Technical Publication

A Comparison of Three Types of Coal Pulverizers

by

L. M. Benson
Senior Engineer, Fuel Burning Product Development
RILEY POWER INC.
a Babcock Power Inc. company
(formerly Riley Stoker Corporation)

C. A. Penterson
Manager, Fuel Burning Product Development
RILEY POWER INC.
a Babcock Power Inc. company
(formerly Riley Stoker Corporation)

Presented to
American Power Conference
Chicago, Illinois
April 22-24, 1985

RPI-0038

A COMPARISON OF THREE TYPES OF COAL PULVERIZERS

by

L.M. BENSON, Senior Engineer
Fuel Burning Product Development
and
C.A. PENTERSON, Manager
Fuel Burning Product Development
RILEY STOKER CORPORATION
WORCESTER, MASSACHUSETTS

ABSTRACT

In a continuing effort to offer the power industry a wide variety of coal handling equipment, Riley Stoker Corporation has recently acquired a European-designed vertical roller pulverizer, embodying some unique features not found in other medium-speed pulverizers.

This paper presents a comparison of the Riley Vertical Roller Mill with Riley's two other pulverizer designs—a low-speed ball tube mill and a high-speed attrition pulverizer. Specific topics include throughput capability, fuel type, availability, reliability, power consumption, product fineness, coal drying capability, feed size requirements and application data.

INTRODUCTION

Since the early 1930's and 40's, Riley Stoker Corporation has provided the power industry with low-speed ball tube mills and high-speed attrition (ATRITA®) pulverizers for use in the pulverization of all available coals, ranging from anthracites to lignites. The most common usage has been in direct-fired coal systems of fossil fueled steam generators. In all, Riley has supplied over 1000 ATRITA units, and 175 ball tube mills having individual mill capacities ranging from 1 to 150 tons per hour.

To complement these pulverizer lines and enable an optimum match of comminution machine with fuel and site-specific conditions, Riley Stoker Corporation recently acquired an exclusive license for the sale and manufacture of a European-designed medium-speed vertical roller mill.

This vertical roller mill (VRM) was developed by F.L. Smidth and Co. (FLS), Denmark, for application in the coal and cement industries. By having over 20 years prior operating experience with other VRM's and in-house expertise designing large rotating machinery, FLS was ideally positioned to develop and provide the industry with an improved state-of-the-art version of a vertical roller mill. And accordingly, in over 30 foreign installations since 1980, FLS has successfully placed in operation their own VRM's, grinding coal or raw meal, with mill capacities ranging from 7 to 300 tons per hour.

The following is a brief description of these three kinds of Riley-supplied pulverizers and fuel systems.

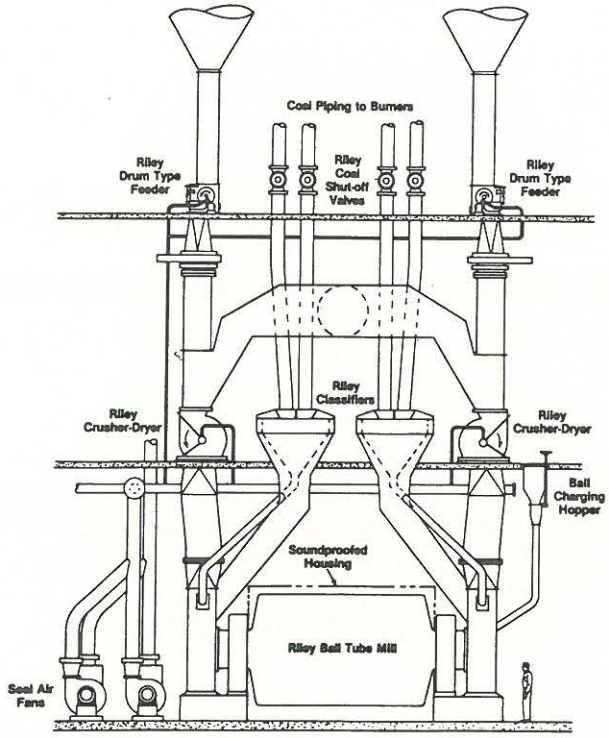


Figure 1 Typical Arrangement of the Riley Ball Tube Mill System

DESCRIPTION OF PULVERIZERS AND FUEL SYSTEMS

Ball Tube Mill

The Ball Tube Mill (BTM) is a cylindrical low-speed grinding mill. It consists of a steel barrel, lined with cast abrasion-resistant liners and partially filled with hardened steel balls. Coal and pre-heated primary air enter one or both ends of the mill from a crusher/dryer or feeder. As the mill rotates, the balls cascade and pulverize the coal by impact and attrition. The pulverized coal is then conveyed by air to centrifugal classifiers. Properly sized pulverized coal exits the classifier into coal piping for transport to the furnace. Oversized product is, however, separated and returned to the mill for further grinding.

