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Optimum Operation and Maintenance of EL Pulverizers

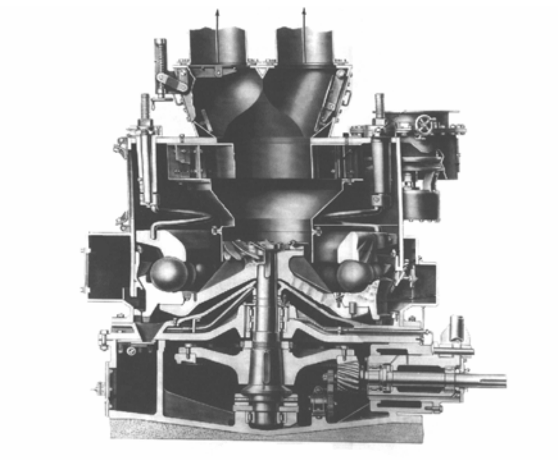


Figure 1 - B&W EL Pulverizer

The EL pulverizer is a medium speed ball-and-race mill working on the ball bearing principle. EL pulverizers are manufactured in 18 sizes ranging from EL-17 to EL-76. The numeric specification on EL pulverizers indicates the pitch circle of the balls in inches. EL pulverizers operate at capacities between 1½ *(EL-17)* to 20 *(EL-76)* tons per hour based on 50 H.G.I. coal. Most electric utility installations utilize the EL-50, EL-64, EL-70 or EL-76. The Babcock and Wilcox EL pulverizers can provide outstanding pulverizer performance when optimum operational and maintenance practices are adhered to. Optimum operation of the EL pulverizer requires the following:

- Coal fineness of 75% passing 200 Mesh and ≤0.1% remaining on 50 Mesh. EL pulverizers that utilize ball bearing type grinding achieve very high 50 Mesh fineness much easier than other types of pulverizers.
- A maximum imbalance of ±5% deviation from the mean dirty airflow between each pulverizer's separate fuel lines.
- A maximum imbalance ±10% deviation from the mean fuel flow between each pulverizer's separate fuel lines.
- Pipe to pipe clean air balance within ±2% of the mean pipe velocity.
- Air to fuel ratio of 1.75 to 1.8 pounds of air per pound of fuel.
- Pulverizer to pulverizer mass air and fuel balance within ±5%.
- Pulverizer outlet temperature of 160°F or higher.
- Minimum fuel line velocity of 3,300 Fpm.

Operation within these parameters is critical to the following items:

- Ensuring stable burner flames
- Prevention of fuel line stoppages, pulsation or slugging.
- Ensuring full design pulverizer capacity is achieved.
- Obtaining acceptable levels on unburned Carbon in Flyash.
- Uniform release and absorption of heat across of the furnace.
- Reduction in furnace slagging and fouling propensities.
- Maintaining furnace and boiler exit gas temperatures within design tolerances.
- Prevention of water-wall wastage and tube metal overheating.
- Maintaining design or better unit heat rate

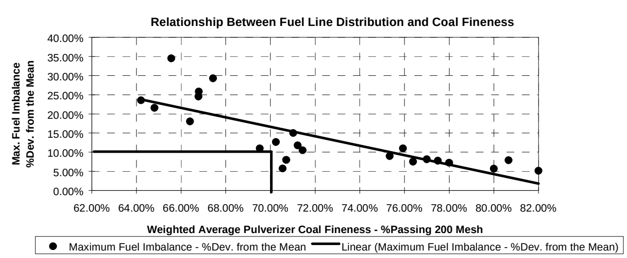
Numerous variables influence distribution of air and fuel between a pulverizer's separate fuel lines. These variables are as follows:

- Size of pulverizer coal particles leaving the pulverizer *(Fineness).*
- System resistance of each individual fuel conduit.
- Total airflow through the pulverizer which is controlled on a ratio of weight of air to fuel.
- Velocity of air/coal mixture passing through each burner line.
- Maintenance of critical components such as the classifier, classifier cone, grinding rings, balls, cabbage cutter, orifices and burner components.

