of 1978.

The following pulverizer problem areas have been and are the most severe based on conversations with the maintenance and operations people at the plant:

1. Lubricating system and oil contamination
2. Vertical shafts (ex-problem)
3. Mill fires
4. Wear

Many of the problems associated with oil contamination have been related to oil and air seals and plugged orifices. The mechanical seal on the lube oil pump failed on several occasions. Plant personnel are looking to a new packing material to replace the mechanical seals and hopefully alleviate the seal difficulty. Also, the vertical shaft seals have been a problem, causing contaminated oil and affecting vertical shaft wear. These air shaft seals have contributed to oil system impeller replacement. Seal air capacity is limited in addition to these oil and seal difficulties. Frequent plugging of orifices has also occurred, resulting in an upset of oil distribution. Plant personnel feel that a modified lube oil system and adequate seal air will solve many of their current maintenance problems.

Problems had been encountered with broken vertical shafts. In fact, vertical shaft breakage had been experienced once on four of the mills (Table D-1). The remedy to this problem was attributed to reducing the spring loading from 20 tons to 15 tons, and straps were welded on the spring adjusting and jam nuts to the spring stud so as to prevent loss of spring loading during operation (Figure D-1).

Vertical shaft breakage is attributed to uneven loading on the bowl caused by improper roller journal spring adjustment. It was also learned that mill fires may draw the temper from the spring; thus, maintenance and spring checks should be made following mill fires to insure that the proper spring adjustment is maintained. Roller journal bearings had been a problem at one time due to the maladjusted spring loading.

Mill fires are another problem area. On the pulverizer outage description computer sheets, these mill fires are not distinguished as to bunker, mill, or fuel line related. Evidently, a majority of mill fires occur when a mill had been taken out of service and then restarted. The frequency of these mill fires is significant based on outage data. Conversations with plant personnel confirmed that isolation and containment of these fires is a real problem. Closing the hammer gates at the boiler to isolate the mill fire from the boiler is a very hazardous operation. In addition, the butterfly valve at the multiport outlet may not adequately isolate the mill from the furnace. Since startup, two of the mill fires have been bad ones. Of the mill fires that do occur, it is felt that most originate in the burner line. Burner line pluggage evidently is a common occurrence due to low coal/air velocity in the burner lines allowing dropout of the pulverzier coal. Fuel line gaskets and oil seals typically burn out with the mill fires. No fires in the pyrite system have occurred.

Wear problems are evident at the multiport outlet and the burner lines. The butterfly gate valve is particularly prone to wear. During the latest scheduled outage, multiport liners were installed to reduce wear. Burner line erosion, particularly in the elbow region, has been evident.

Roll wear has also been a concern. The plant personnel are hoping for increased lifetime of the grinding rolls (up to three to five times more tonnage per set of rolls) by hard surfacing the rolls. Currently, they get about 200,000 tons per set of rolls and about 400,000 tons per grinding ring set. These numbers can be deceptive since the rings and rolls do not always completely wear out before replacement. The rolls or rings may be changed out during an opportune boiler outage for some other reason. Other wear items of concern with other units (e.g. classifier at Units A and B of Plant ID 2 and Unit A of Plant ID 3) are not a problem at this unit.

Work has been performed in several areas to improve pulverizer operation and performance. Coal handling procedures have been greatly improved. The coal delivery to the crushers will be monitored for foreign matter, ash content, etc. Also, the coal delivered to the crusher is approximately four inch lumps or less with typically one inch coal particles maximum being delivered to the mill. The operating personnel at the plant have improved their coal handling procedures to limit outage time due to coal or foreign matter in the equipment. Clay and mud in the coal will also affect the coal handling equipment and shorten mill life.

The number of mill inspections was increased from 1977 to 1978. Ten inspections were conducted in 1977 while 24 inspections had been conducted through August 1978. The increased number of inspections were aimed at liners, rollers, segments in the grinding zone area. Coal fineness measurements are made biweekly for each mill.

Outage time associated with the pulverizer has actually increased over the last four years, mainly due to the installation of an electrostatic precipitator (ESP). Previously, the induced draft (ID) fan at the stack inlet required downtime, but fan wear due to flyash has now been reduced. Work could be done on the pulverizer at the same time the ID fan maintenance work was conducted, and outage time was attributed to the fan. Now it is attributed to the pulverizer.

TABLE D-1

PULVERIZER-FREQUENCY OF COMPONENT REPLACEMENT AND MAINTENANCE

	A	B	C	D	E	F
OVERHAUL-GENERAL (MAINTENANCE)	3	2	2	1	2	3
CHANGED JOURNALS	22	9	11	10	13	9
VERTICAL SHAFT SEALS	11	0	3	3	4	4
*BROKEN VERTICAL SHAFT	1	1	1	0	1	0
HORIZONTAL SHAFT BREAKAGES	3	1	2	1	0	0
NEW SEGMENT PLATES	2	1	1	2	1	2
LUBE OIL PUMPS	7	3	6	3	8	4

*The broken shafts were resolved when the journal spring tension was reduced from 20 tons to 15 tons.

Data collected through May 1978.