There is minimal metal-to-metal contact of the grinding elements in the BTM resulting in very little wear and low maintenance. The mill heads are cast integral with trunnions which are supported in special heavy duty water-cooled bearings. Pressurized air seals between the rotating mill and inlet/outlet boxes prevent leakage of coal dust or air from the mill. Each mill is completely enclosed in an insulated sound-attenuating housing with panels that provide easy access to the mill. The mill is driven by a direct-coupled a.c. motor through a speed reducer and final single helical gear set having the driven gear mounted on the mill barrel.

Figure l shows the application of a ball mill in a typical direct-fired coal system. These systems can be designed with or without crusher/dryers depending on the coal characteristics. Use of crusher/dryers in tandem with ball tube mills provides efficient two stage comminution, resulting in lower overall system power consumption, particularly when pulverizing high moisture and/or oversize coal.

ATRITA Pulverizer

The ATRITA pulverizer is a high-speed, compactly designed machine which reduces raw coal to pulverized coal by the combination of crushing, impact and attrition. The ATRITA has separate crusher, pulverizer, and fan sections—all combined in a shop-assembled package.

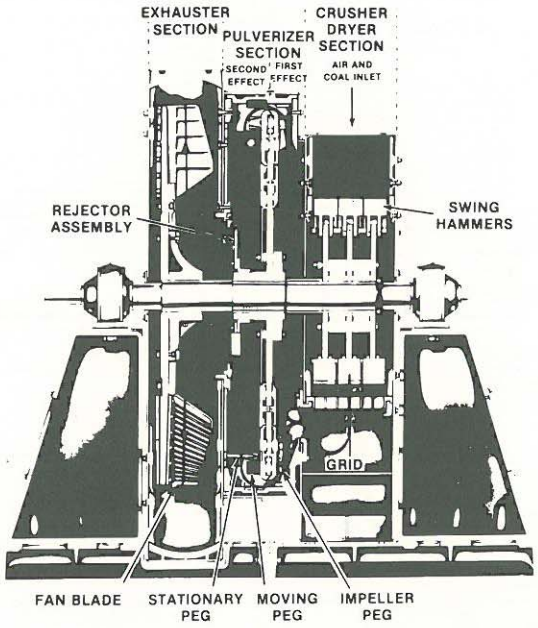


Figure 2 Riley ATRITA Pulverizer

As shown in Figure 2, coal and preheated primary air first enter the crusher section. Here the coal is impacted on a grid section by swing hammers, reducing the coal to a nominal ¼" size. Drying of the coal also occurs in this section. After the coal passes through the grid section, it enters the two-stage pulverizing section. This section further reduces the coal size by attrition and by impact of coal on the moving and stationary parts. There is no metal-to-metal contact of pulverizing elements. Oversized particles do not pass the rejector and remain in the pulverizing section for further size reduction. Properly sized pulverized coal, however, passes into the fan section. In this section, an integral fan wheel, with abrasion-resistant alloy fan blades, transports the pulverized coal from the pulverizer section through the coal pipes to the burners. A typical arrangement of an ATRITA pulverizer system is shown in Figure 3. ATRITA pulverizers can be designed for either pressurized or non-pressurized (suction) operation.

Vertical Roller Mill

The vertical roller mill (VRM) shown in Figure 4 is an air swept, medium-speed, vertical pulverizer with integral classifier. It pulverizes coal by applying hydraulically-loaded grinding pressure through three grinding rollers onto a rotating bed of coal. Grinding pressure can be adjusted to account for variations in coal grindability and desired product fineness.

Raw coal is fed through a centrally located feed pipe to the center of the grinding table. As the flat grinding table rotates, coal is gradually forced out towards the edge where it passes underneath the rollers. When the ground material leaves the edge of the table, it is met by an upward high velocity stream of hot primary air which then dries and carries the pulverized coal through the classifier. Properly sized product leaves the mill and is transported through coal piping to the burners, while the coarse fraction falls back to the center of the grinding table for further grinding.

