CRUSH IT, PULVERISE IT and burn it!

Stephen K. Storm, Storm Technologies Inc., US, stresses the importance of following these simple steps.

Figure 1. Typical crusher design used for large utility boilers to achieve < 0.75 in. raw coal sizing.

Typically, on pulverised coal-fired boilers, coal pulveriser performance encompasses at least 75 - 80% of most firing system opportunities for combustion and steam plant performance improvement. Considering this, the inter-relationships of coal pulverisation must be considered when attempting to optimise combustion, overall unit performance, operability, reliability and capacity. Pulveriser efficacy is challenging many plants in the US, which are undergoing drastic fuel changes. So, what do

Figure 2. Magnetic separator (typical).

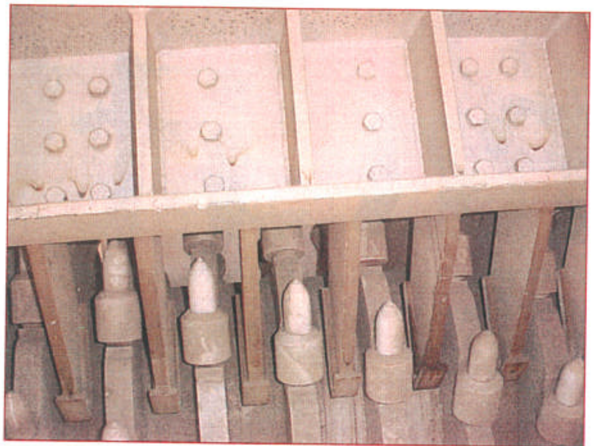

Figure 3. Typical cage crusher teeth.

Figure 4/5.

Figure 6.

we do about it? The solution is often very simple. Performance = C+P+B or in other words, 'Crush it, Pulverise it and Burn it like Hell!' For some it's not that simple. This is considering that many older units were not designed with fuels flexibility in mind. So, this often makes combustion optimisation a challenge whilst firing coals of varying qualities. Regardless, the basics of combustion still apply and approximately 75 - 80% of all the opportunities for improvement are related to coal pulverisation.

The essentials of combustion optimisation

- Raw coal sizing must be consistent and preferably less than 0.75 in. top size; consistent fuel size and removal of foreign matter such as tramp metal is essential.
- Fuel feed to the pulverisers must be smooth during load changes and measured and controlled as accurately as possible. Load cell equipped gravimetric feeders are preferred.
- The fuel lines balanced to each burner must be balanced by the 'clean-air' test ± 2% or better via square edge orifices.
- Fuel lines must be balanced by the 'dirty air' test, using a dirty air velocity probe, within ± 5% or better.
- Fuel lines must be balanced by fuel flows within ± 10% or better.
- Fuel line fineness must be greater than 75 - 80% passing a 200 mesh screen and < 0.1% on a 50 mesh screen.
- Primary air/fuel ratio shall be correct and accurately maintained when above minimum.
- The over-fire air system (if installed) must be controllable.
- The fuel line and/or burner minimum velocities shall be 3300 ft/min.
- Mechanical tolerances of burners and dampers must be within ± 0.25 in. or better.
- Secondary air distribution to burners must be within ± 5% to ± 10%.
- The boilers furnace exit must be oxidising, preferably ≥ 2%.

When pulveriser performance is poor, combustion and steam plant cycle performance is non-optimum. When the combustion process is non-optimum, the plant's performance, reliability and environmental control mechanisms are compromised. As a pre-requisite to combustion optimisation, raw coal sizing should be less than 0.75 in. and consistent. This is typically accomplished either at the mine or at the power plant using a coal crusher. Regardless of where it is done, the task is very important.

As discussed in the 13 essentials of optimum combustion, consistent raw coal sizing to the pulverisers is a good start. Once sizing is minimised to < 0.75 in. this will contribute to a smooth delivery of the coal to the pulverisers and enhance the effectiveness of the magnetic separators (Figure 2). This important fact is often overlooked and/or disregarded even though tramp metal, mining teeth and/or hardened crusher tips, such as those shown within Figure 3, are a nuisance to the critical tolerances, reliability and performance of vertical spindle pulverisers. When these tips or similar hardened mining tool tips come loose and end up within a vertical spindle pulveriser, they can wreck a pulveriser and/or create major long-term performance issues.

On a ball tube mill type coal pulveriser, tramp metal and large rocks become part of the ball inventory. These large rocks can reduce effective grinding surface of the grinding balls in the ball tube mill. However, if the crushers are optimised, rocks granulated and tramp metal separated, the pulveriser can be more effective in lifting tramp metal and crushing rocks. Furthermore, pre-crushing and/or drying coal can often yield a 5% or better true capacity improvement. However, often misunderstood true pulveriser capacity encompasses at least five factors, not simply throughput. These five main factors that comprise pulveriser capacity are: hardgrove grindability (HGI), throughput, fineness, raw coal sizing and moisture (Figure 4/5).