Coal Fineness and Fuel Balance

Utilization of Pre-NSPS burners required 70% passing 200 Mesh and ≤1% remaining on 50 Mesh. Many operators today are forced to utilize Low NOx burners. Low NOx burners require a higher degree of precision in delivery of fuel and air to the furnace. To compensate for fuel and air imbalances and lower exposure time of fuel carbon to free Oxygen at temperatures above ignition points, coal fineness standards required reevaluation. Low NOx burner firing configurations require ≥75% passing 200 Mesh with ≥99.9% passing 50 Mesh. Coal fineness is not always required for acceptable NOx emissions. However, optimum combustion and flyash with ≤6% unburned Carbon *(L.O.I.)*, requires improved fineness. Fineness levels of 75% passing 200 Mesh and 99.9% passing 50 Mesh improves fuel distribution as well as flyash unburned Carbon. Higher coal fineness level will also promote flame stability at lower loads, increasing boiler turn down without the support of oil flames.

As fineness increases, fuel balance improves. The finer the coal, the coal and air mixture characteristics are closer to a fluid than solids in suspension. The more fluid coal/air mixture makes achieving complete homogenization of the mixture leaving the pulverizer much easier. A more homogenous mixture of air and coal results is more even distribution between burner lines. EL Pulverizers utilize a classifier employing centrifugal separation to return coarse coal particles to the grinding zone for regrinding. The "Swirl" imparted by centrifugal classification separates coarse and fine coal particles. Homogenization of the stratified mixture leaving the pulverizer can be achieved with intense swirl. More massive coal particles (lower fineness) have more momentum when entrained in air at a certain velocity and are more easily stratified than finer coal particles that have less mass thus lower momentum. After separation of coarse and fine coal particles, fuel and air balance is further aggravated by airflow imbalance. Typically, burner lines that receive the largest quantity of coarse coal particles have the lowest air velocities. The graph below illustrates data collected on a unit with (5) separate pulverizers with differing maintenance intervals and classifier setting. This graph indicates improving fuel balance with higher fineness level despite other parametric differences.



Raw Coal Size

Maintaining optimum sizing of raw coal to the pulverizer is mandatory in achieving capacity and fineness. Optimum raw coal feed size for EL pulverizers is ¾" to 1". Raw coal feed should never exceed 1¼", raw coal this size can plug throats and cause vibration. Raw coal that is too fine can plug the pulverizer or delivery components upstream of the pulverizer. Regular yard crusher inspection and maintenance is required to maintain optimum raw coal sizing.

Mill Fires

Sudden and large increase in pulverizer outlet temperature usually indicate a mill fire. External inspection during mill fires will reveal a hot mill housing that may peel or char off housing paint. Mill fires require immediate action to prevent further combustion. To extinguish a mill fire, air available for combustion must be reduced.

During a mill fire, pulverizer air flow should not be increased. Increased air flow could result in explosion. The procedure applied to extinguish a fire on an in-service pulverizer is as follows:

1. Increase the raw coal feed to the pulverizer to the maximum pulverizer capacity.
2. Make the transition from hot to cold air operation. Avoid making sudden changes in air flow through the pulverizer.
3. Monitor pulverizer outlet temperature. After outlet temperature has returned to normal, continue operation until temperature stabilizes. Coal flow then may be reduced according to pulverizer demand. Ensure reductions in fuel flow are accompanied by proportional decreases in air flow to maintain a fuel rich mixture.

Pulverizer Skidding

Pulverizer skidding is the sliding or "skidding" of pulverizer balls rather than rotation with upper and lower grinding rings. Skidding happens immediately without any type of warning. Skidding is usually the result of insufficient spring compression, also causing poor fineness, fuel balance and capacity. Skidding pulverizers are indicated by extreme noise in the immediate area of the pulverizer, sudden and large increase in pulverizer motor current *(amps)* and increased mill differential indicating a "plugged mill". Suspension of pulverizer skidding warrants immediate pulverizer tripping. Heat generated by skidding can crack or break balls or the top grinding ring. Besides insufficient spring compression, flat spotted or banded balls and/or large coal chunks or tramp metal *(from raw coal feed)* jammed under the balls can cause skidding.

