Update on in-mill mineral removal to reduce furnace emissions and operating costs

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1. Introduction

This paper deals with the benefits of a in-mill mineral removal technology developed in Australia to remove mineral matter during the coal milling process. The process removes the hard and insoluble minerals, primarily Quartz and Pyrite, which are impossible to remove by other coal cleaning processes, such as washing. Removal of these minerals will not only reduce emissions of particulate matter, sulphur-dioxide, Mercury and Arsenic but will improve boiler operations by reducing mill wear and tube failure. This technology was installed on four 200 MW units in Australia between 2006 and 2009. The data presented is from testing carried out during ten years of operation. This technology is marketed by Hansom Environmental Products as ash removal technology (HEP-ART).

2. In-mill Mineral Removal Technology

Figure 1 depicts a vertical spindle mill commonly used in power stations. The mineral removal equipment is installed in the bottom of the rejects cone, which funnels the classifier reject material on to the centre of the mill table along with the coal feed. A photo of an installation on a full-scale mill is shown in Photo 1. The mineral removal equipment processes the classifier reject material, removing the mineral matter and returning the carbon and material that is not fully ground to the centre of the mill table along with the coal feed. The milling process releases the particles of mineral matter from the organic carbon that binds them into a conglomerate. The mineral particles are then separated from the carbon particles and removed from the mill. This significantly reduces the recirculating mineral matter in the mill.

This technology has been shown, by independent tests in a full-scale mill installation, to be capable of removing over 50% of pyrite and over 40% of the quartz from the coal. The results of the independent tests carried out in Australia at three removal rates are shown in Figure 2. A magnified photo of the mineral matter removed is shown in Photo 2. This photo shows large quantities of individual pyrite and quartz particles with a few organic carbon particles. There are no particles that are conglomerates, involving multiple pyrite and/or quartz particles bound with organic carbon. In the coal burnt during these tests, the quartz particles are generally larger, around the 0.5 mm to 1.0 mm, than the pyrite particles, which are generally less than 0.5 mm.

Photo 1. Installation on a Raymond mill

The coal burned during these tests was a sub-bituminous with about 7.1% ash, 1.3% silica, 0.6% iron and 0.5% sulphur in the dry coal. Each mill processes 40 tons of coal per hour, which includes about 4000 lb/hr of ash. The removed material was between 60% and 80% of the ash, of which between 28% and 55% was pyrite, depending on the removal rate, and about 39% was quartz. The extraction rate varied from a low of 210 lb/hr to a high of 475 lb/hr, in the test data presented in Figures 2.

The sulphur removed is mainly pyritic sulphur, which was about half of the sulphur in the coal tested. Sulphur was about 20% of the material removed, which was equivalent to about a quarter of the sulphur in the coal. Removal of the sulphur will have a significant effect on both SO_2 and SO_3 emissions, resulting in reduced scrubber operating costs. Coals with a higher pyritic sulphur component would have an even higher sulphur reduction.

3. Impact on Mill Performance

The mineral removal reduced the mill differential pressure and mill power by reducing the recirculating mineral matter. The reduction of the recirculating mineral matter also allowed increased mill throughput, which provided a 10% increase in generation capability, from 200 MW to 220 MW. The mill differential pressure was also reduced by over 40%. Figure 3 shows the mill differential pressure vrs coal throughput with and without the mineral removal (note the increased coal throughput with the classifier adjusted).