The Riley VRM has a unique shearing action developed between the flat grinding table and rollers thereby providing more efficient grinding. As the table and rollers rotate, the relative velocity between roller and table constantly changes. This changing velocity causes the roller to slide over a relatively thin layer of coal on the table, thus creating a shearing force. This shearing force combined with the compressive force induced by the rollers enables efficient pulverization of the coal. The thin coal layer is maintained over the mill's entire load range by automatic programmed adjustment of hydraulic grinding pressure.

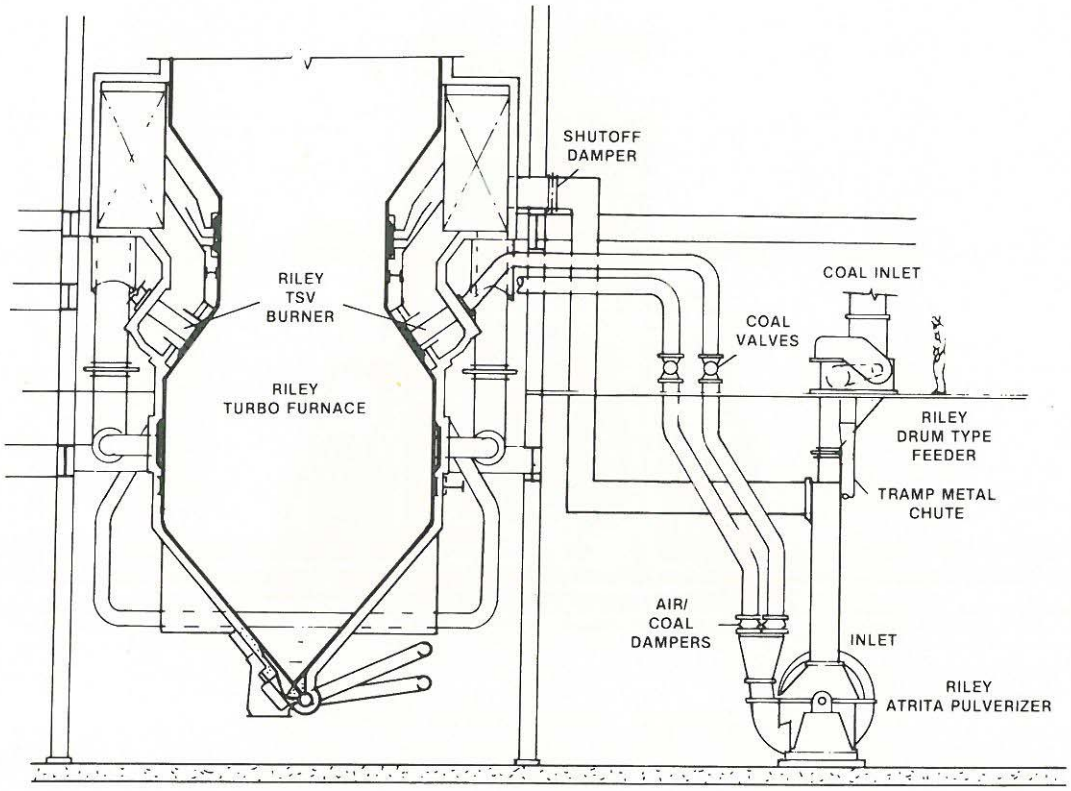


Figure 3 Typical Arrangement of a Riley ATRITA Pulverizer System

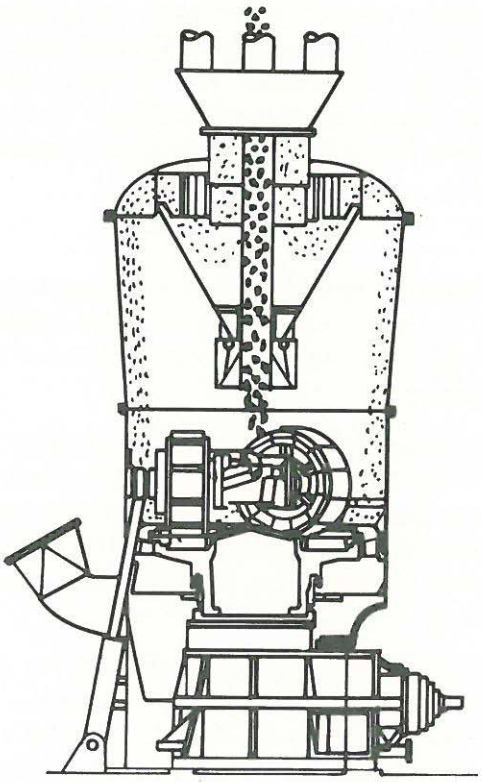


Figure 4 Riley Vertical Roller Mill

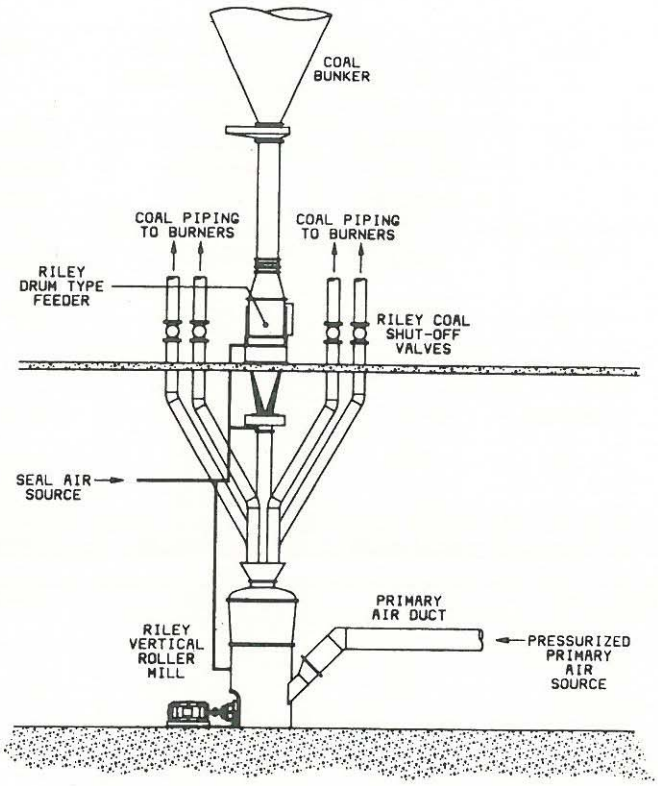


Figure 5 Riley Vertical Roller Mill System

Figure 5 shows the installation of a vertical roller mill in a typical pulverized fuel system. These mills are designed for pressurized operation since primary air fans are located upstream of the mill. Similar to the BTM, pressurized seal air is also used to prevent leakage of coal dust from the mill and to protect bearings in the grinding rollers.