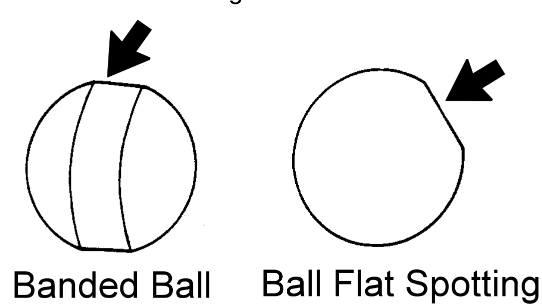


Figure 6 - Grinding Ball Banding and Flat Spotting

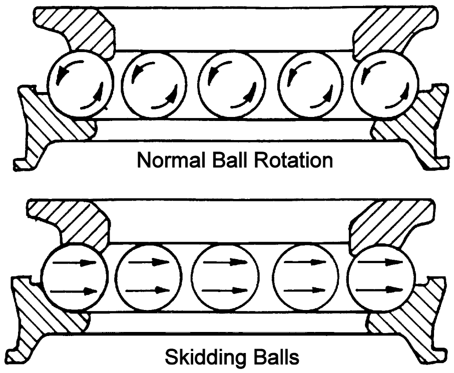


Figure 7 - Normal Ball rotation and during skidding.

Spring Compression

Springs provide compressive force required to grind coal and prevent rotation of the top ring. Insufficient spring tension decreases capacity, decreases fineness and could cause a grinding ring failure. Too much spring tension can cause unnecessary increase in mill power consumption. Spring compression *(vertical length under load)* decreases as grinding elements wear, this decreases force exerted on the top ring and requires periodical adjustment of spring bolts. Adjustment is facilitated by tightening spring adjusting nuts that move spring bolts up or down. During inspection, spring settings are determined by direct measurement from the pulverizer interior. Before and after each spring adjustment, spring setting and external spring bolt dimension shall be recorded. External measurement of the spring bolt is an indication of ring and ball total wear. This also allows determination and spring adjustment with the pulverizer on-line. Figure 3 documents required spring compressions.

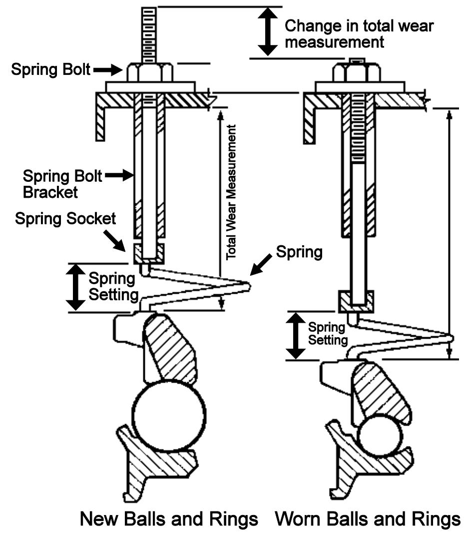
Pulverizer Size	Total Spring Force (Pounds)	Spring Setting (Inches)	Wire Diameter (Inches)	Spring Free Length (Inches)	Number of Springs
EL-50	20,400	4 23/32	1 1/2	8 1/4	4
EL-53	22,100	4 3/8	1 1/2	8 1/4	4
EL-56	22,100	4 3/8	1 1/2	8 1/4	4
EL-64	25,500	5 5/16	1 1/2	8 1/4	6
EL-70	28,900	4 29/32	1 1/2	8 1/4	6
EL-76	30,500	4 23/32	1 1/2	8 1/4	6

Figure 3 - Desired Spring Compression for EL Mills

	Compressed Length of Spring in Inches									
Pulverizer Size	~Pounds of Force per Ball → 1100	1200	1300	1400	1500	1600	1700	1800	Number of Balls	Ball Diameter
EL-50	5 31/32	5 3/4	5 9/16	5 11/32	5 1/8	4 15/16	4 23/32	4 1/2	12	12 1/4
EL-53	5 3/4	5 17/32	5 5/16	5 1/16	4 27/32	4 5/8	4 3/8	–	13	12 1/4
EL-56	5 3/4	5 17/32	5 5/16	5 1/16	4 27/32	4 5/8	4 3/8	–	13	12 1/4
EL-64	6 5/16	6 5/32	6	5 13/16	5 5/8	5 15/32	5 5/16	5 1/8	15	12 1/4
EL-70	6 3/32	5 7/8	5 11/16	5 1/2	5 5/16	5 1/8	4 29/32	4 23/32	17	12 1/4
EL-76	5 31/32	5 3/4	5 9/16	5 11/32	5 1/8	4 15/16	4 23/32	4 1/2	18	12 1/4