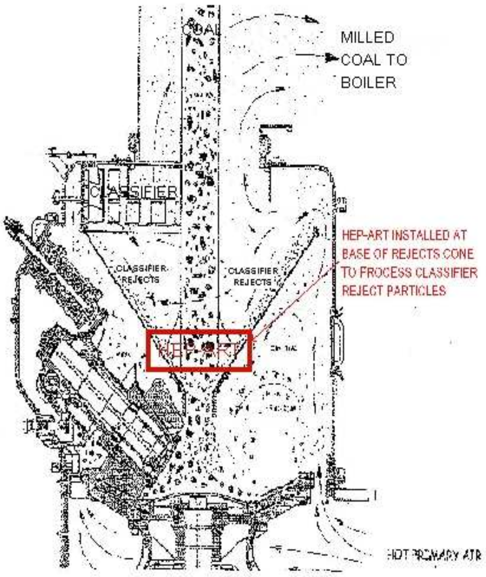

Figure 1. Installation on Vertical Spindle Mill

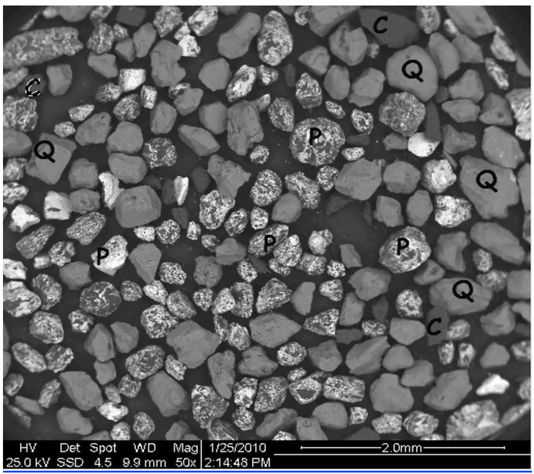

Photo 2. Magnified Photo of Minerals Removed

The fan power will be reduced as a result of the reduction in mill differential pressure. The actual mill power was also reduced as a result of the decreased grinding energy required to reduce the mineral matter to a fine powder that can pass through the classifier to the boiler. Figure 4 shows the mill power versus coal throughput with and without the mineral removal. Tests showed a 10% to 20% reduction in mill power. This reduced auxiliary power will result in a reduced CO_2 emission for the same power generation. In addition to the increased throughput, reduced differential pressure and reduced power consumption, a significant reduction in mill maintenance was achieved, including a 50% reduction in wheel wear rate and reduced boiler tube failure, due to fly ash erosion in high flow regions. Figure 5 shows the reduction in boiler tube failures during the ten years of operation.

