Engineered for THE FUTURE

Peter Rugg, MacArthur Energy, US, describes new technologies to clean and improve coal-based fuels before combustion.

Coal preparation and cleaning is nearly as old as the coal industry itself. However, with today's more stringent clean air requirements, new technologies and new uses for older technologies are supporting efforts to cost-effectively burn coal and other solid fuels with greater efficiency and lower hazardous air emissions. This review is divided into three sections concentrating on the preparation of solid fuel for a coal plant via washing and drying; the removal of criteria pollutants; and the addition of biomass. All of these treatments, taking place before combustion, are various aspects of engineered coal fuels.

The issue

Emissions creation

Coal is a mixture of biomass substance that has been converted over millennia through heat and pressure. It contains moisture, hydrocarbons and ash consisting of various minerals including dirt, sand, sulfur, nitrogen, mercury, chlorine and traces of arsenic, selenium and other metals and materials.

In a typical combustion process, the moisture turns into water vapour; the hydrocarbons turn into water vapour and CO_2; and, while some of the ash falls to the bottom of the furnace, the rest is turned into various airborne emissions. This coal combustion process also adds 10 lb of air to every 1 lb of solid fuel, thus producing flue gases with more than 10 times the mass and 500 times the volume of the original fuel. Finally, the heat of combustion causes other chemical reactions, combining substances in the fuel with substances in the air, producing additional emissions including acid gases as well as dioxins and furans. Government authorities in various world jurisdictions regulate or are seeking to regulate many emissions including dust and ash particles, nitrogen/oxygen compounds, sulfur, mercury, dioxins and furans, hydro-chloric acid (as a surrogate for many acid gases), carbon monoxide (as a surrogate for organic compounds) and CO_2.

Emissions control

By the 1940s and 1950s, many industrial cities burning significant volumes of wood and coal for combined heat and power were inundated with noxious smog. This smog was largely ash in the form of fine particulate matter that was produced in the combustion process. Since the smog was generated in the combustion process, there was no way to remove it through pre-combustion treatment of the fuel. Filters, bag houses and electrostatic precipitators were thus designed to remove the ash of particulate matter from the flue gases on a post-combustion basis and proved to be very effective at reducing smog and cleaning up our air.

Later, when acid gases of sulfur, nitric oxides and various forms of mercury were deemed to be pollutants, the industry again turned to post-combustion treatments to reduce these emissions. Because of the 10-to-1 ratio of added air, post-combustion technologies must treat 500 times the volume of material to remove effluent than if the fuel could be treated before combustion.

As regulations have tightened over the years, it has become more and more costly to scrub flue gas for smaller and smaller concentrations. In some cases, scrubbing for a series of emissions such as particulate matter, SOx, NOx and mercury has created conflict between various flue gas scrubber technologies that degrade their efficiency. These effects have also impacted public policy efforts to promulgate new air regulations.

Pre-combustion technologies enable a better match between the combustion characteristics of a specific fuel with the boiler in which it is to be fired. This improves efficiency, saving both cost and fuel, and helps reduce criteria and greenhouse gas (GHG) emissions. To be efficient and practical, the new clean coal paradigm must include:

- Pre-combustion technologies to remove non-fuel substances from the fuel.
- Mid-combustion technologies to mitigate unwanted emissions that are created in combustion.
- Post-combustion treatment for emissions that can be efficiently removed at the late stage.

Solutions

Washing and drying engineered coal fuels

Historically, coal cleaning was done by hand-sorting: as coal passed on a chute or conveyor, labourers would remove and discard non-coal dirt and ash. During the industrial age, coal mines began to use the principles of specific gravity, employing flotation to separate coal from ash.

