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Distribution of Pulverized Coal Flow in a Power-Station Pipe-Network

Basil R. Paynter and B.P. Huynh
University of Technology, Sydney
Sydney, NSW, Australia

Abstract

This work aims to identify the factors affecting the flow of pulverized coal (fuel) carried by air in pipe-networks to feed the boiler furnaces of a power-station. The pipe-network considered consists of four 457mm-diameter mill pipes which take the pulverised coal of nominal size 75micron from a coal-pulverising mill, to a boiler furnace, with 2 pipes going to its front, and 2 to its back side. Each of these four pipes is in turn divided into two 305mm-diameter burner pipes (totalling 8) which feed the fuel to the furnace. At full load (100%), a total of 45 tonnes/hr of coal would be used. In this work, measurements were carried out at 5 reduced loads ranging from 35.5% to 60.1%. The coal is carried in each fuel pipe by 11.5 to 17 kg/s of air flow. The desired distribution is that fuel is evenly split among all the pipes, namely 25% of the total coal in each mill pipe, and half of that amount in each of the 8 burner pipes. It is found that at low fuel loads, the distribution deviates significantly from the desired one. Distribution, however, improves with increasing load. Geometric layout of the pipes is identified as an important factor, with less fuel flowing in pipes having more bends. On the other hand, the improvement of distribution with higher load (more fuel) is rather unexpected. Results from this work are being used to validate a CFD model which in turn helps with the design of better networks.

Introduction

This paper gives interpretation to measurement data of the distribution of pulverised coal in a pipe network that feeds the coal fuel to a boiler's furnaces of a power station. A two-day test program was conducted in 2008 at Liddell power station "Unit 1H Mill" (New South Wales, Australia) by the company HRL Technology Pty Ltd [1] with the first author's participation; and the data were made available to him. The desired distribution is that coal is evenly split in all the pipes feeding the furnaces; such even distribution gives optimum burning of the fuel, and hence least waste, as well as stable furnace conditions which are very desirable to prevent boiler trips. Uneven distribution often results in the coal not optimally carried by the blowing air, causing deposits, as shown in figure 1. Because often coal-fired power stations consume very large amount of coal, any improvement in the fuel-burning process is very desirable.

Site Description, pipe network and experiments

The site is the Liddell power station in the state of New South Wales, Australia. This power station was built in the early 1970's, and has 4 × 500 MW reheat boilers. Each boiler has two furnaces and eight Raymond-803 bowl mills. The mills (figure 2) are used to process raw coal into pulverised coal that is subsequently used as a fuel in the boilers' furnaces. Primary air is used to carry the pulverized fuel in pipes from the mills to the furnaces' burners. The pulverized coal and primary air mixture from the mills to the burners is transported in cast iron piping with wear resistant bends.

Figure 1. Deposits in a coal-fuel pipe.

Each mill distributes the pulverized fuel through four outlet pipes of 18' (457mm) diameter. These four pipes are then divided each into 2 smaller burner pipes of 12" (305mm) diameter. All 8 pipes are then lead to one boiler elevation (figure 3). The pipe division is done via a distributor or riffle box that has a single inlet and two outlets. There are a total of eight elevations in the boiler, one for each mill. Flexible couplings between each pulverized fuel pipe section accommodate the relative movement between the burners and mill as the furnace expands. Figure 4 shows a schematic of pipe arrangement for one pulveriser mill. At full operational speed, coal flow through the mill will be 45 tonnes/hr. Figure 5 shows photo of a riffle box that divides a fuel pipe into 2 burner pipes; and Figure 6 shows the connection whereby a burner pipe delivers pulverised coal to a furnace.

A microwave-based MIC system [1] was used to measure the real-time coal flow distribution in the pulverised fuel pipes from the mill and the burner fuel pipes after the bifurcation (riffle box). Once the sensors are positioned to be flush with the inside of the lines, the coal flow is measured as emitted microwave energy is reflected by the moving coal particles in the gas stream [1].

The total mV signal from each group is a direct measure for the mass of coal flowing through that group, and is used to check against the DCS Coal Feeder Speed. This is shown in figure 7.

Figure 2. Photo of a coal pulveriser mill.