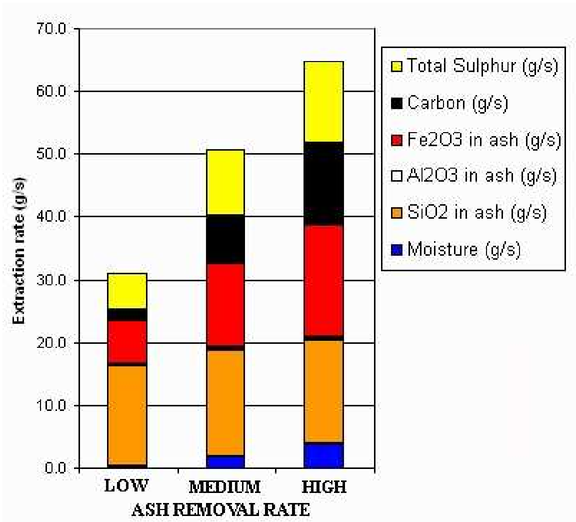

Figure 2. Quartz and Pyrite Removal Efficiency

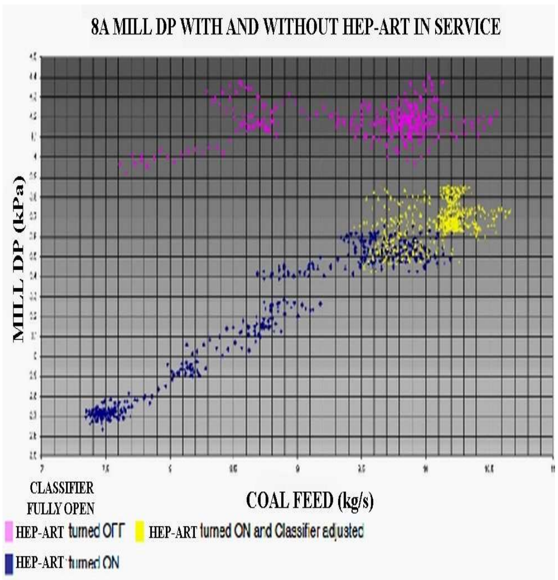

Figure 3. Impact on Mill Differential Pressure

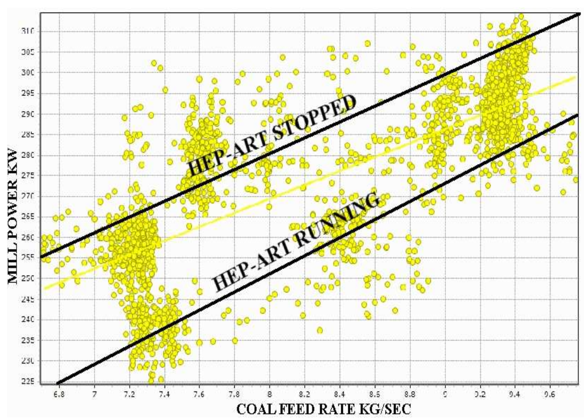

Figure 4. Impact on Mill Power

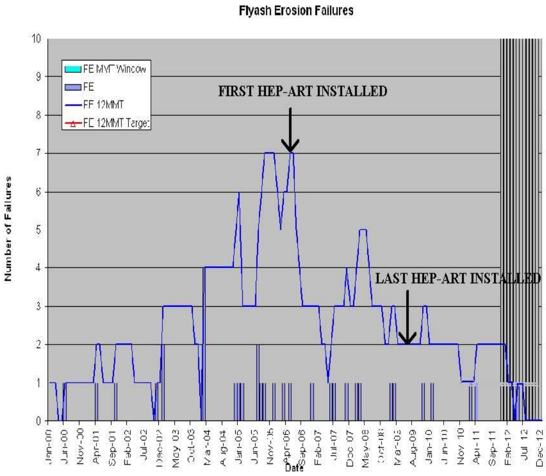

Figure 5. Station Boiler Tube Failures due to Fly-ash Erosion

4. Impact on Emission Control Equipment

As previously discussed, the sulphur emission was reduced by about a quarter on the Australian coal tested, which reduced the SO2 and SO3 concentrations by a similar amount. This would result in reduced scrubber operating costs of about 20%, mainly in limestone consumption and waste disposal. Trona or lime conditioning, to control SO3 emissions, would also be reduced proportionately. The particulate emissions from the boiler would be significantly reduced, due to the removal of the quartz and iron.

As a significant portion of the arsenic and mercury in high pyrite coal are bound in the pyrite, as shown in Figures 6 and 7 from Reference 1. Removal of over half of the pyrite would greatly reduce the arsenic and mercury emissions, thereby reducing the operating cost of any mercury emission control system installed. High pyrite coals would allow even greater SO2, SO3, mercury and arsenic emission reductions, which will result in higher emission control cost savings. The reduced auxiliary power consumption coupled with improved boiler performance, due to reduced slagging and fouling resulting from iron reduction, would result in a reduction in CO2 emissions.

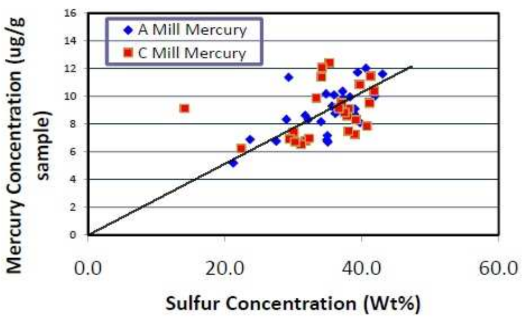

Figure 6. Correlations Between Sulphur (Pyrite) and Mercury from Reference 1

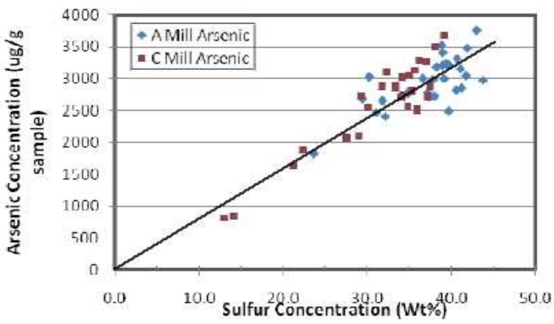

Figure 7 Correlations Between Sulphur (Pyrite) and Arsenic from Reference 3

5. Estimate of Costs and Benefits

The Australian plant does not have sulphur-dioxide or mercury controls but estimates of the reduced scrubber and mercury control consumable costs are based on US costs. The scrubber costs are based on the cost estimates in Reference 2 for wet limestone scrubbing with forced oxidation (LSFO), wet lime scrubbing using magnesium-enhanced lime (MEL), dry lime scrubbing using a conventional spray-dryer absorber and dry lime scrubbing using a circulating fluid bed (CFB) absorber. The mercury control costs are based on 3 lb/MMacf of powdered active carbon (PAC) at a cost of 70 c/lb, a relatively conservative base.

Coal price used in these estimates is $60/ton delivered. The mill overhaul, roller refurbishment, fuel pipe and boiler tube repairs are costed based on an average contract labour cost of $75/hr including all overheads (accommodation, meals and overtime) and assuming a 60 hr week during mill or boiler outage. The price of electricity used to calculate savings on reduced auxiliary power and loss of revenue for plant outage is $50/MWhr.

Mill auxiliary power reduction cost saving is $87 600 per year for each unit, a total saving of $350k/year for the station. Each boiler tube failure, due to fly-ash erosion, requires approximately five days and 500 man hours to repair, one day to shut-down and cool the boiler, three days to scaffold, repair and restore the boiler and one day to start from cold. This results in a loss of 16 000 MWh of generation, a revenue loss of $800k and a labour cost $37 500 for each boiler tube failure. Based on the station experience of a reduction from six to one boiler tube failure per year, this results in a reduction of $4M in lost revenue per year and a labour cost reduction of $187 500k per year for the station.