More sophisticated technologies are employed today. Great River Energy (GRE), working in conjunction with the US Department of Energy (DOE) and Lehigh University, has developed a process called Dry-Fining. The process deploys a fluidised bed that is precisely aligned to achieve close specification gravity separation without the flotation that would increase moisture content. The raw lignite fuel, when passing over the fluidised bed, separates from heavier particles that have been shown to contain elevated levels of sulfur and mercury. This improves the value of the fuel by significantly reducing elements that might become pollutants if emitted after combustion. The driver for the fluidised bed is hot flue gas. The preheating of the fuel leads to a reduction of moisture from 39.5% to 29.5%, thus increasing Btu content/lb from 6200 to 7100 Btu, and reducing the fuel flow rate by about 14%. When burning a smaller quantity of higher value fuel, GRE's Coal Creek plant has reduced mercury and sulfur emissions by 40%, nitric oxide emissions by 20% and CO_2 emissions by 4% while achieving overall plant efficiency benefits of 2 – 4%.

Removal of criteria pollutants from engineered coal fuel

There are two relatively new technologies for the removal of pollution pre-cursors that go beyond washing or separation cleaning.

First, there are several technologies that employ chemical additives to the fuel as it enters the boiler. These chemicals, such as sodium carbonate or calcium carbonate, form a chemical bond with sulfur and some other criteria pollutants and then fall into the ash pit during combustion. These chemical additive technologies can at times achieve 80 – 90% reductions in pollution precursors; their cost efficacy is dependent on the volumes of additive necessary to achieve the desired reductions.

Second, MacArthur Energy has developed thermal treatments that remove moisture, chlorine, mercury, heavy metals, nitrogen and sulfur from coal and biomass fuels. The process involves passing the fuel, which may have been run through gravity separation and heated fluidised bed, through a heated rotary kiln that blocks the incursion of air. The absence of air permits heating to a higher temperature without combusting the fuel. The temperature elevation removes all moisture and vaporises the chlorine, mercury, arsenic, selenium, nitrogen and a portion of the sulfur depending on the level of processing. These gaseous hazardous elements are removed from the kiln separately from the solid fuel. The off gases are treated with small amounts of chemical reagents and activated carbon to properly sequester the hazardous elements for recycling or disposal in an inert state.

The resulting engineered coal fuel burns with higher efficiency, thus reducing fuel flow rate. The reduced fuel flow rate directly reduces CO, CO_2, NOx, and SOx. The absence of chlorine in the fuel precludes the production of hydrochloric acid, dioxins and furans. The absence of mercury in the fuel precludes the emission of mercury or oxides of mercury in the flue gases. Pre-treatment of fuel for these elements

Note

A fact sheet is available online: http://americancoalcouncil.org/associations/10586/files/ECF_factsheet.pdf

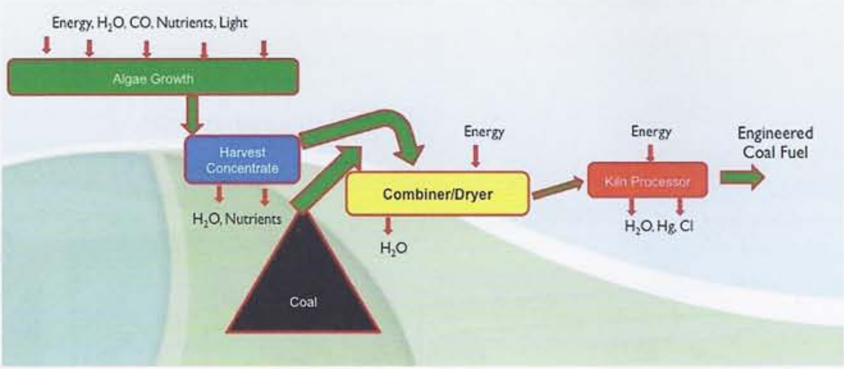

Figure 1. Process flow diagram.

was foreseen in the publication of the latest US final boiler MACT rule (stayed for re-issuance in spring 2012), as operators whose fuels analysis shows low enough levels of chlorine and mercury are exempt from other downstream testing and compliance monitoring.

Adding biomass to engineered coal fuels

Although the US has no national standard or rule for CO_2 emissions, other countries do, and the US has renewable fuel requirements for generators in 35 – 40 states. Outside the US, there is significant demand for biomass burning in existing coal boilers in order to meet greenhouse gas (GHG) emission rules.

