Babcock Power

Technical Publication

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ABSTRACT

Balanced coal and primary air (PA) flow distribution between burner lines is critical to optimizing combustion and burner performance. Low NOx burner performance usually requires that coal flow and PA flow balance between coal pipes be within ±15% and 10%, respectively, of the mean value. Improvements in coal and airflow balance enhance combustion efficiency, leading to improvements in flyash loss on ignition (LOI) and unburned carbon (UBC), CO and NOx emissions.

Orifices or adjustable valves installed in the coal pipes are usually employed to balance primary airflow distribution. Where coal flow imbalance is the result of imbalanced primary airflow, coal flow distribution can be improved by tuning the orifices. In most cases, however, orifices will not achieve the desired coal flow balance if the imbalance is caused by uneven coal flow discharge from the classifier because the orifice adjustment also affects PA flow distribution.

This paper presents a newly-developed technology for correcting coal flow in individual coal pipes from a pulverizer classifier without changing PA flow distribution balance. Performance is demonstrated with CFD modeling and field testing. Online adjustment of coal distribution is also possible with this technology.

INTRODUCTION

Imbalanced fuel flow between coal pipes in pulverized coal fired utility boilers is a longstanding industry problem that hampers combustion efficiency, emissions, and furnace heat distribution. Several adjustable orifice or similar technologies have been introduced to improve primary airflow balance between coal pipes, but fuel imbalance is often independent of the airflow imbalance. Substantial adjustments to airflow often have little effect on the distribution of fuel as it leaves a pulverizer's classifier, resulting in imbalanced fuel distribution to the burners. A technology is needed to correct the problem where it begins: at the discharge of the classifier.

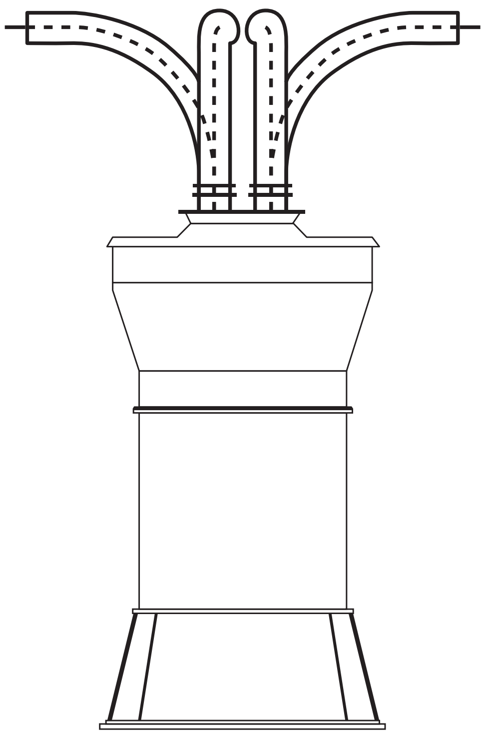
Riley Power Inc., a Babcock Power Inc. company, has developed a device that corrects fuel flow imbalance at the outlet of a centrifugal classifier, and allows control of the distribution of fuel to the pipes. This paper discusses the development of the technology, the installation of a prototype at a large utility boiler, and the results of prototype testing. The technology has been demonstrated to reduce fuel imbalance to within ±10% or less deviation from average while having very little effect on the airflow distribution to the coal pipes. This technology is applicable to most types of centrifugal classifiers either as a retrofit or during initial installation. Currently the technology is Patent Pending.