MILL SYSTEM COMPARISON AND PERFORMANCE

Refer to Table I for a summary of the design features for each mill system.

Mill Comparisons—General

The BTM is a low-speed mill that primarily grinds coal by impact and attrition. The VRM is a medium-speed mill that grinds coal by compression and, because of the low coal inventory in the mill and flat grinding surfaces, develops shearing action as well. For both mills a constant centrifugal force is maintained. The speed decreases with mill size and remains constant for a given mill diameter. The ATRITA mill speeds also decrease with increasing mill size. As described earlier, it is a high-speed mill that pulverizes coal by the combination of crushing, attrition and impact.

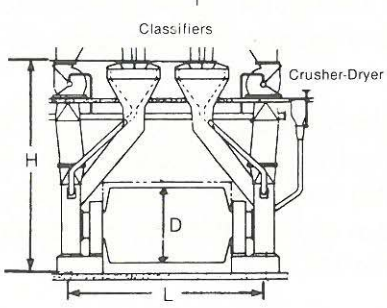
The BTM System should be equipped with a crusher/dryer for high moisture coals, or coals with a top size greater than ¾ inches. The primary crushing and drying is performed in the crusher/dryer. This two-stage approach results in a system that can efficiently pulverize coals having wide ranges of size and moisture contents. Neither the ATRITA design nor the VRM utilizes a crusher/dryer ahead of the mill when grinding either high moisture coals, or large-sized coals.