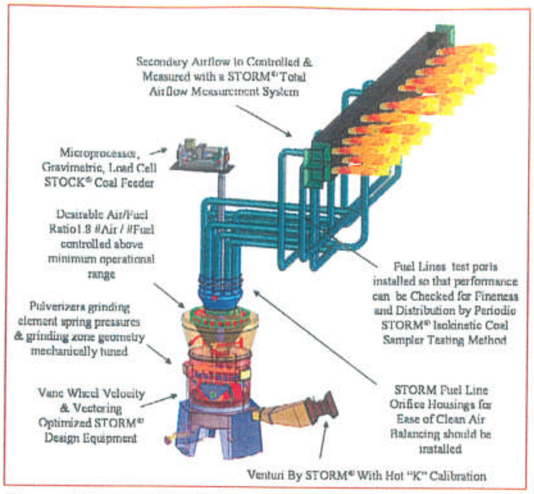

Figure 7. Illustration of the Storm solid fuel injection system approach to combustion efficacy.

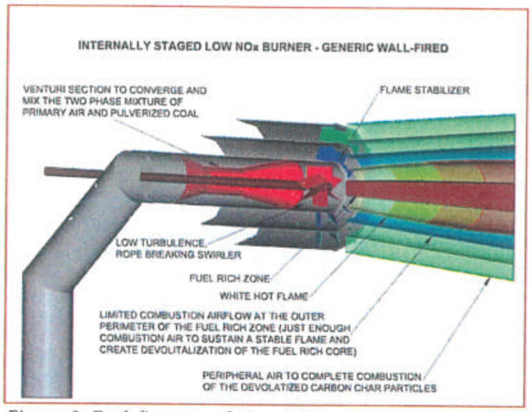

Figure 8. Fuel fineness of 75 - 80% minimum passing 200 mesh improves the fuel bound nitrogen release of the 'de volatilisation' zone.

Figure 9.

As shown in Figure 6, coal quality should be periodically sampled for analysis of sizing and fuel and ash characteristics in relation to pulveriser performance tests.

Important pulverisation

Now that the importance of crushing has been addressed, the simple issue of why pulverisation is important on pulverised coal-fired boilers should be discussed. Perhaps this statement sounds odd, however, owners and operators of PC fired boilers often disregard the relationship of coal sizing and tuning of the pulverisers in regards to overall plant performance. It is the experience of the author that the difference of PC fired boiler operation with good coal fineness versus poor coal fineness is akin to putting a clean premium fuel in your car vs. dirty fuel mixed with sand. Each of the fuels combust, however, it's only a matter of time before the reliability and economic operation are affected. Of course large utility boilers aren't internal combustion engines. For optimum combustion we need to become more fuel-efficient and accurately measure the fuel and air delivery rates (just like a set of cylinders on an internal combustion engine). Following in the path of the auto industry, today Storm also uses large catalytic converters on the exhaust systems of its large power boilers for reduced NO_X levels. Perhaps the power industry's Selective Catalytic Reactor (SCR) isn't exactly the same as a catalytic converter on your car. However, the same principle result for emissions improvement is applied.

Although SCR and scrubbers projects absorb most of the available capital investments for power systems, the pulverisers and firing system performance seem to remain as the root cause of all the problem reliability and efficiency issues. For example, poor coal fineness often compounds issues such as high levels of carbon in ash, increased slagging propensity, dry gas losses, and high de-super-heater spray water flows with major annual costs in boiler efficiency, SCR catalyst wear, increased ammonia consumption and replacement power costs. Inefficient firing systems increase CO_2 emissions, and add up to millions in hidden losses. Because of this, Storm Technologies refers to a remedy for sick pulveriser systems as the STI 'solid fuel injection systems approach.' An example of how this is applied to a typical pulveriser system is seen in Figure 7.

A fine job

Great coal fineness (> 75% through 200 mesh) is better than the typical industry accepted and/or 'typical' coal fineness. Actually, many plants do not even know what the fineness is for months of duration, and when fineness is checked, it is often just a spot check of one pipe per pulveriser. Figure 11 indicates an example of poor coal fineness and STI recommended good fineness, which indicates a rather large difference in micron sizing. First of all, be assured that the coal fineness impacts the time for 'carbon burnout' (due to the particle sizing) as well as improving fuel distribution to each burner line with the improved fineness. The variance from 60% passing 200 mesh results in a typical mean particle size of approximately 80 microns versus a preferable mean particle size of 45 - 60 microns. As you can see in Figure 11, the difference of approximately 60% through 200 mesh and 80% passing 200 mesh is a particle surface area difference of approximately 85%.