PROBLEM: FUEL DISTRIBUTION

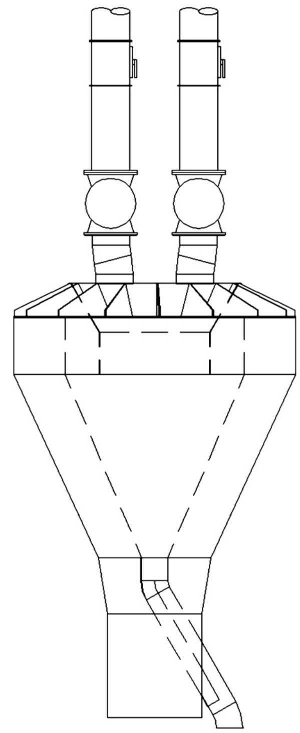
Poor pipe-to-pipe fuel balance is a common problem that can occur with any type of pulverizer system. It is not uncommon for fuel balance between coal pipes to vary by ±30% or more, despite having well balanced primary airflow to the fuel pipes. Fuel imbalance between burners results in a wide range of air/fuel ratios and heat input across the furnace. So-called "heavy" burners do not receive enough primary and secondary air to permit optimized combustion. The excess fuel does not burn as efficiently, resulting in increased carbon monoxide (CO) and unburned carbon (UBC) in the flyash. Large fuel flow variations between pipes also increases NOx emissions and can lead to imbalanced heat input to the furnace and subsequent steam temperature control issues. Unburned carbon and loss on ignition (LOI) decrease boiler efficiency and increase fuel consumption. Elevated UBC and LOI affect flyash quality and ASTM classification for use in concrete [1]. Poor fuel distribution impacts the entire unit and decreases the effectiveness of plant components such as low-NOx burners.

Fuel flow imbalance is commonly addressed by changing pipe-to-pipe airflow with variable or fixed orifices in the coal pipes. Orifices add a non-recoverable pressure loss to the coal pipe which results in a decrease in flow through the pipe. Coal flow balancing with orifices is quite effective if the fuel flow imbalance is caused by highly imbalanced coal pipe airflows. For example, a very short coal pipe without any balancing orifices will have lower pressure drop characteristics, resulting in higher airflow than longer pipes or pipes with more restrictions such as elbows. In this situation, the above-average airflow and air velocity at the entrance to the pipe may entrain excess coal, leading to increased coal flow in that pipe. Balancing the airflows to within ±10% improves the coal flow balance to the extent that it was caused by the imbalanced airflow. This method, however, works poorly if the unequal distribution is caused by stratification of coal at the entrance to the classifier.

Coal stratification at the inlet of a classifier may result from an elbow upstream of a classifier (in the case of an external classifier such as on a ball tube mill) or from uneven airflow inside a vertical mill. Once inside the classifier, the trajectories of fuel particles are controlled by the geometry of the classifier, adjustable vanes, and the airflow distribution. Typically there is insufficient opportunity for the imbalanced flow of particles to reach a homogeneous state inside the classifier, causing non-homogeneous mixtures of air and coal to reach the discharge of the classifier. Since the coal concentration in the discharge region of the classifier is not uniform, the quantity of coal that enters each pipe is not uniform. A device is needed to control the coal flow to each pipe to correct the coal flow imbalances. Typical implementations of centrifugal classifiers are shown in Figure 1 in a vertical pulverizer and a ball tube mill with external classifier.



(a)



(b)

Figure 1. (a) Vertical Mill with Centrifugal Classifier and (b) Stand-Alone Centrifugal Classifier Applied to Ball Tube Mill System

SOLUTION DEVELOPMENT

Riley Power performed computational fluid dynamics (CFD) modeling on multiple design concepts for controlling the coal flow at the discharge of a centrifugal classifier. The model was based on an existing installation of a Riley Power stand-alone classifier, and included ductwork from the discharge of the ball tube mill up to the classifier and coal pipes. The full length of the coal pipes was replaced by short reducing nozzles designed to mimic the flow/pressure relationship of the coal pipes at minimal computational expense. A mass flow boundary condition was used at the inlet and discrete phase particles were injected across the inlet plane. Six particle sizes were injected to represent the particle size distribution entering the classifier. The coupled discrete phase CFD models were solved with Fluent™ software. A simplified model with a straight inlet was first used to prove the function of the concept, and the full model with inlet geometry was used for all additional analysis. The simplified model geometry is shown in Figures 2 and the full geometry model is shown in Figure 3.

