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STORM TECHNOLOGIES, INC.
411 North Depot Street PO Box 429
Albemarle, NC 28002
Phone: 704/983-2040, Fax: 704/982-9657
www.stormeng.com

CFB Boilers and Optimization

Mark Smith, Field Service Engineer and Storm Technologies, Inc. Team

In today's political environment, there is a continuous discussion about "clean coal." Some of the methods to protect the environment include:

1. Western PRB pulverized coal fuel
2. Bituminous coal and SCR and scrubber
3. Bituminous coal and SNCR and Spray Drying Absorption (SDA)
4. CFBs and SNCR and SDA
5. Integrated Gasification Combined Cycle (IGCC)

Of these choices, Storm Technologies believes options 1-4 will meet most of the requirements until 2020. IGCC is a good idea and will eventually be a competitive option. However, for the present time, CFBs present the best option as they are reliable and clean!

What is CFB Technology?

CFB technology utilizes the fluidized bed principle in which crushed fuel and limestone are injected into the furnace or combustor. The particles are suspended in a stream of upwardly flowing air (60-70% of the total air) which enters the bottom of the furnace through air distribution nozzles. The balance of combustion air is admitted above the bottom of the furnace as secondary air. While combustion takes place at 1550-1650 °F (840-900 °C), the fine particles (<450 microns) are elutriated out of the furnace with flue gas velocity of 800-1200 fpm (4-6 m/s). The particles are then collected by the solids separators and circulated back into the furnace. This combustion process is called circulating fluidized bed (CFB). The particles' circulation provides efficient heat transfer to the furnace walls and longer residence time for carbon and limestone utilization. Similar to pulverized coal firing, the controlling parameters in the CFB combustion process are temperature, residence time and turbulence. Moreover, CFB plants are more flexible than conventional plants in that they can be fired on coal and biomass, among other fuels.

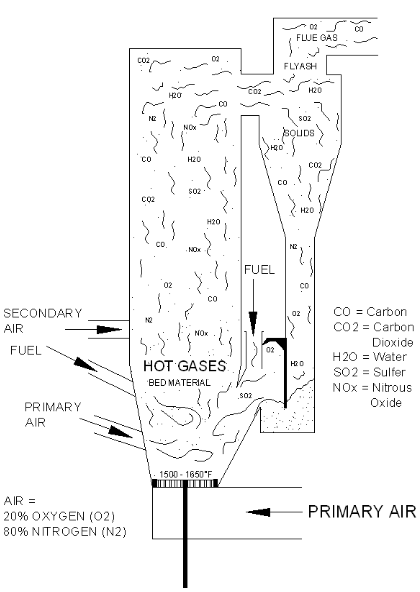

Figure 1

A fluidized boiler's bed material typically consists mostly of limestone products (new and old) as the major bed material, with some smaller amounts of fuel, ash and impurities (for example, rocks or tramp iron).

Calcium oxide content increases with lower sulfur coal contents and high removal rates. The ash content increases with higher ash fuels and those that are less friable.

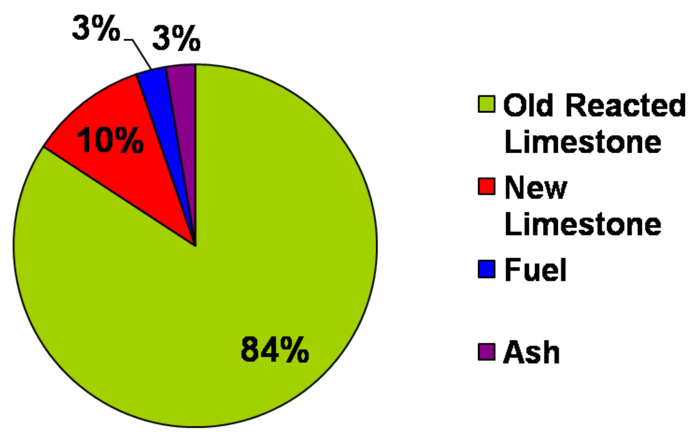

Figure 2

In addition, CFBs reduce the amount of sulfur emitted in the form of SO_x emissions. Limestone is used to precipitate out sulfate during combustion, which also allows more efficient heat transfer from the boiler to the apparatus used to capture the heat energy (usually water tubes). The heated precipitate coming in direct contact with the tubes (heating by conduction) increases the efficiency. Since this allows coal plants to burn at cooler temperatures, less NOx is also emitted. CFB boilers can burn fuels other than coal, and the lower temperatures of combustion (800 °C / 1500 °F) have other added benefits as well.

