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Pulverized Coal Furnaces Or Circulating Fluidized Beds, The Fundamentals Still Apply

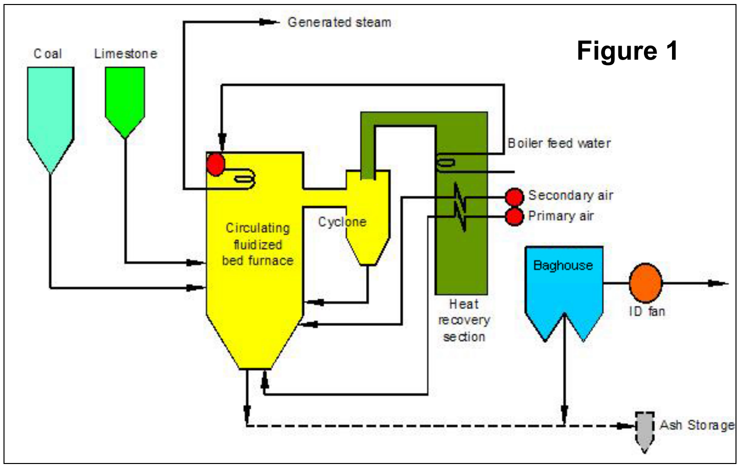
Last Month's subject was the "MAGNIFICENT BOILER FURNACE", and the versatility of 30 year-old pulverized coal furnaces. We discussed the firing of various coals with ever decreasing NO_x levels, and ever increasing time between overhauls. Storm's bread and butter business for years has been pulverized coal fired boiler combustion optimization; and it shows. Looking back on our past newsletters, articles, and technical papers that were published, most are on the subject of optimizing combustion in pulverized coal fueled boilers.

This is Storm's core business, and we will continue to do our best to serve our customers needs for these old dinosaurs. This aging dinosaur fleet of 30 plus year old coal fueled pulverized coal plants are likely to be depended on for decades to come. Planning, sighting, permitting and funding new coal plants seems to be about a hundred times harder than it should be. So, we better keep the existing fleet of geriatric coal plants operating at their best. Opportunities for improvement in heat rate, NO_x, fuel flexibility, reliability and capacity abound in existing plants. Storm will continue doing our part in contributing to excellence in Operations & Management of the existing fleet of pulverized coal plants!

The Future According To Storm Technologies, Inc.

Clean coal power generation using Circulating Fluidized Beds (CFB's) technology is now here. A typical CFB is shown in Figure 1 to the right.

Figure 1



Some reasons why the USA should

1. Build new clean coal plants now, and

2. Achieve optimum efficiency of both existing and new coal plants.

- The USA has about a 250 year supply of coal.
- The USA has more energy equivalent reserves in coal than Saudi Arabia has in energy equivalent oil.
- The USA has about 4% of the world population, but uses about 20% of the total world's energy.
- USA load growth at 1.5% per year will require about 400,000MW of new generation by 2025 to both (a) replace very old coal plants; (some of which are now over 50 years old) and (b) to meet the electrical demand of the third most populated country on the planet, with the strongest economy.
- Reductions of atmosphere release of CO_2, although not considered a problem by many US experts, CO_2 emissions are considered a problem by many other scientists worldwide. So, we should do all that we can to use our "Homegrown Coal" as efficiently as possible.
- Improving heat rates to the range of 9,500 Btu's/kWh from an average of 10,500 Btu's/kWh is a thermal efficiency improvement from 32.5% to 35.9%. Even 30 year old coal plants with 2,400 psi 1000°F/1000°F cycles could do this with minor capital improvements and excellence in O&M.
- "New Source Review" clearly obstructs the option of improving efficiency of existing plants.
- Improving efficiency is simply just the right thing to do, and it makes common sense!

What can we do?