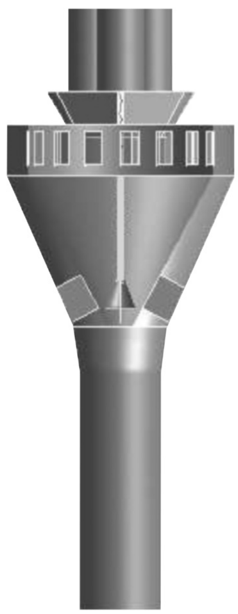


Figure 2. Simplified Straight Inlet CFD Model

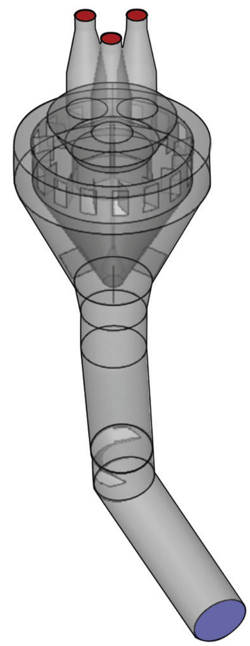


Figure 3. Full CFD Model Geometry with Inlet Elbow

The straight inlet model, without any modifications, produced a relatively uniform particle flow rate to three fuel pipes. All pipes were within ±3% of average. The coal distributor component geometry (currently Patent Pending) was subsequently added to the model to determine if the distribution could be altered. The device was adjusted such that a large change in coal flow distribution was expected to occur. The results clearly proved the concept by shifting the coal distribution from ±3% to ±15% deviation from average. With a proven concept at hand, CFD modeling of the Base Case proceeded with a fully detailed classifier inlet geometry.

The Base Case of the full geometry model was run without the distributor to determine baseline performance including pipe to pipe coal distribution, air distribution, pressure drop, and air velocity profiles. The model results showed poor coal distribution between the pipes, with Pipe 3 at 22% above the average as shown in Figure 4. This result was similar to field test results obtained by the customer using coal fineness recovery rate as an indication of coal flow. Air distribution was acceptable at +3.0% on pipe 1 and -4.2% on pipe 3. The highly imbalanced mass flow rate of coal in each pipe results in different amounts of pressure drop in each pipe induced by the solids loading. Pipe 3, with the highest coal flow, receives the least airflow due to its higher solids loading.

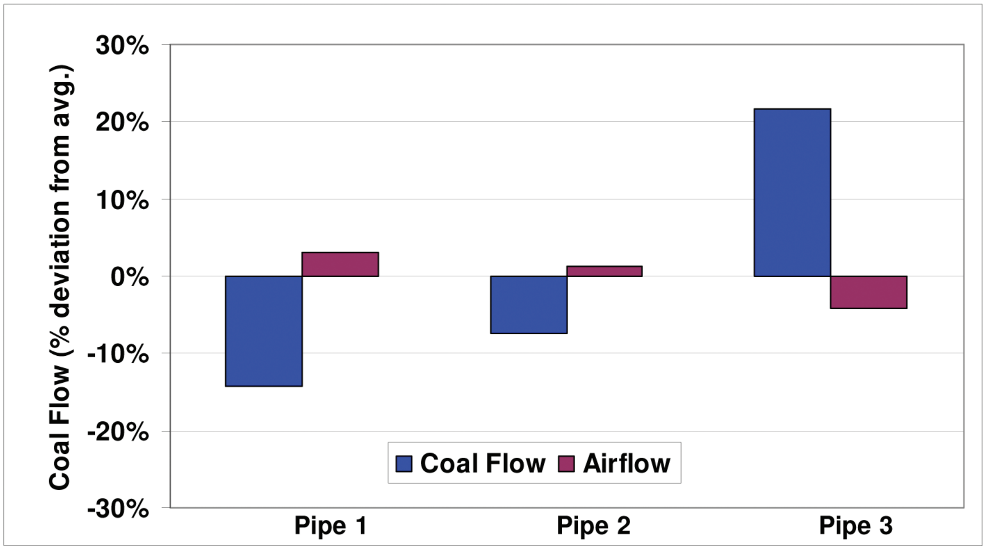


Figure 4. CFD Baseline Coal and Air Flow Distribution

The first adjustment of the distributor device in the model was made based on patterns observed in the straight inlet CFD model. The device has several adjustable components, each with unlimited position increments. The geometry was updated and CFD model run with all other parameters identical to the baseline case. The results showed significant improvement after only one adjustment. The coal flow in pipe 3 reduced from +22% to -4%, and pipe 2 became the highest pipe at +9% above average as shown in Figure 5. Airflow balance improved due to the more closely matched solids loading in the three pipes. As predicted, the device itself had little, if any, direct impact on the pipe to pipe airflow distribution.