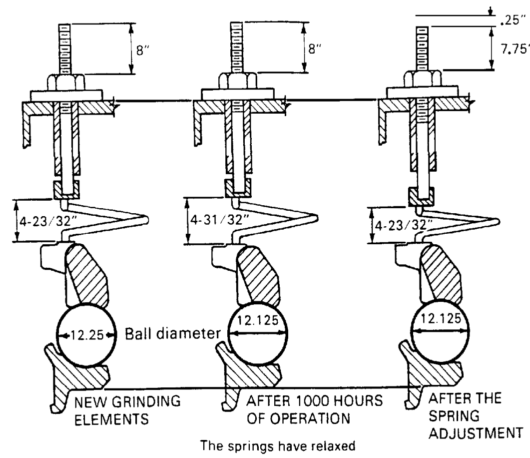
Not Recommended ← | → Recommended

Figure 4 - Spring dimensions on EL pulverizers



Spring Compression

Accurate maintenance and inspection records may facilitate prediction of spring compression change based on hours of operation. When adjusting spring setting by spring bolt external measurement, counter-clockwise turning of the spring bolt adjustment nut increases spring compression. One counter-clockwise turn of the adjusting nut will compress the spring bolts approximately 1/8". Figure 5 illustrates a theoretical situation where records indicate an increase in total wear measurement every 1000 hours of operation.



*This example is for the EL-76 mill. Recommended spring setting is 4 23/32".

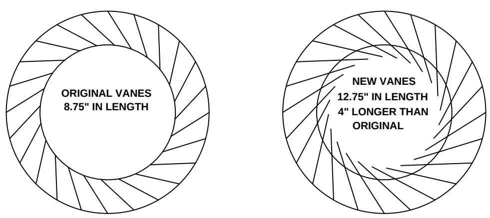
Figure 5 - Spring Adjustment by External Measurement

As a result of wear, balls become smaller and wear deeper pockets into the grinding rings. As balls wear and become smaller, available grinding surface decreases and space between the balls increases. Average gap between grinding balls should be approximately 5/8". Fill-in balls are added when additional space between balls becomes large enough to accommodate extra balls to increase total grinding surface. EL-50 through EL-76 pulverizer grinding balls are 12¼"Ø when new. Worn balls, or sets of balls, of various size are usually classified and kept on hand. When balls are added, balls inserted must be within ¼” of the average diameter of other balls in the pulverizer. When average ball size is smaller than 9¼” diameter, the pulverizer should be overhauled and all balls replaced with 12¼” diameter balls.

Common Pulverizer Modifications

Less than desired pulverizer performance after mechanical and maintenance variables have been addressed may be due to marginal pulverizer capacity or coal quality different from the pulverizer design. Pulverizer modification is often required to achieve desired fineness and fuel balance.

- Extended classifier blades. Increased blade length increases swirl rejecting more coarse particles and improving fuel distribution. Extended classifier blades can improve fineness between 5% and 15% passing 200 Mesh. Figure 8 illustrates typical classifier blade extensions for an EL pulverizer and improvement in fuel distribution.



	PRE-MODIFICATION TESTING			POST-MODIFICATION TESTING	
	DIRTY AIR VELOCITIES	RECOVERED SAMPLE (g)		DIRTY AIR VELOCITIES	RECOVERED SAMPLE (g)
MAXIMUM DEVIATION	+8.27%	+13.2%		+1.55%	+5.45%
MINIMUM DEVIATION	-6.07%	-18.3%		-2.33%	-6.05%

DEVIATIONS ARE %DEVIATION FROM MEAN VELOCITY OR RECOVERY WEIGHT

Figure 8 - Improvement in Fuel Balance with Extended Classifier Blades

- Installation of angled classifier blades will improve coal fineness by changing the diameter of the swirl. Blades are angled further towards the outside of the mill and the back of other classifier blades. Larger coal particles, which are accelerated more than fines due to higher momentum collide with classifier blades and are rejected.