Mill overhauls were performed annually prior to the mill modifications and bi-annually following the installation. Each mill overhaul required 1500 man hours, including roller rebuild and fuel pipe repair, at a cost of $120 000 per mill.

The mill overhaul cost reduced from $2.4M per year for the station to $1.2M, a saving of $1.2M per year. The annual station savings, identified as resulting from reduced maintenance, was $1.5M and this also provided additional annual revenue of $4M due to reduced forced outages.

An estimate of the station’s scrubbers consumable and auxiliary power savings, based on the cost estimates in Reference 4, are given in Table 1. These costs are calculated for the Australian 1% sulphur coal and for a high sulphur (3%) coal, assuming a 40% sulphur removal. Reduced water consumption is not considered and auxiliary power reduction, due to reduced milling and material handling, is assumed to be 20%.

The station's scrubber operating cost saving for the low sulphur Australian coal varies from $960 000 per year, when using a wet limestone scrubber with forced oxidation, to $2 715 000 per year, when using a dry lime scrubber using a conventional spray-dryer absorber. With a high sulphur coal (3%), this increases to between $2 490 000 and $3 670 000 when using a wet limestone scrubber.

Table 1. Station Scrubber Operating Cost Saving

Type of Scrubber	Australian 1% Sulphur Coal	High Sulphur Coal (3%)
Wet limestone scrubbing with forced oxidation	$540 000 Reagent $420 000 Power	$1 650 000 Reagent $840 000 Power
Wet lime scrubbing using magnesium-enhanced lime	$1 000 000 Reagent $320 000 Power	$3 080 000 Reagent $590 000 Power
Dry lime scrubbing using a conventional spray-dryer absorber	$2 360 000 Reagent $355 000 Power	N/A
Dry lime scrubbing using a circulating fluid bed	$2 290 000 Reagent $260 000 Power	N/A

Table 2. Savings Resulting from Installaion

Increased Revenue (due to reduced forced outages).	$4 000 000
Reduced Maintenance Costs (due to reduced mill and boiler repairs)	$1 500 000
Reduced Auxiliary Power Cost (due to reduced mill and scrubber power consumption)	$770 000
Reduced Scrubber Reagent Costs (due to 40% in mill sulphur removal by HEP-ART)	$540 000
Reduced Powdered Activated Carbon Cost (due to 25% in mill mercury removal by HEP-ART)	$1 160 000
TOTAL ANNUAL STATION SAVINGS	**$3 970 000**

The mercury emission control annual powdered activated carbon consumable cost is estimated at $1 160 000 per year for each unit, giving a station operating cost of $ 4 640 000. A 25% reduction in mercury emission, resulting from the pyrite removal during the coal milling process, will result in a $1 160 000 saving per year in powdered activated carbon (PAC).

The station capital cost for the supply and installation of the mineral removal equipment was $6M and the additional coal cost per year was $1M for the carbon lost in the process. The annual savings for an equivalent 1GW station burning a similar low sulphur coal in the United States are listed in Table 2.

6. Conclusion

This results in an annual net station benefit, due to operating cost reductions of $3 970 000 giving a Return On Investment of 65% and a payback of capital in 1.5 years. In addition an increased annual revenue of $4 000 000 is achieved, due to reduced forced outages. It should be noted that these costs do NOT include the following benefits:

1. Increased boiler efficiency and reduced soot-blowing due to reduced slagging and fouling, as a result of the 79% reduction in the pyrite entering the combustion process;
2. Increased boiler efficiency due to improved combustion, resulting from the improved classifier settings enabled by the reduced mill differential pressure;
3. Reduced particulate emission, due to reduced quartz and pyrite entering the boiler;
4. Reduced CO2 emission, due to the reduced auxiliary power and increased boiler efficiency;
5. Reduced SO3 formation, due to the reduced SO2.

These additional benefits will result in additional significant cost savings, due to reduced boiler cleaning, reduced soot-blowing, and reduced SO3 mitigation costs.

References

[1] Conrad V., Looney B., Snowden B., Gilliam D., Ethridge T., Alfee B., Kutney J., Sensible Removal of Arsenic and Mercury from Pulverized Coal – Economic and Environmental Benefits, The 35th International Technical Conference on Clean Coal & Fuel Systems, June 6 to 10, 2010, Clearwater, Florida, USA.

[2] DePriest, William and Gaikwad, Rajendra, Economics of Lime and Limestone for Control of Sulphur Dioxide, Proceedings of Combined Power Plant Air Pollutant Control Mega Symposium, Washington, DC, May 2003.