1. Educate the public and politicians on the benefits of eliminating NSR and modifying existing plants for improved heat rates. Such as:
   - Natural gas should be used for job creating industries and domestic use; not for power generation. Natural gas is too precious to burn in power boilers!
   - Building 400,000MW of new coal generation capacity over 16 years equates to about one 500MW unit per week for sixteen years. This forecast seems inevitable, based on the age of existing power plants, world energy supply and demand issues. Especially, the expected continued shortage of natural gas and even LNG.
   - Upgrade existing plants, for example:
     - (a) New superheaters and reheaters, new ductwork and airheaters with leakage below 8%, new turbine rotors and new condensers.
     - (b) Build new clean CFB plants for bituminous coals, to re-power some old PC plants.
     - (c) Build new clean state of the art, proven reliable, supercritical plants for western fuels.
2. Most of all, and for minimum cost, apply the fundamentals to improve heat rates now! This newsletter outlines some fundamentals that can be applied to circulating fluidized bed boilers.

Check the published operating costs, and heat rates of the top plants in the USA, some coal CFB's are listed right along with the "Best" pulverized coal plants. Based on the operating records of competitive heat rates and generation costs, it needs to be acknowledged that CFB technology and commercialization has reached prime time. As most of the readers of this newsletter know, we need to build many new power plants, and we need to start now. Some predictions suggest at least four new units per month for the next twenty years. Expected load growth over the next ten years is not likely to be satisfied or produced by hydrogen fuel cells, windmills or even natural gas. The way we see it, CFB's are commercially proven, environmentally clean and economically viable. So, we look forward to seeing good business in both optimizing pulverized coal combustion and in CFB optimization for the next couple of decades. IGCC's are coming, but CFB's are proven. Good for America, with a 250 year supply of homegrown coal. Also good for all suppliers like those of us with products and services for optimizing coal combustion. We remain very optimistic on the future of COAL.

CFB's - HOW THEY HAVE EVOLVED:
A brief review of The Evolution of Clean Coal Combustion leading up to Clean Coal Fueled Large Utility Scale Units

During the last 30 years, CFB's have progressed from laboratory scale, to full size commercially competitive solutions for clean coal combustion. Some of the top USA plants, ranked by heat rate, emissions and lowest generation cost, are CFB's. CFB plants under construction in Europe are not only electric utility sized, but are now moving into supercritical steam cycle pressures for improved heat rate. Because CFB's have progressed into being a proven clean coal commercial solution, we thought it would be timely to review the evolution of CFB's (See figure 2 below). Also, we will review the fundamentals of fluidized bed combustion.

The Evolution of Coal Combustion over the last 80 years:

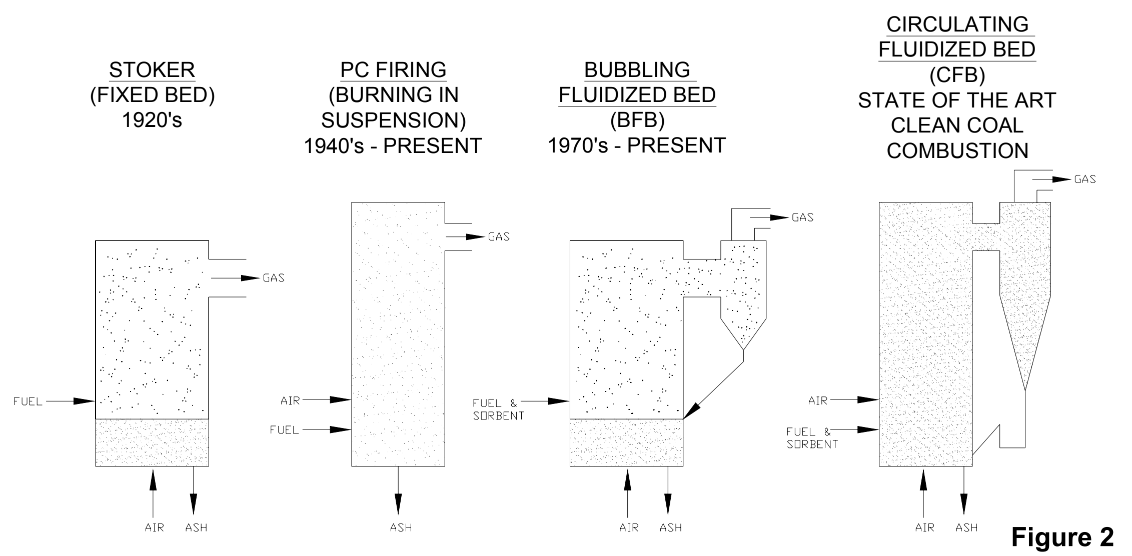


Figure 2

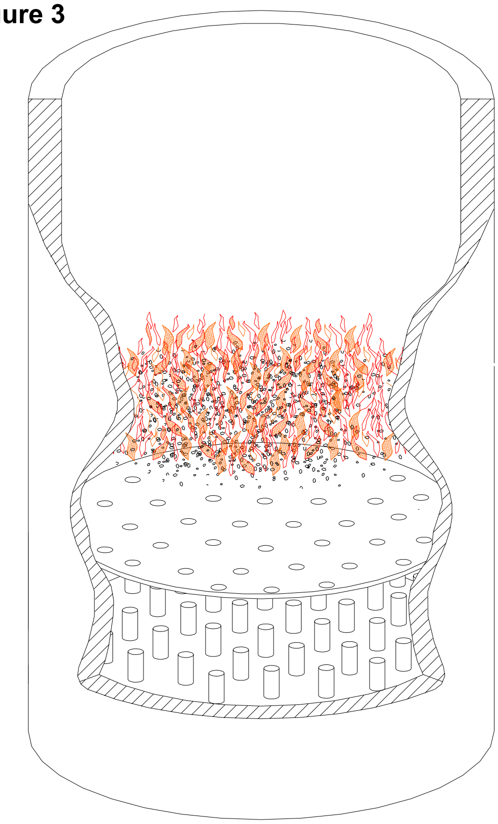
Fluidized Combustion Fundamentals

In a fluidized bed boiler, upward blowing jets of air suspend burning coal, allowing it to mix with limestone that absorbs oxides of sulfur. In a "fluidized bed boiler," crushed coal particles float inside the boiler, suspended by the fluidizing jets of air. The red-hot mass of floating coal (called the "bed") bubbles and tumbles around with limestone.

Fluidized Bed Technology Fundamentals

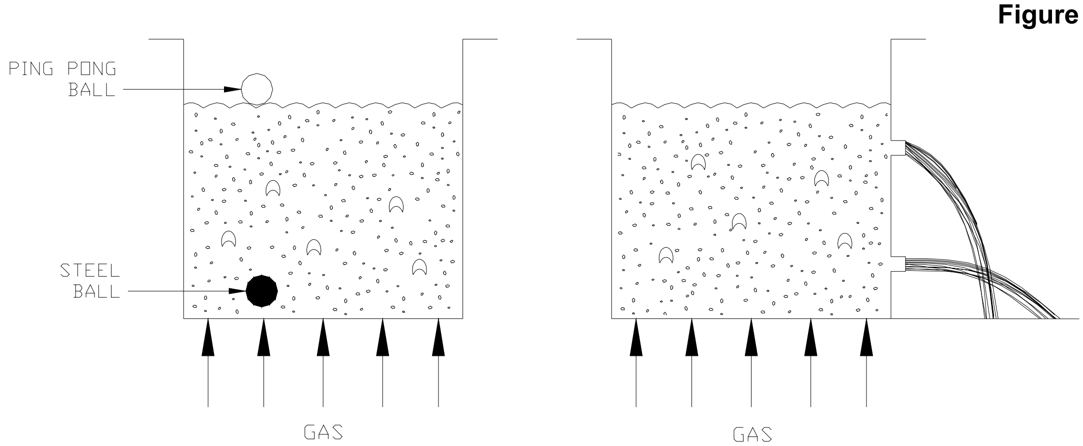
Much like, fluidized hot flyash in a pulverized coal boiler with pressurized air blown into the bottom of an ash hopper for fluidization. As shown to the right in Figure 3.