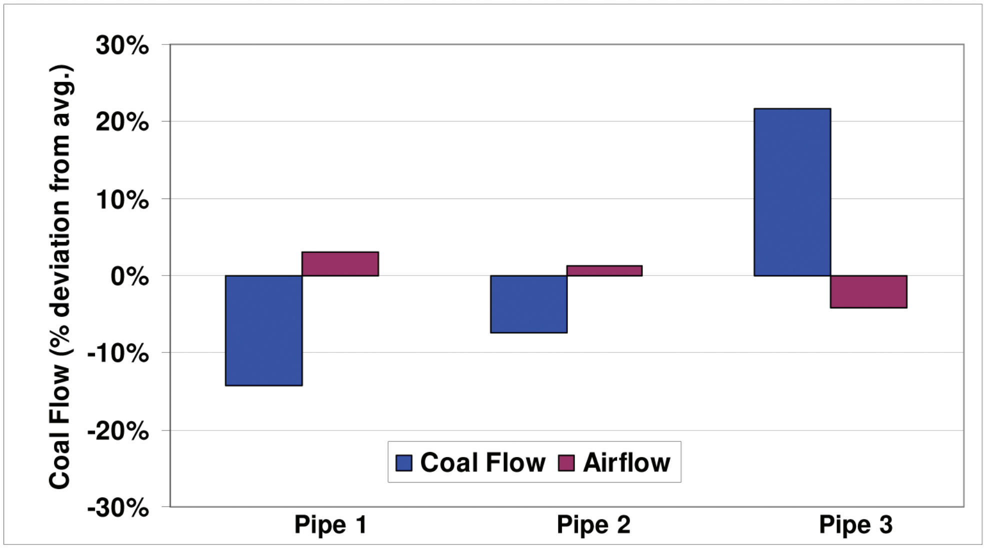


Figure 5. CFD Case 1 Coal and Air Flow Distribution

Additional cases were performed to improve the coal distribution and quantify the effects of various adjustments of the device. The best case resulted in well-balanced coal distribution with the worst pipe at 5.9% above average. Airflow remained within 3.1% of average as shown in Figure 6. Table 1 summarizes the CFD coal and air distribution results.