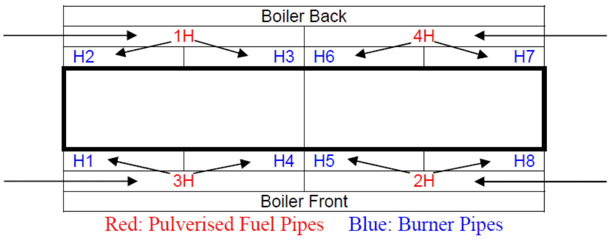

Figure 3. Layout and labelling of pipes from the 1H-pulveriser mill [1].

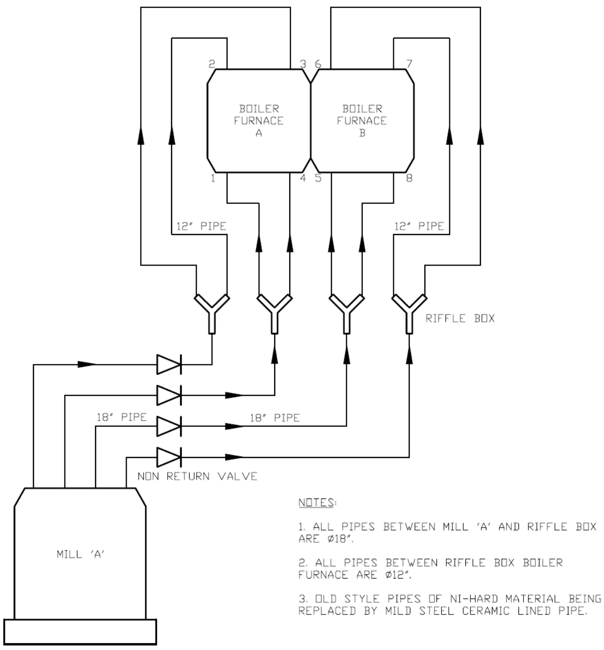

Figure 4. Schematic of a pipe-network from a pulveriser mill to a boiler; pulverised-fuel or mill pipes are before the rifle box, burner pipes after; all 8 burner pipes connect to the boiler at a same elevation.

Figure 5. A riffle box divides a fuel pipe into 2 burner pipes.

Figure 6. A 12'' (305mm) burner pipe delivers pulverised coal to a boiler's furnace.

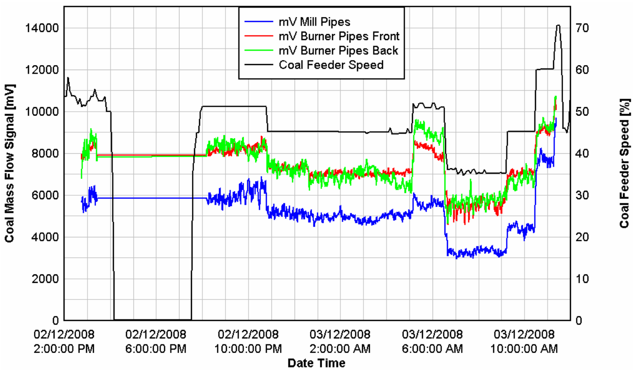

Figure 7. Measured total coal flow signals and DCS (distributed control system) coal feeder speed (as percent of mill operational speed) [1].

Results and Discussion

From measurement data provided to the first author by HRL Technology Pty Ltd [1], a sample of which is shown in figure 8, an integral estimate of the deviation from the desired distributions can be obtained, as shown in figure 9. In this figure, x-axis is coal feed speed as fraction of the feed speed corresponding to full capacity of 45 tonnes/hr of coal. The two y-axes indicate the integral deviations from the desired distributions of pulverised coal on the pipes; these are 25 % of the total in each of the 4 pulverised fuel pipes (so that 4×25 = 100%), and 50% or half in each of the two burner pipes emanating from a pulverised fuel pipe. The integral deviations are simply computed according to the following formulas

For the 4 pulverised fuel pipes (1H, 2H, 3H, 4H, in figures 3 and 8): $\sum$ [percentage in a pipe – 25]^2

For the 8 burner pipes (H1, H2, …, H8 – figures 3 and 8): $\sum$ [percentage in a pipe – 25]^2

From this figure, it is evident that as pulverised flow rate (feed speed) increases, the deviations are reduced in both categories of pipes. On the other hand, air mass-flow rate in general increases with higher coal fuel rate, as indicated in figure 10.

The substantial improvement towards even distribution of fuel flow in the pipes as more fuel is transported is interesting.