Figure 3



Fluidization is defined as a process through which fine solids are transformed into a fluid like state through contact with either a gas or a liquid. The modern CFB is a combination boiler furnace and a chemical reactor. Low NO_x combustion and SO_2 capture are efficiently combined in the fluid bed furnace (See Figure 3A).

Figure 3A



Circulating Fluidized Bed (CFB)
Technology Fundamentals

Carbon Monoxide (CO) and Char are strong NO_x reducing agents. These agents strip Oxygen from the NO_x in a reduction action that produces elemental Nitrogen (N_2). In a CFB system, a significant amount of the total air is introduced above the grate, and fuel is below these air ports. Creating a substoichiometric zone in the lower combustor with resulting high concentrations of Char & CO. Reduced conditions in the lower combustor are the key for attainment of a NO_x emissions level in the range of 0.1#/mm Btu. Further reductions are accomplished with an SNCR system installed at the furnace exit. It has also been proven that NO_x emissions increase with higher Ca/S, especially at high SO_2 removal rates. Thus, minimizing Ca/S is important to NO_x emissions as well as to limestone cost (See Figure 4).

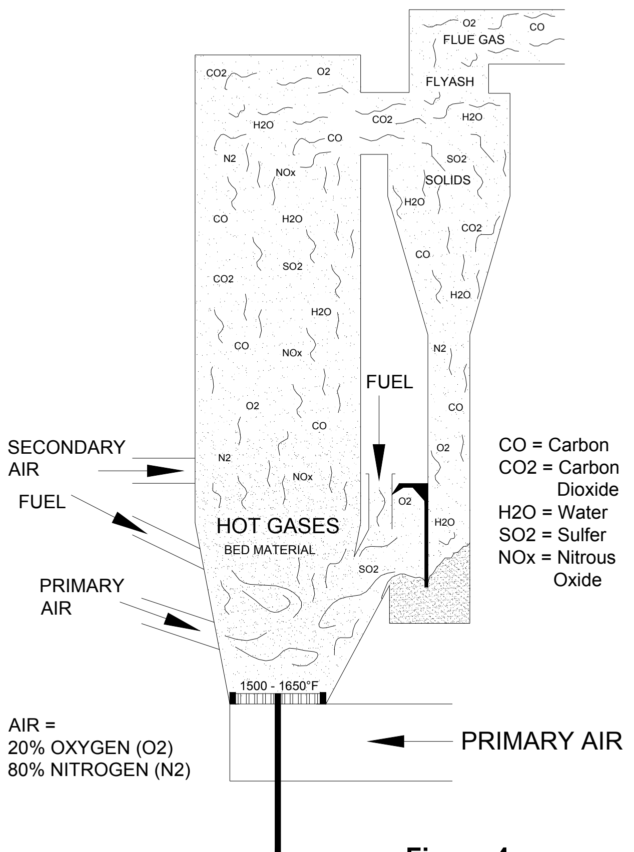


Figure 4

So, where are we today?

Progress has been made! The 300MW size range CFB units have progressed to the systems, as has been commercially proven at JEA. This well publicized repowering project has proven that clean coal combustion is economically and environmentally viable.