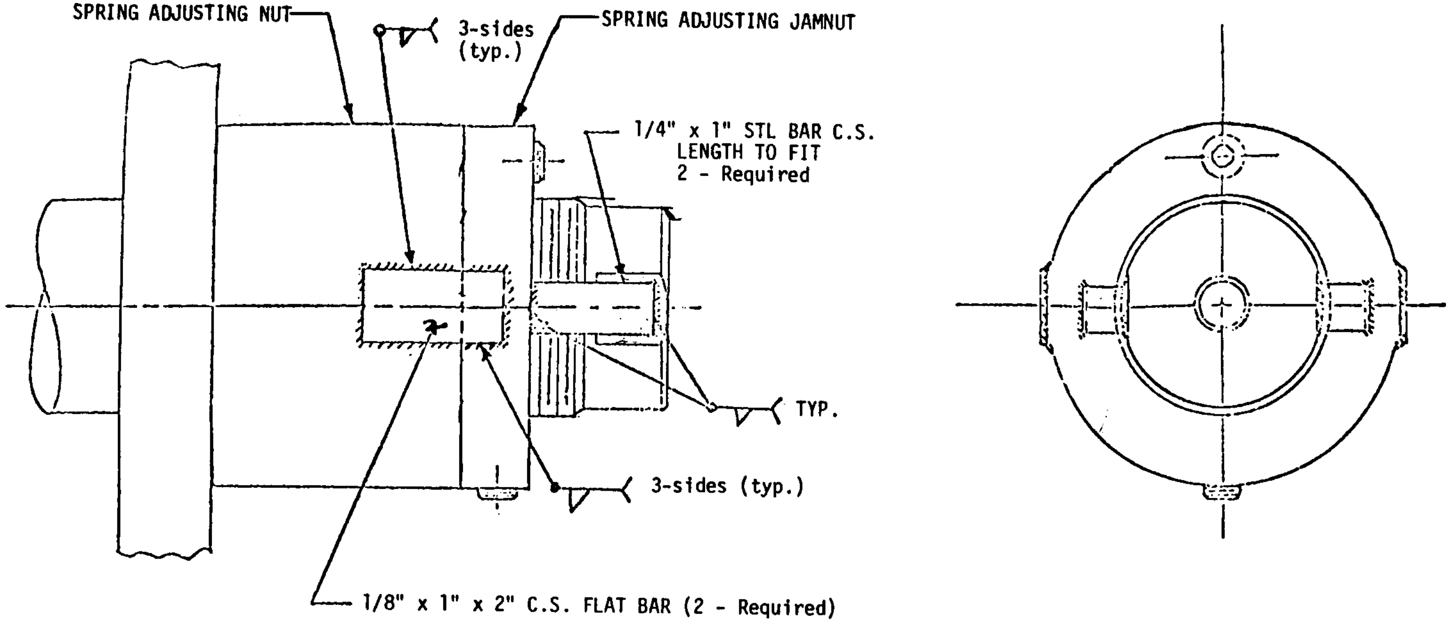


Figure D-1

FIELD ALTERATION TO SECURE SPRING ADJUSTING AND JAM NUTS TO SPRING STUD

APPENDIX E

CASE STUDY 4: PLANT ID 23, UNIT A

Unit A of Plant ID 23 is a 650 megawatt rated capacity coal fired utility boiler operated since May 1977. The coal being burned at the plant is a subbituminous western coal from Gillette Mine Belle Ayr Seam in Wyoming. The unit has seven roll and race pulverizer mills rated at 62 tons/hour but only six mills are required for full load.

Problem areas have been minimal due to the limited amount of time that the plant has been in commercial operation. The only significant problems with the mills to date have been seals. One problem had been pressurized oil leaking out of the gearbox cover near the intermediate shaft between the initial and secondary gear reduction junction. While this difficulty did not lead to outages, it was more or less a nuisance for the plant. The manufacturer modified the gearbox lubricating oil system by introducing the oil spray at the top of the gearbox. This design alteration seemed to be effective in eliminating this problem.

Air seals have also been an area of concern. Air seals have been satisfactory in the roll assembly but some air leakage has occurred around the yoke area. Yoke air seal clearances were a particular item of concern during preventative maintenance inspections. Basically, the air seal is a bronze labyrinth with air seal packing followers. In the past, asbestos braided packing was used for the seal followers but now a high temperature steam packing (1-1/4 inch square) is being used on all seven mills. The old packing material was being burned away due to the high temperature primary air input. Primary air and seal air were backflowing past the seal into the horizontal shaft motor housing. A problem with fly ash contamination in the motor resulted.

As evidenced by the modifications made to cope with the oil seals and air seal problem areas, "fixes" will be devised by both the manufacturer and utility to decrease maintenance and improve reliability and performance. Significant modifications have also been made or will be tried in the following areas:

1. Pyrite plow.
2. Classifier vanes.
3. Throat liners.

Within the first three to six months of operation with these mills, spring loaded pyrite plows were installed to replace the counter weighted plows initially designed for these mills. It should be noted that the pyrite plow is attached to the yoke to sweep pyrites and foreign material to the pyrites box. Brackets are bolted to the plow to support the yoke.