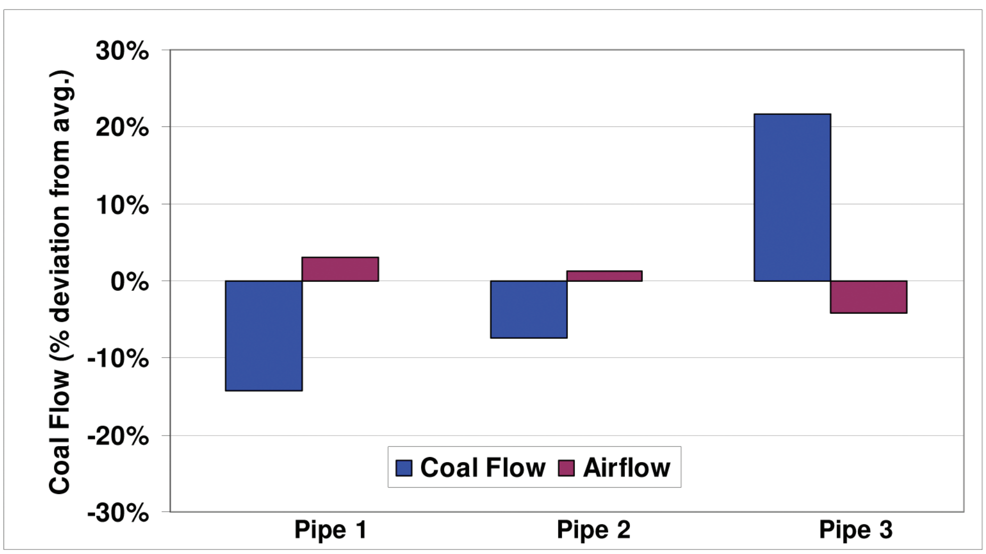


Figure 6. CFD Best Case Coal and Air Flow Distribution

Table 1 - CFD Results Summary

CFD Case		Coal and Airflow Distribution at Classifier Discharge (% deviation from average)			Δ Pressure Drop from Base Case (iwc)
		Pipe 1	Pipe 2	Pipe 3	
Base Case	Coal	-14	-7.4	22	n/a
	Air	3.0	1.2	-4.2	
Case 1	Coal	-5	8.9	-3.9	0.05
	Air	2.8	-2.6	-0.2	
Best Case	Coal	-3.4	-2.5	5.9	0.65
	Air	2.3	0.8	-3.1	

CFD results strongly suggested the device had the ability to control coal flow distribution from the classifier without interrupting airflow distribution or significantly increasing the pressure drop of the classifier. A prototype design was begun for a full-scale test installation in the field.

PROTOTYPE INSTALLATION AND TESTING

A prototype was designed for a customer's plant where coal distribution had been a consistent problem over the years due to the classifier inlet duct configuration. The plant has ball tube mills with static centrifugal classifiers. The coal distributor device was built into a fully assembled replacement discharge turret to minimize intricate fitup and welding in the field and instead allow a fully shop-assembled device to be welded into place. The new turret was fabricated and tested in the shop before being shipped to the plant. Sections of coal pipes above the classifier were temporarily removed to allow the existing turret to be removed and the new turret put in its place. The device was installed on both classifiers on one ball tube mill.

Figure 7. One of Two Prototype Distributors on Shipping Pallet

The device can be adjusted externally online to optimize coal flow distribution. The prototype design featured manual adjustment, but other actuation methods could be considered. Following installation, the distributor was set at the “zero” position to obtain baseline data. In the “zero” position, no effects are expected from the coal distributor device. However, a small design difference between the original discharge turret and the replacement turret results in a shift of coal distribution compared to the distribution prior to the installation.

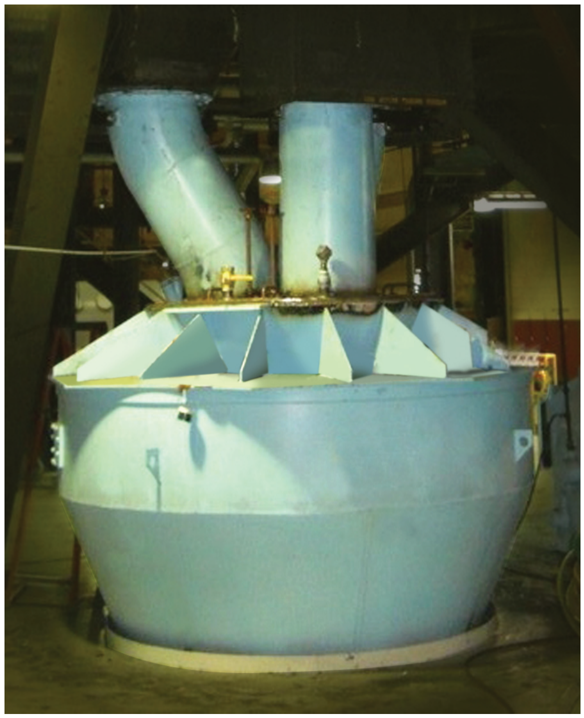


Figure 8. Static Centrifugal Classifier with New Coal Distributor Turret

Field Testing of Two Prototype Coal Distributors

Baseline testing was performed in the “zero” position to determine baseline coal fineness and distribution as well as pressure drop and air distribution. Coal fineness sampling was performed using the ASTM method, which uses dirty air testing to determine the coal pipe air velocity for isokinetic coal sampling. Coal sample weights were used to determine the coal flow distribution between the pipes. All tests were performed with approximately the same primary air and coal flow during each test. Two baseline tests were performed on each classifier, although the data from one test was discarded due to layout in one of the coal pipes. The baseline coal distribution results are shown in Figures 9 and 10. The figures show the coal flow deviation is much worse than recommended for good combustion (±15%).