FW System Overview

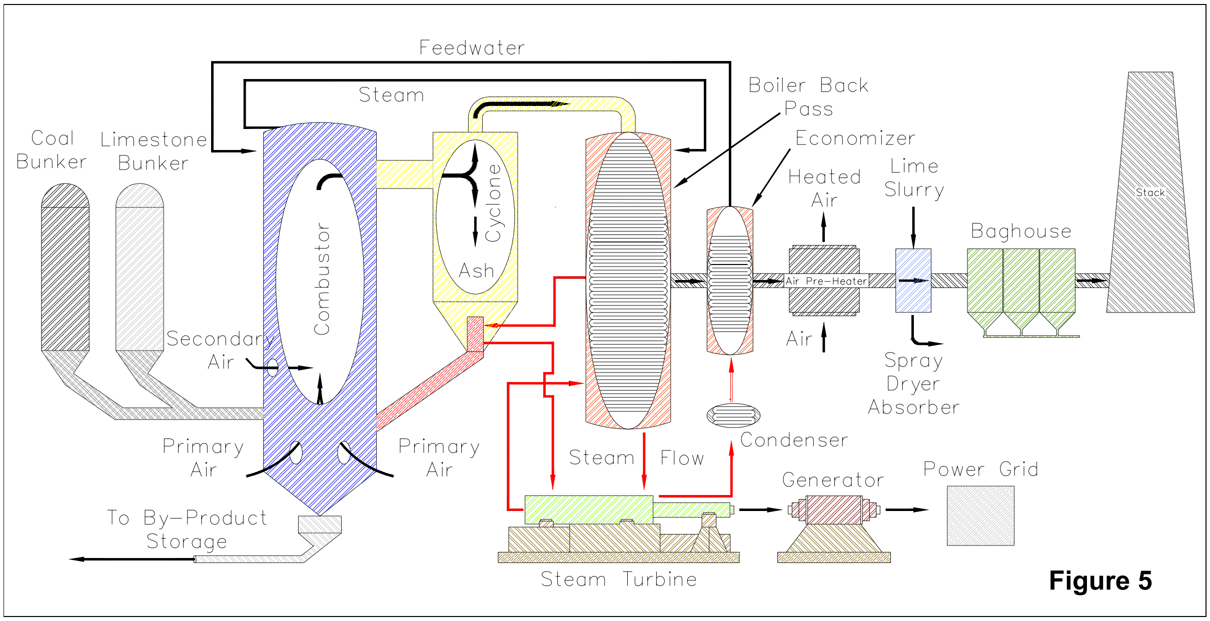


Figure 5

The JEA system is shown above in Figure 5. This leads to the importance of precise control of combustion airflows into the bed. Necessary on CFB's not only for NO_x, but also for combustion efficiency and sorbent efficiency. Eventually, as has been proven on pulverized coal plants, the unit heat rates can be improved upon as a result of improving combustion efficiency. Figures 6 and 7 illustrate typical combustion airflow paths into a CFB.