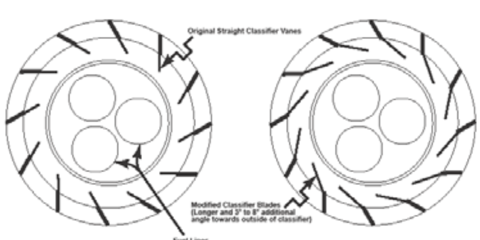


Figure 9 - Angled classifier blades on an EL

- Extension of classifier outlet skirts or “inverted top hat”. This is performed to change the direction of the coal particles in a downward direction towards the classifier reject area. The increased downward momentum and 180° turn of the particles with higher mass allows less of these large particles to be carried to the fuel lines. A 1” extension of the inverted top hat is usually sufficient. Extension of 2” or more will complicate pulverizer disassembly during routine maintenance.

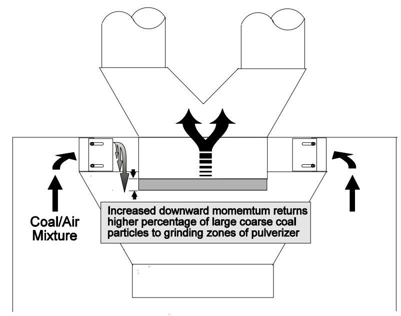


Figure 10 - Inverted Top Hat Extension

- Installation of raw coal deflectors. If raw coal deflectors are absent on EL pulverizers, raw coal is dumped on the outside of the grinding ring. This prevents coal from passing from the inside to the outside diameter of the grinding ring as required for efficient pulverization. The lower pulverizer ring rotates at approximately 90 Rpm on an EL-64,70 or 76 and 100 Rpm on an EL-50 at the shaft. Coal dumped on the outside of the grinding ring will not be able to overcome the centrifugal acceleration to pass through the balls. When this occurs, coal must be transported to the classifier by air through the throat and then circulated to the grinding zone through the tailing discharge. Improper circulation through the mill results in reduced capacity, high mill differential and reduced fineness. Figure 11 illustrates a typical raw coal deflector installed in an EL Pulverizer.

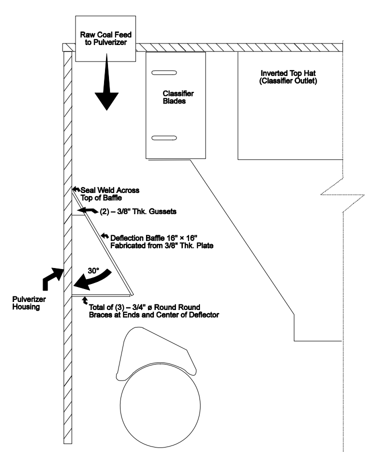


Figure 11 - Raw Coal Deflector for EL Pulverizers

Pulverizer Vibration

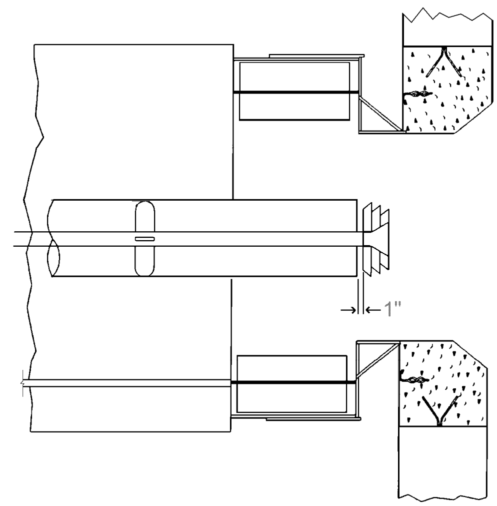
Non-optimum pulverizer air flow can sometimes cause EL pulverizers to vibrate. The mill level also plays a factor in vibration. Pulverizers that are operating fuel lean will vibrate much more than a pulverizer operating at correct air/fuel ratio. Excessive vibration after verification of mill coal level and air flow warrants an internal inspection. Mechanical factors that can cause excessive vibration are as follows:

- Ball flat spotting or banding
- Foreign objects in the pulverizer
- Broken grinding rings
- Excessive ring run-out
- Large raw coal sizing.