Over the past 7 – 10 years, many trials have attempted to add raw biomass to a coal fuel supply. Unfortunately, the inherent differences between hard, dry, black coal and soft, wet, green biomass have led to many issues in boiler operations. In addition, many biomass fuels are high in alkali compounds that tend to reduce the fusion temperature of the coal ash, promoting problems with boiler slag. Finally, much biomass material has high chlorine content leading to boiler corrosion and the creation of higher amounts of acid gases.

Several companies are pre-treating biomass to solve these problems. These companies are compacting and pelletising biomass into a stable, higher calorific value solid fuel to aid generators in meeting renewable fuel mandates. Other companies dry low rank coals and compact them to form a higher value more stable and transportable coal fuel.

MacArthur Energy's patent-pending blending technology combines coal and biomass into a homogeneous mixture that runs seamlessly in existing coal infrastructure. By combining the coal and biomass before the final coal upgrading in a thermal kiln, the moisture and chlorine are removed from the coal and the biomass. In addition, mercury and other criteria pollutants are removed from the coal as detailed above. Mixtures can range up to 50% biomass. The process is agnostic on the form of biomass, whether woody pulp or grass based. When the biomass fuel is purpose grown, such as algae, it is often possible to grow biomass fuel with lower alkali levels with less chance of ash fusion (Figure 1). These fuels can be produced to the same specifications as the thermally treated engineered coal fuels noted above, with the added benefit of a higher reduction of GHGs and compliance with renewable fuel source regulations.

Conclusion

All of the companies mentioned above are, or have been, part of the American Coal Council's Coal 2.0 Alliance (see sidebar). They and others in the group offer a suite of diversified technologies to treat coal and biomass before it is burned in order to improve efficiency and reduce emissions. In many cases, these technologies may be the only available options for smaller boilers with limited or no space for downstream flue gas treatment. While these technologies are not yet widely deployed, their use is gaining acceptance and several companies are forging alliances with universities and industry partners to advance pilot and development projects.

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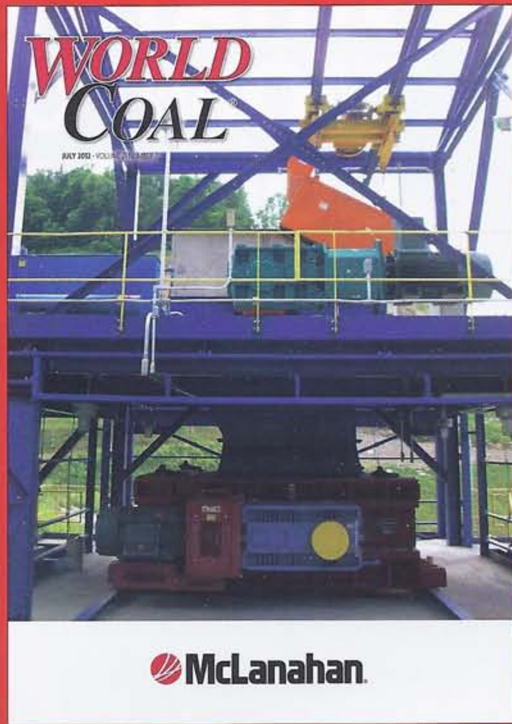
World Coal is a fully-audited member of the Audit Bureau of Circulations (ABC). An audit certificate is available from our sales department on request.



Cover Information

McLanahan Corp. supplied a 30 in. dia. x 96 in. wide tertiary direct drive crusher-sizer to Arch Coal. The sizer was placed at the company's new Leer preparation plant in Grafton, West Virginia. McLanahan is known for designing and manufacturing crushers for primary, secondary, and tertiary reduction of low silica materials. For more information on the direct drive crusher-sizer or any of McLanahan's equipment or systems, visit the website below or contact: sales@mclanahan.com

For more information, please visit:

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