Simply put, optimum coal fineness and desirable portions of air and fuel to the burners is absolutely critical for acceptable combustion performance and control of emissions. This is considering that as fineness increases, fuel balance improves. The reason for this is the fact that the larger coarse coal particles have higher momentum when entrained in air at a certain velocity and are more easily stratified than finer coal particles that have less mass, and thus lower

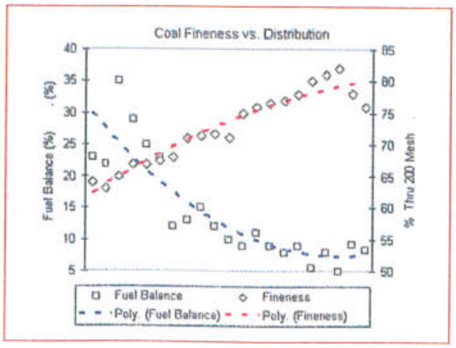

Figure 10. Compilation of recent STI testing data w/ polynomial trends.

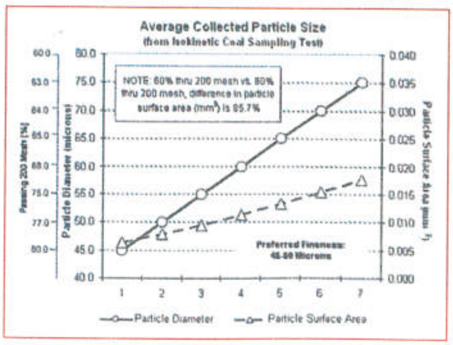

Figure 11. Fineness versus particle surface area graph.

momentum (see Figures 8 and 9 for examples of some recent STI testing data).

After coarse and fine coal particles are separated, fuel and air balance is further aggravated by imbalances in airflow. Typically, burner lines that receive the largest quantity of coarse coal particles have the lowest dirty air velocities. Considering this, it is critical to achieve equal resistance between fuel lines. This is also why fuel line balancing attempts with 'in service' adjustable orifices is very seldom repeatable. In addition, improved fuel distribution allows for more uniform burning in the furnace and equitably distributed oxygen across the furnace. Finely distributed 45 - 50 micron coal exiting the coal nozzle contributes to a more symmetrical and well defined flame shape. This repeatable distribution of fuel and air with a stable and symmetrical flame development, combines with combustion air staging to combust the fuel with minimum NO_X formation and reduced and/or minimised slagging. This is mandatory with typical low NO_X burners (Figure 10) and staged combustion.

The ultimate test

Savings from reliability issues, heat rate improvements and the ability to flexibly fire various fuels is a huge economic advantage. Furthermore, fuels flexibility yields economic justification for application of optimisation programmes to the pulverisers. Performance and maintenance should be driven by periodic testing and not by t of coal throughput. If you own, operate or affiliate yourself with an end user/PC fired power plant, the following test proves the importance of mills:

Take 50 g of a representative sample of flyash and sieve it through a 200 mesh sieve. Calculate the percentage passing 200 mesh and then separate the coarse particle ash (+200 mesh) and the fine particle ash (-200 mesh) in separate sample containers. If coal fineness is an acceptable level of 75 - 80% through 200 mesh, then the flyash should be approximately > 90% through 200 mesh. However, if the flyash is only 70 - 80% through 200 mesh, this is the first sign that pulveriser performance is poor. Next, test the composite, fine and coarse particle ash samples for unburned carbon (UBC) levels. If the fine particle ash (-200 mesh) is very low in carbon content, but the coarse particle ash (+200 mesh) is high, this suggests that the loss on ignition (LOI) or UBC rates are 100% related to the pulverisers. If the fine particle ash has high LOI levels, then this is related to poor mixing of air and fuel in the furnace and needs to be addressed further with comprehensive boiler testing to determine the areas requiring improvement. Figure 11 shows a sample which has very low fine particle ash LOI. However, the coarse particle ash (which was > 20% of the total flyash) has 50% LOI or UBC levels, which was all related to the pulverisers. One can clearly see the coarse particle ash particles on the right are black (carbon) and once pulveriser performance was improved, so was combustion.

Conclusion

In Storm's experience, the correct and long lasting approach to mill performance optimisation and fuel line balancing is to consider the coal crushers, feeders, pulveriser, primary airflow, fuel lines and burners as an entire system. As previously noted, STI considers this approach 'the solid fuel injection system (SFIS) approach.'