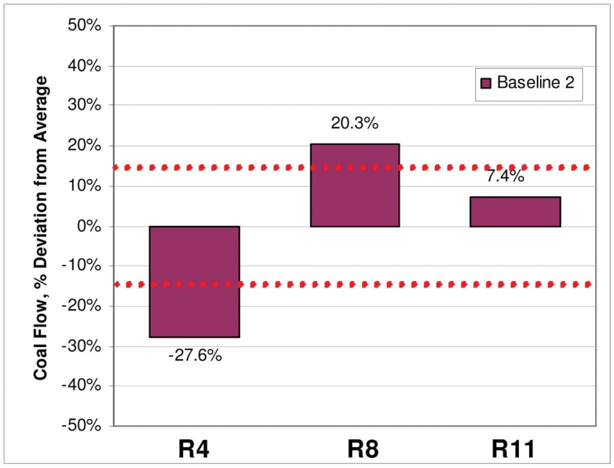


Figure 9. Classifier A Baseline Coal Distribution

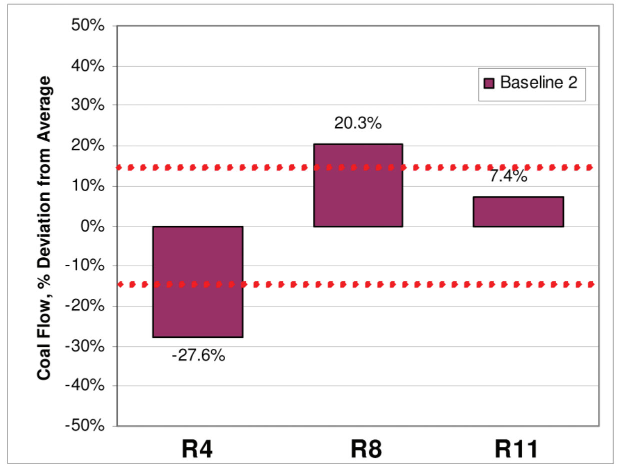


Figure 10. Classifier B Baseline Coal Flow Distribution

The baseline coal distribution was very poor, with a range of –27.6% to 20.3% deviation from classifier average on Classifier A, and –20% to 31.7% on Classifier B. The repeated test on Classifier B shows that a certain level of variation is to be expected from test to test due to normal fluctuations of the air and coal flow, and the repeatability of the test. However, the repeated tests confirm the general trend showing very heavy coal flow in one pipe (+32%) and reduced flow in the other two pipes (-12% to –20%).

A series of adjustments were made to each classifier. Following each adjustment, coal fineness testing was performed to evaluate the effects of the adjustment on coal distribution. The first two trials on classifier B were not successful in improving coal distribution, and in fact increased the "heavy" pipe to +48% on the second adjustment. For the third test, a different setting was tested with good results. Coal distribution changed significantly by reducing the "heavy" pipe to +13% above average and the other pipes to about –7%. The correct location for adjustment had now been identified, and further tuning could be performed.

The subsequent test overcorrected for the heavy pipe, resulting in a drop to –18%. Further fine tuning resulted in a final coal distribution ranging from –6% to 7% from average. Figure 11 shows the final coal distribution obtained after six adjustments to the coal distributor.