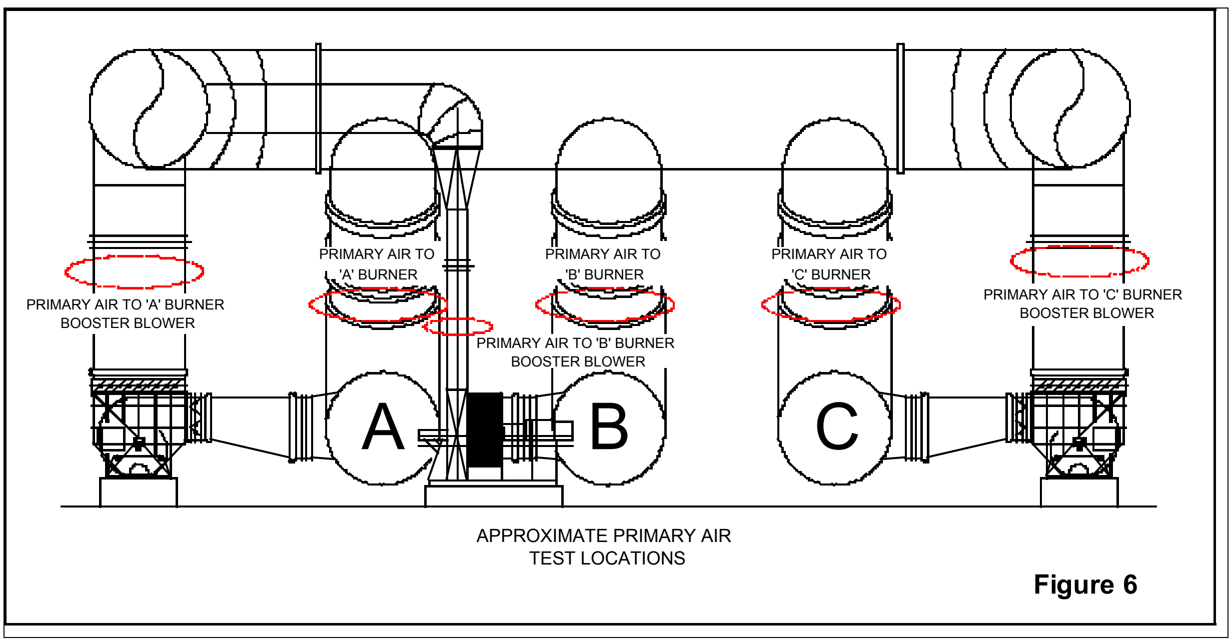
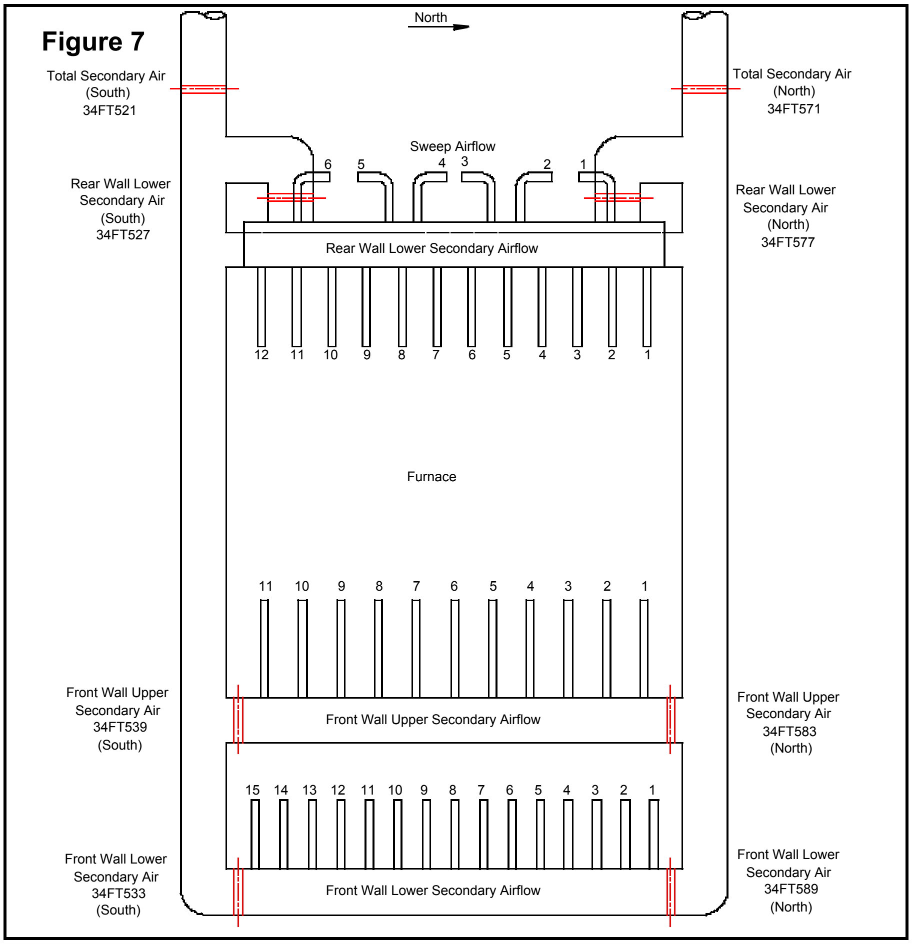


Figure 6



So what do we do to optimize CFB combustion?

You knew we would get around to applying the fundamentals sooner or later. Inherent in the design of CFB's is the controlled combustion at temperatures in the range of 1,400 to 1,700°F. These lower temperatures and the fluidized combustion process result in low NO_x production. In addition to producing low NO_x, CFB's also capture most of the fuel sulfur with the limestone sorbent injected into the bed.

Sounds simple enough, so where are the opportunities? Even with the much longer residence time and recirculation of the ash in a CFB, combustion airflow needs to be precisely measured and controlled. A CFB furnace must control, not only the temperature and the rate of combustion air, but it must also sustain the chemical reactions of SO_2 removal in the furnace.