A classifier vane modification was made to one of the mills in February 1978 to improve coal fineness passing through the 200 mesh sieve. The vanes were altered from 12 inches to 18 inches. The result of this change was an increase in the percentage of coal passing through the 200 mesh from approximately 65% to 72%. These longer blades are now used on all the mills.

The only wear problem that has been evident with the mills has been the cast iron throat liners where vigorous mixing of the coal/air mixture comes in contact with the liners. A design change with fabricated steel liners will be tried on one of the mills to determine if the throat liners will wear better. Overall, wear has not been a severe problem with these mills. While the average number of hours on these mills is low (4,000 to 6,000 hours), the rolls are reported to be in very good condition. These rolls are expected to last at least five years.

During hot startup of tripped fully loaded mills, small explosions have occurred in all seven mills. It was felt by the plant personnel that improper purging and coal accumulation in the mill had led to this problem. However, the small explosions encountered during hot startup have not been recurrent.

In terms of maintenance practice at the plant, preventative maintenance has been rigorous to obtain high performance. Inspections and maintenance have been conducted at 50 hours, 500 hours, 1,000 hours, and 3,000 hours, respectively, for each mill. Such items as checking to make sure the proper spring compression is maintained, checking to see that the pressure frame is centered on the rolls and changing the oil in the roller assemblies after 3,000 hours have resulted in a low maintenance mill.

Documentation of overhaul and repair records include the following component areas for the mills since startup:

- Rolls
- Pressure frame
- Bowl
- Gearbox
- Seals
- Classifier
- Air ducts
- Coal Feed pipes
- Swing valve
- Mill inlet
- Pyrite section
- Seal air
- Wear
- Lubrication
- Mill housing

A spring compression of 20 tons has been maintained since startup and checked periodically. Roll pivot pins and wear plate clearances have been monitored during scheduled outages. At each mill, seal air flanges have been pulled tightly over each roll to insure air seal for the roller assemblies.

Since a spare mill is available, forced outages due to the pulverizer have not occurred yet. One mill can be shut down for maintenance work while the other mills are carrying full loads. Most of the mill components except the swing valve and classifier blades are accessible for work or repair.

APPENDIX F

CASE STUDY 5: PLANT ID 25, UNITS A AND B

Units A and B of Plant ID 25 are both rated at 1,300 megawatts generating capacity. Unit A began commercial operation March 1973 while Unit B went commercial in November 1973. Both units have 11 roll-race mills rated at 62 tons per hour, and most of the time, all 11 mills are needed for full load operation. At the beginning of commercial operation, both Units A and B had the ball-race mills. Units A and B were designed to operate with ten ball-race mills in operation for full load service based on the design coal (11,200 Btu/lb, HgI = 50, 7.7% moisture, 16.25% ash). However, these ball-race mills (rated at 50 tons per hour) gave poor coal fineness which resulted in furnace and reheater fouling, slagging, and extremely high pulverizer maintenance costs. Twelve ball-race mills were replaced with the roll-race mills in 1975. The remainder of the ball-race mills were replaced with the roll-race mills in 1977.

The biggest problem with the roll-race pulverizer mills has been wear. Specifically, pulverizer housing, throat inserts, slope plates, classifier, swing valves, and burner line piping have all been subject to erosion due to the abrasive nature of the coal. In order to reduce the rate of system failures for the mills due to wear, specific modifications have been implemented.

1. Pulverizer Housing--Originally, the manufacturer had partially lined the housing with ceramic, but additional sections of the housing were sustaining high wear. Ceramic housing liners have been added to the pulverizer housing to prevent erosion. Ceramic lining adhesive in the grinding zone had failed, especially after exposure to high temperatures as a result of mill fires. This ceramic lining is now welded and glued on.

2. Throat Inserts--Throat inserts are welded to the top and front edges of the air inlet vanes to prevent wear. These inserts have been a nagging problem since startup. The throat area, like the classifier blades, is subject to high erosion rates.

The pipe insert type throat lasted about 135,000 tons. Hard surfacing of the pipe inserts increased the wear life up to 365,000 tons. The manufacturer has now designed flat throats for better air distribution to reduce throat erosion evident with the pipe insert. Turning vanes have been installed in the primary air duct for better air distribution to the pulverizer windbox.

3. Slope Plates--Slope plates have been the greatest source of wear on these mills. These plates were redesigned to reduce their surface area and their angle of relationship to coal flow. Ceramic brick has been tried as well as chromium carbide overlay (Tapco plate). Foreign objects such as steel would tend to break out the ceramic. The chromium carbide is very wear resistant, and based on material cost and outage time, chromium carbide material is more advantageous than ceramic or conventional plate material.

4. Classifier--Problems with the classifier have included erosion problems in the classifier skirt and over the top of the classifier blades, leading to decreased fineness. A solution was to cover the classifier skirt surface with ceramic brick and to weld a 1/4" x 2" x 2" angle in the top of the classifier against each blade to prevent cross flow of coal eroding the skirt.

5. Swing Valves--Swing valves were another source of erosion wear. The situation is dangerous in case of mill fires and explosions. If the valves begin to leak, furnace pressure can cause a flashback if primary air pressure is lost on any pulverizer. Wear resistant valve seats and plates have been installed on the mills, but the success of this modification cannot be documented at this time.