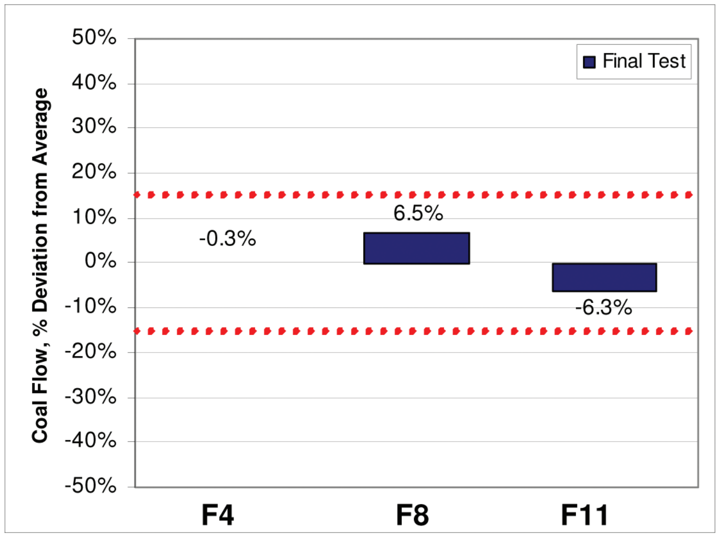


Figure 11. Classifier B Final Coal Distribution

Classifier A achieved similar results after three adjustment iterations. The best coal distribution achieved was +7%, -6% on the second adjustment iteration. However, after additional small adjustments, the official "Final" test distribution was slightly worse at –8%, +14%. Following the tuning of both coal distributors, the distribution on both classifiers was well within ±15% and the testing had proven that small adjustments to the coal flow were possible.

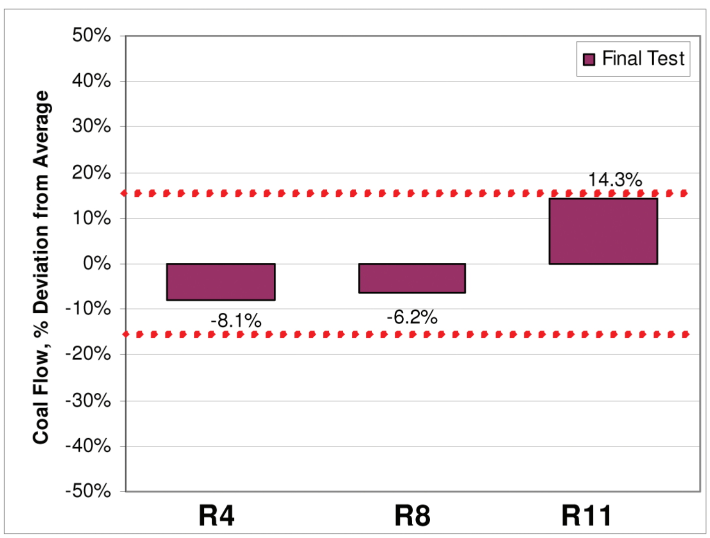


Figure 12. Classifier A Final Coal Distribution

Time Requirements for Adjustments

One or two people adjusted the prototype coal distributor device in about five minutes. Tuning iteration time was determined by the time required to perform fineness testing. Including fineness testing time and at least half an hour for the mill system to stabilize, iterations were completed in approximately two to three hours each. Well-balanced coal flow was achieved after three to four iterations. Use of an online coal flow measurement system such a PfFLO would greatly reduce the time required for tuning.

Dirty Airflow Distribution

Although dirty air testing was not performed during each adjustment iteration, dirty air testing was performed following the final coal distribution test to determine the effects of adjusting the coal distributor on the airflow distribution. The dirty air test data showed minimal changes to dirty air distribution compared to baseline, but the data was discarded due to a large increase in primary air header pressure that occurred during the dirty air testing. The test was repeated at a later date with steady unit load to ensure that the primary air pressure and flow would be constant during the test. The dirty air results are compared to the baseline dirty air test results in Figure 13. The results show that dirty airflow distribution shifted slightly from baseline to final. The final airflow distribution, which was well balanced during baseline testing, remained within ±5% except for two pipes that were ±6% from average. Riley Power typically recommends primary airflow distribution within ±10% of mill average. The coal distributor prototype data indicates that the movement of the coal distributor minimally affects primary air distribution, although further testing should be performed to determine a better understanding of the relationship between coal distribution changes and primary air distribution with this device.