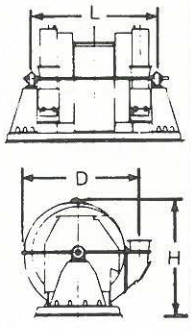
Coal Characteristics

Coal characteristics are integral to pulverizer system selection, sizing and performance. The production capacity for each mill depends upon the following feed properties:

Maximum Feed Size — In general,the coal entering a mill system should be crushed to a size no larger than

Item	Units	Ball Tube Mill with Crusher-Dryer	Ball Tube Mill without Crusher-Dryer	ATRITA	Vertical Roller Mill
Primary Method of Grinding	—	Crushing/ Impact & Attrition	Impact & Attrition	Crushing, Attrition & Impact	Compression & Shear
Mill Speed	RPM	15-22.5	15-22.5	900-1800	34-59
Capacity	Tons/Hr.	7-154	7-154	3.5-27	6.5-101
Desired Coal Properties					
- Feed Size	Inches	< 2.5	< 0.75	< 2.5	< 1.25-3.5
- Total Moisture	%	0-50	0-20	0-50	0-50
- Grindability (HGI)	—	35-110	35-110	35-110	35-110
- Abrasiveness	—	Low-High	Low-Severe	Low-Med.	Low-High
Prod. Fineness thru 200 Mesh Standard Screen	%	70-95	70-95	70-95	70-95
Typical Air to Coal Ratio at 100% Mill Load	—	1.25	1.25	1.1 - 1.3	1.4
Specific Power @ 100% Mill Load & Typical Conditions					
- Crusher-Dryer	KWH/Ton	1-2	—	—	—
- Mill	KWH/Ton	10-15	13-19	—	6-11
- P.A. Fan	KWH/Ton	3-5	3-5	—	3-5
- Total	KWH/Ton	14-22	16-24	15-22	9-16
Start-Up Time	Minutes	15-20	15-20	1-5	5-10
Noise-Mill Only	db	80-85	80-85	65-75	80-85
Approx. Dimensions					
- Mill Dia. (D)	Feet	7-15	7-15	5-10	5-15
- Mill Length (L)	Feet	12-30	12-30	5-11	9-24
- Mill & Classifier Height (H)	Feet	32-50	32-50	5-10	13-38





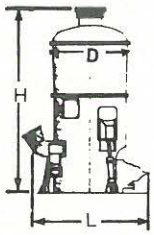


Table I

2 inches. This is required to prevent blockage of the feeding and handling equipment prior to the mill. BTM's with crusher/dryers can grind coals of almost any size without mill deration. Occasional lumps of 3-4 inches will not affect mill performance. In fact, the standard capacity of the mill increases 10% if a crusher/dryer is incorporated. The recommended top size is ¾ inches for the BTM without a crusher/dryer. Otherwise, deration of the mill occurs. The ATRITA pulverizer can also handle large pieces of coal without mill deration. The crusher section crushes the coal prior to entering the grinding section. The VRM requires coal to be small enough to be drawn-in between the roller and table. The recommended coal top size varies between 1-¼ inches to 3-½ inches, depending on mill size.

Total Moisture — The ranges given for each mill indicate the moisture levels that the mill can handle without a considerable reduction in capacity. ATRITA and VRM units can grind coals with moisture levels up to 30% and 15%, respectively, without reduction in mill capacity. The BTM does not have the volume of internal recirculation required to adequately dry high moisture coals. The high temperature air needed to dry the coal does not mix as intimately with the coal. However, a BTM equipped with a crusher/dryer upstream of the mill provides an efficient drying and pulverizing system for high moisture coals.

Grindability — The most widely accepted method developed to determine the ability of coal to be pulverized is the Hardgrove Grindability Index (HGI). All mill capacities are based on a standard coal with HGI = 50. The larger the value for HGI, the easier it is to grind the coal, resulting in a higher mill capacity. An HGI of 35 reduces the mill capacity about 20%. Coals with HGI less than 35 can be pulverized, but mill capacities are reduced significantly. For low rank coals, HGI varies with moisture content. A value for HGI must then be determined that corresponds to the moisture content of the coal as it enters the mill.

Product Size Adjustment

Standard pulverizer capacities are based on the product passing 70% through a 200-mesh standard screen. The BTM system and VRM have externally adjustable vanes in their centrifugal classifiers. The vanes can be turned to slightly increase or decrease the fineness to suit boiler requirements. The ATRITA pulverizer contains rejector arms in the classifier section, which are adjusted for the desired fineness. All mills can achieve up to 80-95% through 200-mesh, if desired, but the mill capacity may be considerably reduced at the higher fineness levels.