6. Burner Line Transport Piping--Originally, steel was used for piping bends (15 inch nominal I.D.). The abrasive coal/air mixture eroded this piping section easily. Later when switching from the ball-race to the roll-race mills, basalt lined pipe bends were tried (17 inch nominal I.D.) due to higher velocities of the larger capacity mills. This basalt line pipe also showed erosion. Currently ten mills have 15¼" ID basalt lined pipe bends and twelve mills have 17¼" basalt lined pipe bends.

The largest single unscheduled maintenance item has been the pyrite plows and chamber. The problem with the plows has been spring failure due to metal fatigue. Heavier stainless steel springs have been used as replacements for the defective springs. Smaller springs, holding the spring and plow in place, were breaking allowing excessive wear in the bushing. Preventative maintenance checks of the pyrite plow have been instituted during emergency boiler outages. These checks have uncovered plows about ready to fail, thus avoiding unexpected failures. Mill fires have, it is thought, originated in the pyrite chamber where coal dust accumulates in a crevice, dead space area, etc. Wear in the pyrite chamber was also evident; in fact, the pyrite chambers of ten pulverizers have now been lined with ceramic material to prevent erosion. Pyrite buildups were encountered with the twelve flat-bottom pulverizers originally installed. The newer sloped-bottom pyrite chambers have not caused any difficulties.

Fires had been a problem at one time in these mills. A tabulation of mill fires and explosions for the pulverizers shows that fires occurred in both the flat-bottom and sloped-bottom pyrite boxes since startup. However, no mill fires have occurred in the past year. Modification to the pyrite plow and gate is responsible for this improvement.

Classifier blades have been extended by trial and error to nineteen inches to improve the fineness. Fineness is monitored on a weekly basis for each mill.

At the Plant, a weekly pulverizer summary report is kept for each mill. This report includes tons ground during that week, the total tons ground since startup, tons on the grinding ring and grinding tires, and tons since scheduled maintenance. Scheduled maintenance is performed at intervals of approximately 135,000 tons of coal with inspections performed on the pulverizers, feeders, burners, and coal valves. Wheel and ring wear measurements are taken during this maintenance outage to predict when a major overhaul is required for each pulverizer. Major overhauls were expected to occur after 750,000 to 950,000 tons coal, but it appears that the wear rate decreases with use; thus, approximately 100,000 to 150,000 more tons of coal are expected to be ground between major overhauls. A major overhaul consists of the following steps:

- Replace roll wheel tires
- Replace grinding ring elements
- Rebuild ceramic housing liner
- Throat insert replacement
- Miscellaneous

A detailed check list has been devised for the scheduled maintenance of the roll-race pulverizer. This includes above the feeder gate, coal feeder, below feeder gate, pulverizer and the burners.

Maintenance costs have been approximately $0.35 per ton coal ground in 1978 for labor and material. Included in this cost are the pulverizer, primary air fan, and pulverizer seal air fans. This cost is expected to decrease due to work done to reduce wear.

Appendix G

CASE STUDY 6: PLANT ID 30, UNITS A,B

Unit B of Plant ID 30 is a 500 megawatt rated capacity coal fired utility boiler in operation since August 1973. The coal being burned at the plant is a sub-bituminous eastern coal. The unit has six modified planetary roll mills rated at 45 tons/hr, and all six mills are required for full load. All of the mills were modified with an extra large lube oil filter installed on the speed reducer. While Unit B was the steam generating unit of particular interest, it should be noted that Unit A also has planetary roll and table mills, rated at 38 tons/hr. These four mills are for a 325 megawatt rated capacity unit. Discussion of modifications made to the pulverizers on Unit A will be included as well.

The most significant problems identified at Unit B were thrust ring breakage, premature gearbox failure and mill skids. Cracking in the thrust ring area occurs with great frequency. Further evidence of thrust ring trouble is supported by the parts replacement data in Table G-1. Five thrust rings have been replaced on one mill, an average of about one per year. To alleviate this situation, a high carbon steel is being tried as the thrust ring material rather than the normal NiHard material. The high carbon steel material is expected to wear faster than the NiHard, but the tensile properties of the carbon steel should enable it to eliminate the thrust ring cracking problem.

TABLE G-1

PARTS REPLACEMENT DATA

UNIT B

Item	Year Replaced	Quantity Replaced	Reason for Replacement
Thrust Bearing	1978	1	Badly pitted and galled
Upper Radial Bearing	1978	1	Badly pitted and galled
Worm Gear	1978	1	Badly worn
Worm Shaft Bearings	1978	1 each type	Badly worn
Worm Shaft Seals	1978	1 each type	Badly worn
Grinding Table Segments	1978	1 set	Badly worn
Rollers	1974,76,78	3 sets	Badly worn
Spherical Blocks	1974,76,78	3 sets	Badly worn
Thrust Ring	1974,75,76,77,78	5	Badly worn
Wear Bars	1974,76,78	3 sets	Badly worn
Classifier Vanes	1976,78	2 sets	Badly worn
Mill Shut Off Damper	1976,78	2 sets	Badly worn

This list is incomplete for all six mills but is typical for a particular mill.