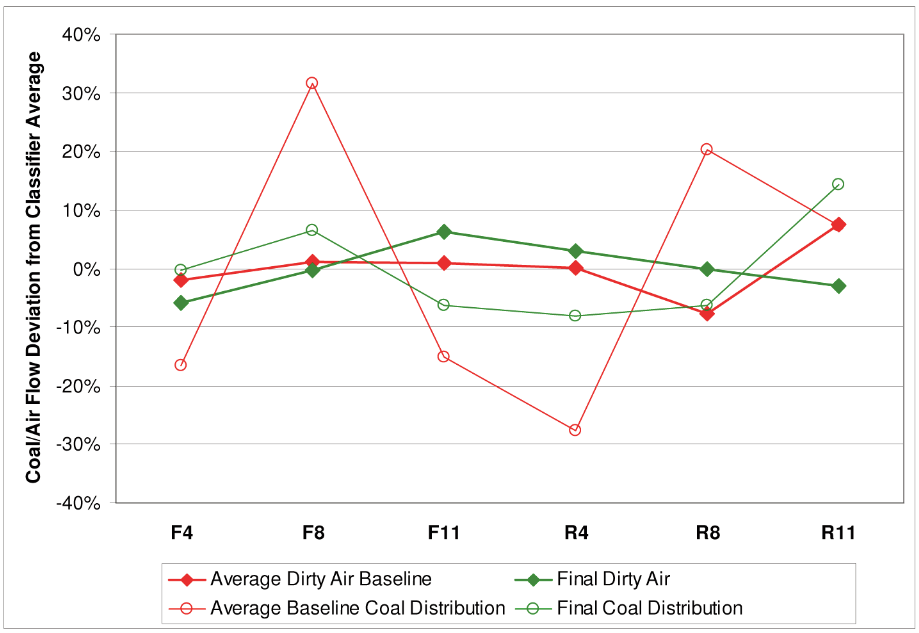


Figure 13. Coal and Dirty Air Distribution, Baseline and Final

Coal Fineness

The coal distributor is integrated into the classifier discharge turret where it alters the trajectory of coal particles passing through the classifier and into the coal pipes. To ensure that the device does not change the classification performance of the classifier, the baseline coal fineness was compared to the final test coal fineness. The two baseline test fineness results were averaged, and compared to the final test coal fineness. The final test was performed at slightly lower coal throughput (6% lower) and therefore an increase in coal fineness is expected. The fineness increased at the lower coal throughput as predicted by Riley Power's standards, indicating that the coal distributor had little or no impact on the coal fineness. The coal fineness results are shown in Table 2.

Table 2 - Coal Fineness Results

	Baseline Average	Final Average
Coal Throughput (kpph)	109-110	102
50 Mesh (%)	98.5	99
100 Mesh (%)	92.8	95
200 Mesh (%)	71.7	78

Pressure Drop

The coal distributor design features inherently low pressure drop due to the fact that is does not significantly change or restrict air flow through the classifier and does not increase velocity of air inside the classifier. The CFD simulations predicted up to 0.65 iwc increase in pressure drop during the best coal distribution case. The predicted pressure drop depends on the number of adjustments made to the device at any one time. The prototype testing did not clearly show an increase or decrease in pressure drop due to unstable pressure readings and variability between tests. More data is needed to better quantify the pressure drop of the device, but it is believed to be minimal based on the available CFD and field data.

CONCLUSIONS

The new coal distributor concept was developed and evaluated through CFD modeling and prototype field testing, and is capable of improving coal flow distribution to ±10% or better on centrifugal static classifiers. The prototype design has been tested on two centrifugal classifiers in a pulverized coal fired power plant with ball tube mill pulverizers. Test results clearly show the ability of the device to shift coal flow between fuel pipes on the classifier while having little effect on the primary air distribution. If employed on a unit-wide basis, the coal distributor is expected to provide several benefits such as reduced LOI and CO, improved heat rate, and improved heat distribution to the boiler. Future testing will determine the unit-wide effects of improved coal distribution.

As of this writing, a patent is pending on the coal distributor device.

ACKNOWLEDGMENT

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REFERENCES

1. Obla, K.H., "Specifying Fly Ash for Use in Concrete", Concrete inFOCUS, Spring 2008, National Ready Mixed Concrete Association, Silver Spring, MD.

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