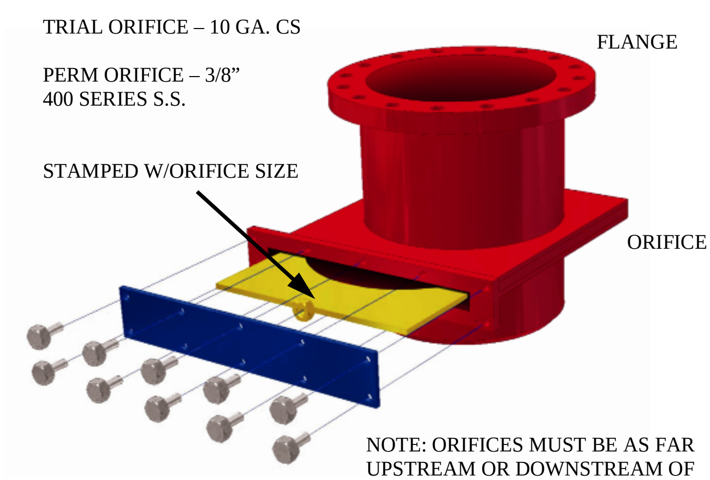
Clean Air Balancing

Balancing system resistance of fuel lines on clean air is the first step of an empirically derived approach to balancing pulverizer fuel and air. Clean air balance is defined as balance of airflow between a pulverizer's fuel lines in the absence of fuel. This is achieved by forcing air through the pulverizer at normal operating mill outlet temperatures with primary air fans while the feeder remains off-line. Clean air balance is determined by measuring the velocity of air flowing through each individual fuel line with a standard Pitot tube*.* Primary airflow optimization will be discussed later in this report. In most cases, primary airflow is higher than desired and will be reduced to optimize performance. Prior to optimization of primary airflow it is prudent to perform clean air balancing. This will insure minimum fuel line velocities are maintained after optimization of primary airflow. Air velocity in all fuel lines must exceed 3,300 feet/minute *(Fpm)*. Fuel line velocities above 3,300 Fpm will insure coal entrainment in primary air. Velocities below 3,000 Fpm allow coal to fall out, accumulate or "dune" in horizontal runs of fuel lines. The 3,300 Fpm minimum velocity includes a 10% safety margin above the absolute minimum line velocity of 3,000 Fpm allowing for some imbalance in air flow between pipes. Coal line accumulations may cause burner pulsation's, flame instabilities and possible stoppages. Fuel lines are balanced by an iterative process utilizing 10 Gauge carbon steel trial orifices. Clean air balance with a maximum of ±2% deviation from the mean between all fuel lines on a pulverizer must be achieved. After optimum orifice configuration is determined, permanent 400 Series stainless orifices are installed. Typical coal line orifices are illustrated by Figure 13**.**

Computer modeling is sometimes performed to determine orifice sizing. Following installation of orifices, clean air balance should always been verified by Pitot traverse of fuel lines. Clean air tests by Pitot traverse is also required to ascertain if any fuel line resistance's not shown by drawings are present. Boilers with EL pulverizers utilizing pre-NSPS burners typically utilize a concentric ring coal diffuser. If so equipped, diffusers on <u>all</u> burners must be at uniform position to ensure differences in fuel line system resistance's are not caused by dissimilar positions. Proper diffuser position is also required to maximize diffuser effectiveness and to promote efficient mixing of fuel and air at the burner. Optimum diffuser position is achieved when the diffuser is centered in the coal nozzle with ±1/8" tolerance and the diffusers trailing edge is 1" beyond the coal nozzle tip. (Figure 12)



<u>Figure 12</u> - Proper Position of B&W Con. Ring diffuser



<u>Figure 13</u> - Typical Coal Lines Orifices