Specifically:

Calcinations of Limestone:

$CaCO_3$ + Heat $\rightarrow$ CaO + CO_2

Reaction with sulfur oxides (sulfation):

$CaO + O_2 + SO_2 \rightarrow CaSO_4$

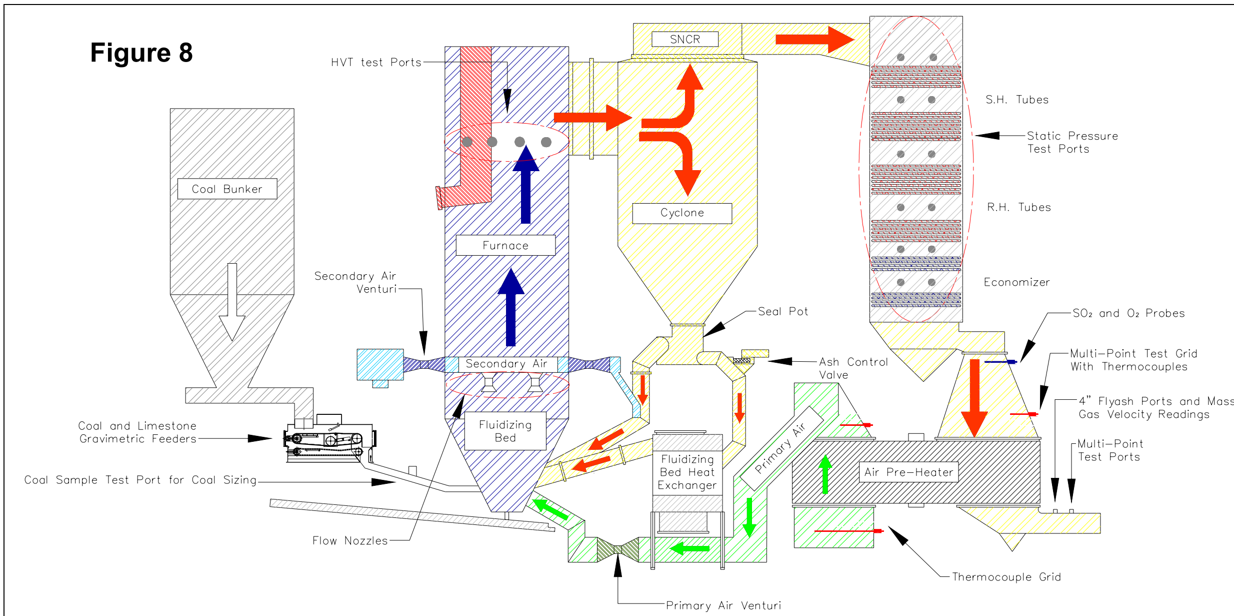
These reactions work best in the temperature range of 1500 to 1700°F. If the temperature is too high, two adverse affects result:

1. higher NO_x can be produced than what a CFB is capable of and,
2. the limestone sulfur reactions are less efficient.

The Storm Approach is to measure and control air; fuel and sorbents with tried, proven, and calibrated measuring elements. Figure 8 shows flow and nozzle venturis; the combustion airflows which require optimum measurement accuracy.

Typical CFB Combustion Airflows

Figure 8



Storm continues to recommend venturis and flow nozzles to be utilized for combustion airflow measurement and control. Key to their success has been Hot “K” Calibrations, as used for pulverized coal boiler combustion airflows. Typical Storm design flow elements for combustion airflow measurement of the primary airflow of a CFB are shown below.

THE FOLLOWING IS A CHECKLIST OF MAJOR STORM RECOMMENDATIONS FOR CFB OPTIMIZATION:

- Optimum Coal Sizing
- Optimum Air & Fuel Measurement Accuracy
- Optimum Air & Fuel Distribution
- Balanced flue gas constituents across the CFB furnace (combustor) and exit locations (as feasible) and ensure uniformity in heat transfer & gas velocities.
- Non-optimum conditions with the previous can result in
  - poor combustion efficiency
  - tube erosion due to increased localized gas velocities
  - non-optimum NO_x or SO_2 removal
  - and require higher sorbent feed rates.
- APH and/or System Air in-leakage
- Conduct a performance preservation plan to insure the previous are acceptable. This plan should include the following at a minimum.
  - airflow measurement calibrations
  - O_2 probe & SO_2 probe calibrations
  - periodic coal sampling for sizing analyses
  - collect daily fly ash LOI analyses
  - conduct routine APH and boiler efficiency tests
  - conduct periodic gas mapping of the furnace & system
  - and system “Oxygen Rise” tests to identify tramp air in-leakage.