Extensive gearbox maintenance was performed on the mills at both Units A and B. Due to gearbox design, it is evidently impossible to visually inspect the thrust bearing without removing the entire worm gear. On one particular mill, it was determined that a step seal spacer was badly deformed and the bull gear shaft was badly scored in the area of the upper radial bearing. It was noted that the entire thrust load appeared to rest on the spacer. This meant that a two inch wide spacer was resting on a one inch shaft step.

Several modifications have been made to the mills at Units A and B to improve mill availability while decreasing mill maintenance time. These alterations include:

1. Stainless steel spherical wear blocks were replaced by paraboloy blocks on one mill March 1975. As it turned out, the blocks operated for three years service with about 3/8 inch wear, but blocks were found to be extremely difficult to remove from the satellite shafts. It was decided to flip the blocks and use them on the unworn side. The spherical blocks on another mill were changed from stainless to NiHard (2/79).
2. During installation of a classifier vane assembly on one of the mills of Unit A (3/29/78), the problem of the vanes seizing was tackled. Seizing vanes have not been the problem since the modification was introduced.

It was mentioned that one mill explosion had occurred with a Unit B mill and was due to operational error. Mill fires do occur on these mills.

During inspection outages, records are kept of replacement, rebuilds, wear rates, and clearance for various mill components and associated components. The major areas of concern in the check list are the primary air plenum chamber, grinding section, classifier section, dampers, pitot tubes, thermocouples, speed reducer and feeder. The inspection chart includes rolls, grinding segments, spring ring guides and spring compression.

Appendix H

CASE STUDY 7: PLANT ID 31, UNIT A

Unit A of Plant ID 31 is a 500 megawatt rated capacity coal fired utility boiler operating since December 1970. The coal being burned at the plant is an eastern bituminous coal. The unit has six planetary roll mills rated at 38 tons/hr. All six mills were required for full load at one time, but the inclusion of a distribution steel cone for the raw coal pipe outlet has enabled five mills to maintain 96% full load.

Based on discussions held with plant personnel, several significant problem areas exist with these mills. Excessive wear problems have been experienced in the seals and gearbox while excessive breakage problems have been encountered with the thrust ring and bearing drive worm shaft. The worm gears evidently become badly pitted and galled and have been a recurring problem. The gearbox housing on the mills had been reworked but no significant modifications have been made to the gearbox. The Plant is going to try a synthetic oil to improve system lubrication.

Breakage and cracking problems have been associated with the satellite rollers and thrust rings. Frequent replacement of these mill components is evidenced by the grinding zone parts inventory for each mill (Table H-1). On mill A3, thrust ring breakage and replacement occurred in monthly intervals from August 1977 to October 1977.

Mill fires have been another problem area. These mill fires were attributed to wet coal as well as coal accumulation in the grinding zone region of the mill. Evidently several of the fires have been located in the conduit region. Some work is presently being done to prevent coal accumulation in the grinding zone. A mild steel cone at the outlet of the raw coal pipe has been installed to better distribute the coal in the grinding zone. It should be noted that this modification has also been installed in all the mills at Plant ID 30. Operation and maintenance of the mills at Plant ID 31 has been improved by this modification.

Table H-1

PARTS REPLACEMENT DATA,
Plant ID 31, Unit A

Mill No. A1	A2	A3	A4	A5	A6
Rolls Sp. Blocks Segments Thrust Ring [6/75]	New Bearings Rolls Sp. Blocks Segments Thrust Ring [5/75]	Rolls Segments Sp. Blocks Satellite [10/76]	Rolls Segments Sp. Blocks [6/76]	Bearings Sp. Blocks Rolls Segments [10/75]	Satellite Sp. Blocks Rolls [11/74]
	Broken Thrust Ring Thrust Ring Rolls [12/76]	Broken Thrust Ring [8/77]			Rolls Satellite Segments Sp. Blocks Thrust Ring [3/77]
		Broken Thrust Ring [9/77]		Rolls Thrust Ring [10/77]	Rolls Thrust Ring Segments [10/77]
		Thrust Ring Rolls Satellite [10/77]			

Rolls wear must be worn 3-1/2" before change out unless broken

Appendix I

AVAILABILITY DATA

A limited amount of quantitative data on mill availability was provided by the utilities. The data base from the questionnaire included unit hours on line, outage type, outage duration hours and megawatt hours lost on an annual basis. Table I-1 presents this availability data for the bowl mills (74 mills total), and Tables I-2 and I-3 present the roll-race mills (20 mills total) and ball-race mills (38 mills total). Such information as forced outage rates and mill unavailability are presented but the limited data base prevents an accurate assessment.

Table I-4 has been included to show the relative amount of megawatt hours lost due to various factors associated with a pulverizer system. A data base of 52 mills was established for the bowl mills and 18 mills for the planetizing roll mills (Table I-4). In some instances, the megawatt hours lost due to a component of the pulverizer documents the seriousness of the problem associated with the mills (e.g. mill fires at Plant ID 5 D). The data also indicates where improvements have been instituted and where problem areas still exist at particular plants. In general, coal and mechanical failures were significant in terms of megawatt hours lost due to forced outages on both the bowl and planetizing roll mills. Tables I-5 and I-6 show the ranking of lost generation causes for the pressurized bowl mills and planetizing roll mills.