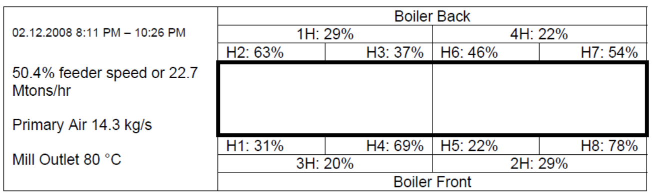

Figure 8. Realative coal mass flow at 50.4% (of full capacity) feeder speed [1]; desired distributions are 25% in pulverised-fuel pipes, and 50% in burner pipes.

While the corresponding air flow rate also increases, but this increase is not large. Thus as pulverised-fuel flow nearly doubles, air flow rate increases by only about 10%. Thus higher flow velocity is not a strong reason. The reason seems to lie in the better mixing effects related to much higher Reynolds number. If fluid density is taken to be approximated to that of the powder mixture of air and coal, then it can be seen that as pulverised coal flow rate increases, this density increases quickly, thanks to coal's high density. Thus the effective Reynolds number also increases quickly, despite the fact that flow velocity does not change very much (coal powder and air are taken to flow at about the same speed; this assumption is quite close to reality).

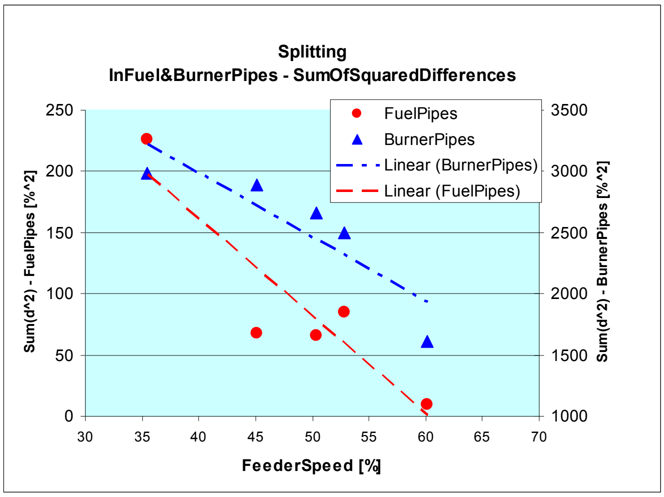

Figure 9. Reduction in the fuel flow distributions in the pipes; sum of squared deviations from desired distributions (25% in pulverised-fuel pipes, 50% in burner pipes); feeder speed is in % of full-capacity speed which corresponds to 45 tonnes/hr of coal. Raw data from [1].

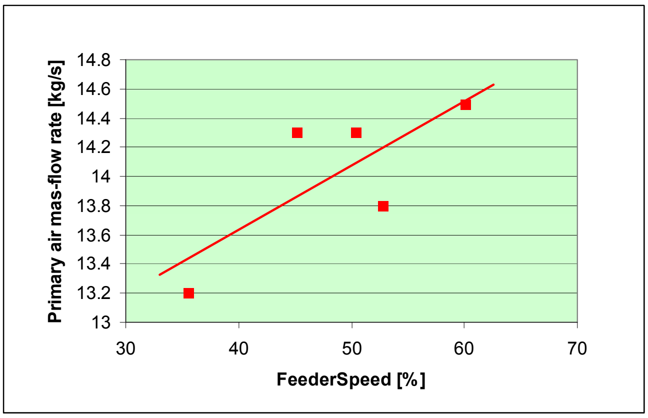

Figure 10. Primary air mass-flow rate versus feeder speed (fraction of coal-feed speed corresponding to operating capacity). Raw data from [1].

Conclusion

Interpretation to measurement data of the distribution of pulverised coal in a pipe network that feeds the coal fuel to a boiler's furnaces of a power station has been presented. Distribution becomes more even as coal flow increases toward operational (full) capacity, while air flow increases only slightly. This is attributed to the substantially higher effective Reynolds number of the pipe flow of coal-air mixture, due to the very high density of the coal powder relative to the air's.

Acknowledgements

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References

[1] Barlow, M. and Korbee, R., 2009, "Liddell Power Station – Mill 1H Pulverised Fuel and Airfow Measurements", Report No: HLC/2008/413, HRL Technology Pty Ltd, January.