Circulating Fluidized Bed (CFB) Technology Fundamentals

Advantages of CFB Boilers

- Combustion efficiency is improved in the CFB boiler compared to a bubbling bed boiler. This is primarily because the elutriated particles are separated from the flue gas in cyclone collectors and returned to the furnace for further exposure to combustion temperature and high turbulence. This fact results in an increase of up to 4% in overall combustion efficiency. These particles are the circulating bed material within the "hot loop" . The hot loop is a term given for the circulating path of bed material inside the boiler.

Other Advantages of CFB boilers are:

- can burn a wide range of low-grade or high-grade fuel, including low volatile coal or petroleum coke
- better sulfur capture with less limestone and low SO_2 emissions
- lower operating temperatures, compared to other types of boilers, thus reducing the chance of slag and excess stack emissions
- Improved heat transfer and the increase of residence time for fuel and limestone
- lower NO_x emissions because of low operating temperatures, less than 1700°F
- lower operating temperatures translate into less pollutants and less equipment needed to clean up the combustion process while burning a variety of fuels. Less "backend" flue gas cleaning can result in reduced parasitic auxiliary power consumption and thus a resultant better "Net Heat Rate".

Clean coal combustion in CFB's in our opinion, is not only economically feasible, but also a patriotic approach to responsible, clean power generation in America. Not only can we utilize vastly different fuels (from waste to fluid coke), but it can be done by reducing our country's demand for imported energy. Also, do it cleanly, and at the same or better thermal efficiency, as state of the art pulverized coal fueled boilers.

This is where we think coal combustion in the USA will be moving toward the next decade. CFB's are here to stay! This is the opinion of Dick Storm and the staff of Storm Technologies, Inc.

Sincerely,

Richard F. (Dick) Storm
President

ENERGY FACTS:

- "The energy content of the nation's coal resources exceeds that of all the world's known recoverable oil." (DOE Webpage, "Coal" www.energy.gov)

- The total energy demand is projected to increase 97.7% to 136.5 quadrillion Btu from 2002 to 2025, which is an average increase of 1.5% per year.

- Low NO_x burners are used by 75% of America's coal based power plants as efficient means to reduce emissions that contribute to urban smog.

- According to the National Energy Policy developed by President George W. Bush's administration, "the US will need to build 1,300 to 1,900 new power plants, or about 1 new power plant a week", for the next twenty years (National Energy Policy, May 2001, 1-6).

- Not too long ago on CNN, the advisor to Jordan's Crown Prince Abdullah, Adel A Jubeir, commented on America's pain at the pump is self-inflicted. He cited over regulations and restrictions, as well as the lack of building proper energy facilities (such as refineries) as America's major energy problems.

- According to the Department of Labor, the US unemployment rate, as of March 2004, is at 5.7% How many people could be employed through rebuilding of our infrastructure to utilize more home grown power generation. Based on 50 plants under construction at one time, this could easily provide employment for 50,000 craftsman in the field and a like number (or more) by manufactures and architectural engineering firms.

- Utility emissions have decreased significantly since the passing of the Clean Air Amendment; SO_2 is down 76%, NO_x 60% and PM-10 almost 96% (Americans for Balanced Energy Choices, April 2004).

- Reasonable cost energy is directly related to a thriving economy. Lower cost and friendlier regulations (like removal of NSR) can contribute to improved economic competitiveness.

Richard F. Storm
and the Staff of
Storm Technologies, Inc.
Wish All Our Customers
A Very Joyous and Safe Holiday Season.