The effect of coal properties on mill wear and performance is documented in Table I-7 for the seven case studies. Grinding elements and excessive wear problems associated with the coal are indicated. Coal properties (HgI, moisture) content, ash, sulfur, abrasiveness) are included with wear cycles and mill maintenance costs if available. The coal quality at Plants ID 3 A and 25 represent the potential wear problems that both western and eastern coals can cause. The western coal used at Plant ID 3 A is highly abrasive causing excessive wear inside the mill. The eastern coal used at Plant ID 25 is a high sulfur, abrasive coal causing excessive wear in the grinding zone and classifier region. High maintenance costs have resulted from numerous modifications, documented in Appendix F, to improve performance and reduce wear.

TABLE I-1 AVAILABILITY DATA - BOWL MILLS

Plant/Unit	#Mills/ Each Unit	#Mills at Full Load	Outage Data (Time Period)	Unit Hours On Line	Outage Type #F	#S	Outage Duration Hours F	S	MwHr's Lost	Forced Outage Rate	% Unavailability Due to Mills
ID2 A	8	7	1976	6120	15	32	98	2036	8765	1.6	
			1977	7290	44	32	369	2036	27570	4.8	
			1/78-9/78	3760	24	24	269	1527	17735	6.7	
B	8	7	1976	6180	4	32	28	2036	2620	0.5	
			1977	6700	49	32	298	2036	17510	4.3	
			1/78-9/78	4280	39	24	328	1527	23530	7.1	
[2]ID11 A	6	6	1976	6065	13		971		123037	13.8	
			1977	4171	14		458		43386	9.9	
			1/78-10/78	3374	6		643		81742	16.0	
[2]ID12 A	6	6	1976	3387	12		42.5		6503	1.2	
			1977	6938	22		527.1		27610	7.1	
			1/78-9/78	5927	38		1569		106773	21.0	
ID14 A	10	10	7/75-7/76	6130	12	35	497		28230	7.5	
			7/76-9/76	1897	7	11	91		8135	4.6	
			10/76-9/77	7000	20	40	494		27465	6.6	
			10/77-9/78	6125	7	34	272		15620	4.3	
[2]ID12 B	6	6	1976	7351	39		710		49127	8.8	
			1977	4861	33		929		60204	16.0	
			1/78-9/78	2581	1		294		17098	10.2	
[2]ID12 C	6	6	1976	6415	80		788		69960	10.9	
			1977	6420	26		442		32707	6.4	
			1/78-9/78	5050	29		854		96861	14.5	
[3]ID19 A	6	6	1/76-12/15/78	20398	16		306		1815	1.5	
B	6	6	1/76-12/15/78	22188	25		783		3335	3.4	
ID21 A	6		1976						7896		0.2
			1977						22344		0.5
			1/78-7/78						64848		2.2
			8/78						23520		6.3
ID22 A	6		1976						268800		3.1
			1977						50400		1.3
			1/78-7/78						44520		1.6
			8/78						7392		2.2

[1]Forced Outage Rate = $\frac{\text{Forced Outage Hours}}{\text{Forced Outage Hours + Service Hours}} \times 100\%$

where Forced Outage Hours--time in hours during which pulverizer was unavailable due to a forced outage
Service Hours--total hours the unit was on line

[2]Information taken from curtailment data. Company records do not accurately classify curtailments as forced or scheduled. Most scheduled pulverizer maintenance is performed during the annual unit outage and is not reflected in the above information.

[3]Outage duration does not reflect hours when unit is off and work is done on the mills, only when it causes an outage or a reduction in load.

TABLES I-2 and I-3
AVAILABILITY DATA
ROLL-RACE AND BALL-RACE MILLS

Plant/Unit	#Mills/ Each Unit	#Mills @ Full Load	Outage Data (Time Period)	Unit Hours On Line	Outage Type #F	Outage Type #S	Outage Duration Hours F	Outage Duration Hours S	MwHr's Lost	Forced Outage Rate	% Unavailability due to mills
[1] ID24 A	10	8	1/1/78- 12/20/78	6808	16	1	482		0		
	10	8	1/1/78 12/20/78	6998	14	1	330		0		

[1] Outage duration does not reflect hours when unit is off and work is done on the mills, only when it causes an outage or a reduction in load.

Plant/Unit	#Mills/ Each Unit	#Mills @ Full Load	Outage Data (Time Period)	Unit Hours On Line	Outage Type #F	Outage Type #S	Outage Duration Hours F	Outage Duration Hours S	MwHr's Lost	Forced Outage Rate	% Unavailability due to mills
ID34 A	7	7	1976						425376		6.5
			1977						700560		10.7
			1/78-7/78						284760		6.5
			8/78						10248		1.9
B	7	7	1976						409416		6.2
			1977						507528		7.7
			1/78-7/78						416976		9.5
			8/78						58128		10.4
C			1976						197232		3.0
			1977						314664		4.8
			1/78-7/78						281400		6.4
			8/78						45696		8.2
D	7	7	1976						367920		5.6
			1977						212520		3.2
			1/78-7/78						284760		6.5
			8/78						7224		1.3
ID35 A	10	10	1976				77	641	3600		
			1977				782	1944	36450		

Table I-4. Pulverizer Associated MwHr's Lost (Percentage Basis)