Abrasion/Corrosion Considerations

There are several laboratory test procedures to predict the abrasive tendency of coal. Knowing the abrasive tendency of coal is important when designing the mill system. Highly abrasive coals are apt to shorten the life of the grinding elements in the ATRITA and VRM units. Wear-resistant materials are used to obtain the maximum life of the wear parts. The BTM can grind abrasive coals with little wear to the mill itself. The grinding balls wear faster, but they can be easily replenished during operation. Coals that are corrosive, or acidic, could also cause wear problems for any coal handling or grinding system. This occurs in low temperature areas where surface moisture is present.

Primary Air Requirements

The air-to-coal ratios listed in Table I are typical values for each system at 100% mill load. Primary air is used to dry and convey the coal. High moisture coals require high primary air temperatures in order to dry the coal. Often times, the air to coal ratio is increased in order to reduce the required primary air temperature. Increasing the volume of primary air for coal drying has little effect on mill operation. However, the air-to-coal ratio should be kept relatively low in order to maintain proper burner operation and turndown.

Power Consumption

The power requirements are based on 100% mill load, while grinding a wide range of coals to a desired product fineness. The power requirements given for the VRM compensate for the additional power needed when parts are worn. The BTM and ATRITA power requirements are not appreciably affected by wear of the grinding parts.

Mill Turndown

All of the mills can provide high turndown and quick response times. System turndown is normally limited by burner stability. Start-up times given indicate the time required to reach full load.

Maintenance Considerations

Maintenance requirements are related to coal properties, in general. Maintenance requirements for the BTM are minimal. The balls, which are the principal wearing parts, are replaced while the mill is in service. The balls are stored in an air-tight lock hopper and fed to the mill by gravity. Mill liners usually last over 10 years before needing replacement. Swing hammers in the crusher/dryer can be replaced in a few hours. The wear elements of both the ATRITA and VRM designs can be completely overhauled in a one or two day outage. Neither mill has to be dismantled. All pulverizer parts are accessible and are designed for ease of repair. The roller and table liners in a VRM are segmented to facilitate easy replacement. In general, the grinding elements for the VRM should last two or more years, while an ATRITA pulverizer overhaul occurs every 1-2 years.

Sound Levels

The BTM, ATRITA, and VRM designs are relatively quiet mills. Silencer housings are used around the BTM, whereas the VRM and ATRITA mills are inherently quiet machines and require no sound-attenuating devices.

Space Considerations

A BTM system requires more space than either the ATRITA or VRM system. The crusher/dryer mill, and classifier are all separate pieces of equipment. The ATRITA pulverizer is the most compact unit of the three. As mentioned earlier, the crusher/dryer, pulverizing, classifying, and fan sections are all combined in a shop-assembled package. The VRM is also relatively compact. It contains both the pulverizer and classifier in one unit. See Table I for relative sizes.

SUMMARY

The optimum mill design can be determined for a particular need. Coal characteristics, plant size, and application must all be considered when designing the system. All of the items listed in Table I must be evaluated prior to equipment selection. Cost factors determining the economics of each grinding system are: initial capital cost, erection cost, power, maintenance, and availability. These three mill systems can pulverize all ranks of coal and are available in capacities that can be used in industrial or utility units.

Highly abrasive coals require slow moving equipment to avoid excessive wear. High speed mills can pulverize abrasive coals, but the life of grinding elements are considerably shortened. Ball tube mills are rugged machines that require very little maintenance, even when grinding abrasive materials. In addition, the BTM system contains a dual feeder arrangement capable of maintaining MCR if one feeder is forced out of service. This mill system is generally used for large utility installations where availability of the mill is of prime importance.

Because of its compact design, the ATRITA pulverizer is ideal for smaller industrial installations where space is limited. It has a rapid response to load changes, and provides quick start-up and shut-down capability.

The Vertical Roller Mill is a compact mill that incorporates the grinding and classifier section in one unit. No precrushing or drying is necessary. It has a low specific power consumption and a high drying capacity. Because of its size, efficiency, versatility of operation, and maintenance requirements, this mill type has the broadest range of application.

The handling, pulverizing, and burning of coal involves many variables and a wide range of conditions. Riley Stoker Corporation has met these various requirements by providing the industry with a wide variety of fuel burning equipment. As future conditions change, Riley Stoker will continue to develop the technologies necessary to meet the demands of the industry.