The key to maintain low NO_x emissions is creating a reducing condition environment. In a CFB system, a significant amount of the total air is introduced above the grate and fuel is launched below these air ports. Carbon monoxide (CO) and char are strong NO_x reducing agents as they strip

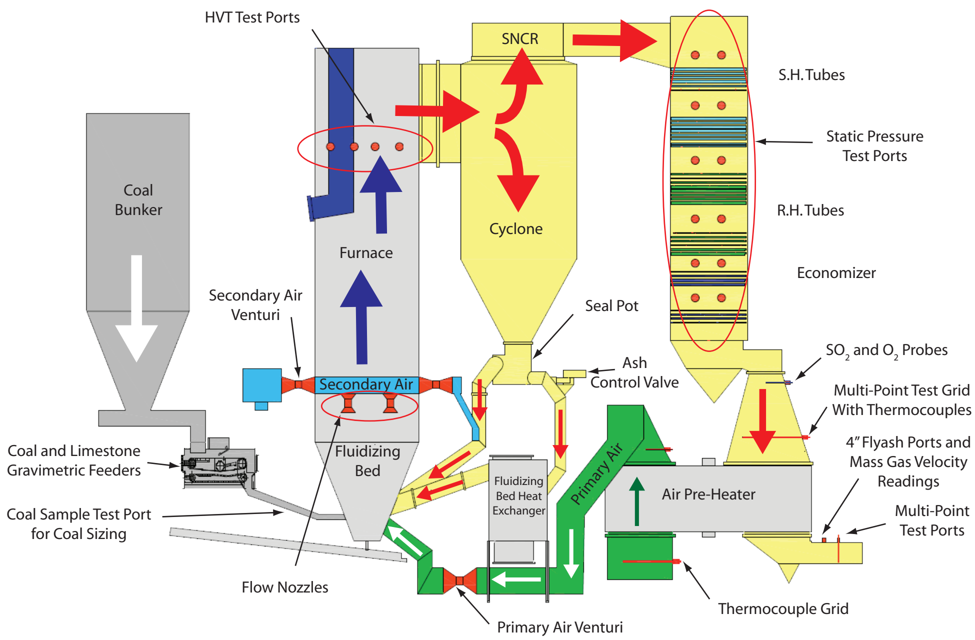

Figure 3

oxygen from the NO_x in a reduction action that produces elemental nitrogen (N_2). By creating a sub-stoichiometric zone in the lower combustor with high concentrations of char and CO, a NO_x emission levels can be as low as 0.1 lb/mmBtu. Additional NO_x reduction (as required) is typically accomplished with SNCR at the Cyclone Inlet. Furthermore, it has been proven that NO_x emissions increase with higher Ca/S, especially at high SO_2 removal rates. Therefore, minimizing the Ca/S ratio is important to NO_x emissions as well as to limestone cost.

The Fundamentals

Maintaining optimal combustion performance is essential in efficient performance. Storm Technologies has always believed in the simple belief of applying the fundamentals to achieve the goal:

1. Crush the Coal
2. Mix with limestone
3. Absorb up to 90% of the sulfur in the fuel when combusted in the CFB bed and prevent it from entering the flue gas
4. The mixture of coal (some with very high sulfur content) and limestone are blown into the lower bed of the boiler with heated air.
5. Air is also introduced into the bottom of the bed as well as secondary air above the bed to maintain an overall bed average temperature of approximately 1,600 °F (~850 °C) which is well below the ash-softening temperature for nearly all fuels.
6. Keeping the combustion temperature low and properly staging the combustion air greatly reduces the formation of NO_x. At the furnace exit, ammonia is also commonly injected in the gas stream (SNCR) to further reduce NO_x.
7. High combustion efficiencies are achieved because the solids' residence time in the furnace is much greater than most PC fired units by the collection/re-circulation of solids in the cyclones and the highly turbulent state of the solids/gas in the furnace.
8. Water walls in the main combustor and cyclone absorb heat energy from the combustion process to generate steam. Hot ash and limestone are separated in cyclones. Hot gases leaving the cyclones enter a heat exchanger.
9. Apply the calcinations process to the limestone:

$$CaCO_3 = CaO \text{ (Lime)} + CO_2$$
$$MgCO_3 = MgO + CO_2 \text{ (driven off)}$$

10. Most of the sulfur in the fuel is oxidized during combustion and converted to SO2, however some of the inorganic bound sulfur is retained in the ash. The sulfur dioxide combines with the calcined lime in the reaction:

$$SO_2 + CaO + \tfrac{1}{2}O_2 = CaSO_4$$

Applying the fundamentals is important and Storm's approach for optimum combustion can be implemented using these simple steps:

The STORM Approach for Optimizing a CFB

1. Optimum coal sizing
2. Optimum air and fuel measurement accuracy
3. Optimum air and fuel distribution
4. Balanced flue gas constituents across the CFB furnace (combustor) and exit locations (as feasible) and ensure uniformity in heat transfer and gas velocities.
5. APH and/or system air in-leakage
6. Non-optimum conditions with the previous can result in:
   a. Poor combustion efficiency
   b. Tube erosion due to increased localized gas velocities
   c. Lower than design NO_x or SO_2 removal
7. Conduct a performance preservation plan to insure the previous are acceptable. This plan should include the following at a minimum:
   a. Airflow measurement calibrations
   b. O_2 probe and SO_2 Probe Calibrations
   c. Periodic coal sampling for sizing analyses
   d. Collect daily fly-ash LOI analyses
   e. Conduct Routine air preheater and boiler efficiency tests
   f. Conduct periodic gas mapping of the furnace and system

In conclusion, CFB boilers improve combustion efficiency; can burn a wide range of fuels, provide lower NO_x and SO_2 emissions, and operate at lower temperatures. These benefits allow versatility and compliance with environmental laws and policies. However, as with any operation, care must be taken to ensure that the CFB is operating efficiently. Developing and maintaining a plan for continuous improvement must be taken to ensure maximum efficiency.