Mill Type	Plant ID/ Unit	Year	Seals	Lube Oil	Bearings	Shaft Failures	Mechanical Failures	Coal	Foreign Matter	Pulv. Cap. Limited	Pulverizer Feder	Mill Reject Removal	Primary Air Fan	Motor	Electrical	Control Modifications	Fires/Explosions	Testing	Inspections	Other	Unknown	Unspecified	MwHr Lost
BOWL MILL	ID5A	1975	0.	1.8	0.	0.	2.7	4.9	0.	0.02	0.3	0.	0.	0.	0.	0.	0.	0.	0.	8.8	0.	81.5	334060
		1976																					
		1978(thru Aug)	0.	0.	0.	0.	0.	23.8	0.	0.	48.7	0.	0.	0.	0.	1.8	0.	21.5	0.	4.2	0.	0.	2133
	B	1975	0.	0.9	3.3	11.8	1.1	3.7	0.1	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.9	0.	78.2	273312
		1976	0.	0.	0.	0.	0.	7.9	0.	0.	0.	31.1	0.	0.	0.	0.	0.	45.3	0.	15.7	0.	0.	1374
		1977	0.	5.5	0.	0.	0.1	42.7	3.8	0.	0.	0.	0.	0.	0.	19.3	0.6	17.1	0.	10.9	0.	0.	7600
		1978(thru Aug)																					
	C	1975	0.	0.	0.	0.	0.	1.8	0.	0.	0.	0.	0.	0.	0.	2.3	0.	0.	0.	0.	26.6	69.3	10154
		1976	0.	0.	0.	0.	0.	29.7	0.	0.	0.	0.	0.	0.	0.	1.6	58.3	0.	0.	0.	10.4	0.	24836
		1977	0.	0.	0.	0.	0.	5.8	0.	0.	0.	0.	0.	0.	0.	94.2	0.	0.	0.	0.	0.	0.	8678
		1978(thru Aug)																					
	D	1975	0.	24.2	0.	0.	17.8	33.8	0.	0.	0.	0.	0.	0.	24.2	0.	0.	0.	0.	0.	0.	0.	3481
		1976	0.	0.	0.	0.	1.0	17.8	0.	0.	0.	0.	0.	0.	0.	0.	74.1	7.1	0.	0.	0.	0.	22494
		1977	0.	0.	0.	0.	0.	18.4	0.	0.	0.	0.	0.	0.	0.	0.	81.6	0.	0.	0.	0.	0.	207
		1978(thru Aug)																					
	ID6A	1975																					
		1976																					
		1977	14.0	15.0	5.0	0.	0.	0.	2.0	0.	0.	0.	0.	0.	0.	3.0	30.0	0.	0.	31.0	0.	0.	17060
		1978(thru Aug)	0.	7.0	0.	0.	7.0	4.0	2.0	0.	0.	0.	0.	0.	0.	35.0	17.0	0.	24.0	4.0	0.	0.	8575
	ID7A	1975																					
		1976																					
		1977	0.	5.0	17.0	0.	6.0	11.0	0.	0.	0.	0.	4.0	1.0	7.0	0.	7.0	0.	9.0	17.0	16.0	0.	156656
		1978(thru Aug)	0.	8.0	0.	0.	12.0	13.0	1.1	0.	0.	0.	0.	0.8	0.	0.2	12.8	0.	36.0	12.6	3.5	0.	92526
	ID8A	1975	0.	0.5	0.	0.	86.0	0.5	1.0	0.	0.	0.	0.	3.0	0.	3.0	1.0	0.	3.0	2.0	0.	0.	112000
		1976	0.	2.0	0.	0.	17.0	33.0	1.0	0.	0.	23.0	0.	0.	0.	8.0	3.0	0.	0.	13.0	0.	0.	22248
		1977	0.	19.0	0.	0.	39.0	8.0	0.	16.0	0.	0.	0.	0.	0.	3.0	2.0	0.	0.	13.0	0.	0.	18030
		1978(thru Aug)	0.	0.5	6.0	0.	84.0	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	7.0	2.5	0.	0.	44313
	ID9A	1975	0.	0.	0.	0.	1.2	20.1	0.4	0.	0.	0.	0.	0.	63.9	13.0	0.	0.	1.3	.1	0.	0.	22980
		1976	0.	0.	0.	22.2	8.3	29.7	9.6	6.1	0.	0.	4.1	5.9	0.	0.	3.6	0.	9.9	.6	0.	0.	96846
		1977	0.03	5.6	0.	0.	4.8	25.8	8.0	0.	0.	0.4	0.8	0.	0.	0.1	12.9	0.	34.1	7.47	0.	0.	84922
		1978(thru Aug)	2.1	2.4	0.	61.3	0.	7.0	6.0	0.	0.	0.	15.4	0.	0.	0.4	3.0	0.	0.	2.4	0.	0.	32054
PLANETIZING ROLL	ID30B	1975																					
		1976																					
		1977	0.	0.	0.	0.	0.	0.	0.	0.	0.04	0.	0.	0.	0.	0.	0.	0.	0.	3.76	0.	96.2	34490
		1978(thru Aug)	0.	0.	0.	0.	0.03	17.9	0.	0.	21.4	0.	0.	0.	0.	0.	0.	0.	0.	15.3	0.	45.4	33328
	ID31A	1975																					
		1976	0.	0.	0.	0.	0.	0.	0.	0.	15.2	0.	0.	0.	0.	5.8	9.0	70.0	0.	0.	0.	0.	3982
		1977	0.	1.3	0.	0.	49.6	9.8	0.	0.	9.7	0.	13.2	0.	0.	11.0	0.	0.	0.	5.4	0.	0.	22647
		1978(thru Aug)	0.	0.	0.	0.	51.0	34.6	0.	0.	0.	0.	14.4	0.	0.	0.	0.	0.	0.	0.	0.	0.	75766
	ID32A	1975	0.	0.	0.	0.	49.1	24.3	4.9	0.	0.	0.	15.0	5.7	0.	0.6	0.4	0.	0.	0.	0.	0.	78427
		1976	0.	2.6	0.	0.	0.	31.8	7.6	0.	0.	0.	30.1	9.5	0.	0.6	17.4	0.	0.	0.4	0.	0.	80471
		1977	3.3	28.6	19.3	0.	15.3	8.1	4.6	0.	0.	0.	4.8	5.6	0.	1.5	0.	0.	0.	8.9	0.	0.	89431
		1978(thru Aug)	0.	0.8	4.2	0.	57.9	21.3	2.6	0.	0.	0.	0.2	0.	0.	0.	13.0	0.	0.	0.	0.	0.	46872

TABLE I-5

RANKING OF LOST GENERATION CAUSES--PRESSURIZED BOWL MILLS

DATA BASE: 52 MILLS

Problem Area	MwHr's Lost	% Total	Ranking
Unspecified	493,026	35.30	1
Mechanical Failures	190,728	13.66	2
Coal	140,145	10.04	3
Inspections	94,773	6.79	4
Other	93,251	6.68	5
Fires/Explosions	78,299	5.61	6
Shaft Failures	73,399	5.26	7
Bearings	39,163	2.80	8
Lube Oil	38,309	2.74	9
Unknown	33,587	2.41	10
Electrical	26,493	1.90	11
Control Malfunctions	22,907	1.64	12
Foreign Matter	21,452	1.54	13
Primary Air Fan	15,853	1.14	14
Motor	11,380	.82	15
Pulverizer Feeder	7,948	.57	16
Mill Reject Removal	5,884	.42	17
Testing	3,993	.29	18
Seals	3,087	.22	19
Pulverizer Cap. Limited	2,952	.21	20
	1,396,629	100.04	

TABLE I-6

RANKING OF LOST GENERATION CAUSES--PLANETIZING ROLL MILLS

DATA BASE: 18 MILLS

Problem Area	MwHr's Lost	% Total	Ranking
Mechanical Failures	129,213	27.78	1
Coal	96,275	20.70	2
Primary Air Fan	54,272	11.67	3
Unspecified	48,310	10.39	4
Lube Oil	28,399	6.09	5
Fires/Explosions	20,767	4.46	6
Bearings	19,229	4.13	7
Motor	17,123	3.68	8
Other	15,900	3.42	9
Foreign Matter	15,291	3.29	10
Pulverizer Feeder	9,948	2.14	11
Control Malfunctions	4,791	1.03	12
Seals	2,951	.63	13
Testing	2,787	.60	14
Shaft Failures	0	0	15
Pulverizer Cap. Limited	0	0	15
Mill Reject Removal	0	0	15
Electrical	0	0	15
Unknown	0	0	15
	465,196	100.01	

TABLE I-7

Effect of Eastern and Western Coal Properties on Mill Wear

Plant/Unit	Number Mills/ Each Unit	Number Mills at Full Load	Startup Date	Grinding Elements	Excessive Wear	Coal Type[4]	HgI	Percent Moisture	Percent Ash	Percent Sulfur	Abrasiveness	Major Overhaul Tonnage Throughput (X1000)	¢/Ton Coal Ground
[1]ID 2, A,B	8	7	8/71,7/72	Yes	No	W	34	24	15	.8	2.3	400	16-20
[1]ID 3 A	6	5	5/75	Yes	Yes	W	52	26.5	10.1	0.6	2.3	500-700	NA
B	6	5	3/78	No	No	W	NA	28.7	5.5	0.43	NA	500-700	
[1]ID 7 A	6	6	10/72	No	No	E	58	7	1.5	1.5	1.5	NA	NA
[2]ID 23 A	7	6	5/77	No	No	W	61	30	5.8	.3	NA	NA	NA
[2]ID 25 A,B	11	11	3/73,11/73	Yes	Yes	E	57	10.1	16.3	3.5	2.9	1,000	34
[3]ID 30 A,B	6;4	6;4	5/70;8/73	Yes	Yes	E	50	7.5	11.6	2.5	NA	NA	NA
[3]ID 31 A	6	5	12/70	Yes	Yes	E	55	5.5	8.5	3.7	NA	NA	NA

[1]Pressurized Bowl Mills at Unit

[2]Roll-Race Mills at Unit

[3]Planetizing Roll Mills at Unit

[4]W-Western Coal
E-Eastern Coal

NA - Not Available