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COMBUSTION

LABORATORY REACTORS

ADDRESSING ENVIRONMENTAL NEEDS THROUGH RESEARCH AND DEVELOPMENT

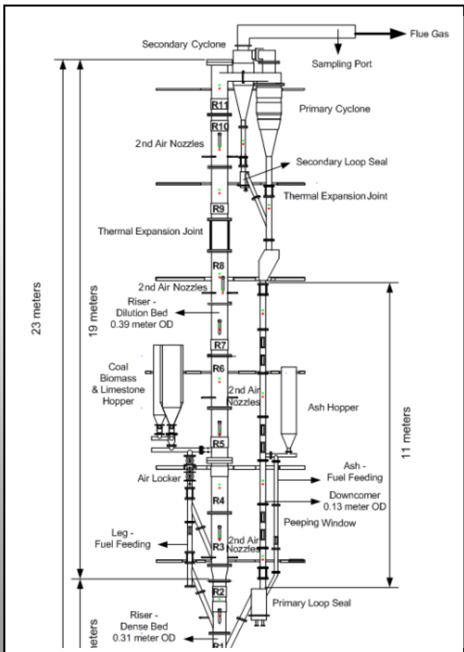

Figure 1 – 0.6 MW_{th} CFBC System

1. 0.6 MW Circulating Fluidized-Bed Combustion System (CFBC): Operation temperature up to 1100℃, Resident time: 3-10s, Coal feed rate:180 lb/h

The CFBC system is primarily housed in a 89-foot tall steel-framed and steel-sided building comprised of eight steel grate floors, a concrete ground floor and a small mezzanine. This CFBC system is designed to operate at the ambient pressure and dense bed temperature at 850°C with a full-load thermal capacity at 0.6MW_{th}. Over-fire combustion operation and combustion (thermal) partition arrangement make the primary air ratio 65% and the secondary air ratio 35%. The excessive air is controlled at a ratio of 1.2. Based on hydrodynamics calculations and a selected average particle size of coal (0.8 mm), the total pressure drop is calculated to be 22.9 kPa. Two sections in the riser have two diameters: 0.31 m at the dense bed (3.1 m in height) and 0.39 m at the dilute bed (16.6 m in height), bridging with a transition section (0.46 m in height). Three main thermal expansion joints (0.91 m in total height, 3 pieces) are used to balance the height change and ensure the system is stable under higher temperatures. Thus, the total height of the CFBC system is about 23 m. The diameter for the stand pipe is 0.13 m. The critical parameters of the cyclones are 0.6 m in diameter of the primary cyclone and 0.5 m for the secondary cyclone. There are 30 bubble caps (6 holes, each having a diameter of 4.5 mm) above the windbox used as gas generated for the primary air. There are three layers of tangentially-oriented secondary air nozzles, each having diameters about 0.027 m. The detailed schematic of the 0.6 MW_{th} CFBC system is shown in Figure 1.

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Developed Technologies in Combustion

1. Patented HBr Injection Technologies for Mercury Emission Control
2. Slipstream Honeycomb Catalyst And Sorbent Injection Facility and Capabilities
3. Bench-scale Fixed Bed Catalyst Evaluation Facility
4. Chemical Looping Combustion
5. Carbon Capture & Sequestration.

2. 2.5" I.D. multiple-purpose coal gasification unit, Operation temperature up to 1100℃, Resident time 3-10s, Feed rate 1-10 lb/h

The pilot-scale gasification facility includes a multi-purpose fuel feeding system with a maximum capacity of 5 Kg/hr of solid fuels and a multi-purpose gas injection system to handle a wide range of feeding materials into the gasifier. Solid fuels will include coal, biomass and solid wastes. Gas agents will include methane, re-circulated CO_2 and steam. It can be operated under two general modes, the air gasification mode and the oxygen gasification mode. Temperature can be achieved as high as 1100°C. Most importantly, a side ash discharger of the gasifier has been built into this advanced gasification facility for flexible control of the residence time of solid char inside the gasifier. The schematic of the pilot-scale gasification facility is shown in Figure 2.

Figure 2 – The schematic of the pilot-scale gasification facility

3. SCR Slipstream Reactor System: Operation temperature up to 350℃, Resident time: 1-3S, Space velocity: 1800 hr^{-1}

A pilot-scale slipstream SCR reactor has been designed to simulate the "full-scale" applications of an SCR system, as shown in Figure 3. The flue gas, which is extracted from the well-insulated intake pipe before the SCR slipstream reactor, is split into two streams whose ratio is controlled by manual flashboard valves to adjust the slot area of the outside flue gas pass. The bypassed flue gas functions as a "strengthened" heat insulation due to its higher temperature which minimizes the heat transfer rate by decreasing the temperature difference between the introduced main stream of flue gas and the bypassed flue gas stream. Thus, this slipstream reactor can be well insulated so that the temperature drop across the SCR slipstream reactor is below 20 ºC. The area of the inside pass is 0.152 by 0.152 meter, and the outside pass is a 0.01 meter slot around the inside square. The total height of the reactor is 6.6 meter. The pilot-scale SCR have a two-layer catalyst to simulate variation of the residence time for gas-solid contact. Each catalyst chamber is 1meter in height. The specific locations of the sampling ports are in relation to the locations of the catalysts. There are 3 sampling ports located at the inlet, middle, and outlet of each SCR catalyst bed. The "inlet" refers to the location before the first catalyst layer, "middle" refers to the location between the first and the second catalyst layers, and the "outlet" is at the outlet of the second catalyst layer. The Hg, NH_3, NO_x and other flue gas samples can be taken at inlet and outlet of the SCR slipstream reactor using CEMs. To prevent the fly ash from depositing on the SCR catalysts, an ash-blower using compressed air was designed and installed. To ensure the control and even distribution of spike-gas injection, three static mixers distribution of spike-gas injection, three static mixers has been built and installed at different locations in the SCR slipstream reactor. The precise control of spiking gas addition also can be achieved through the construction of a multi-port mass flow controller that has the capability of being set to inject a predetermined amount of gas from one to four attached cylinders including SO_2, HCl, Cl_2 and NH_3. SO_3 or HBr addition can use solution injection equipment with a predetermined concentration of H_2SO_4 or HBr solutions, respectively. The solutions vaporized to generate SO_3 or HBr spiking gases inside the SCR reactor with the desired spiking concentration. All injection ports for spiking gases are set up below the first Hg sampling port, which left the "inlet" sampling port unaffected. The injection of NH_3 is separated from other spiking gas lines to ensure operational safety.

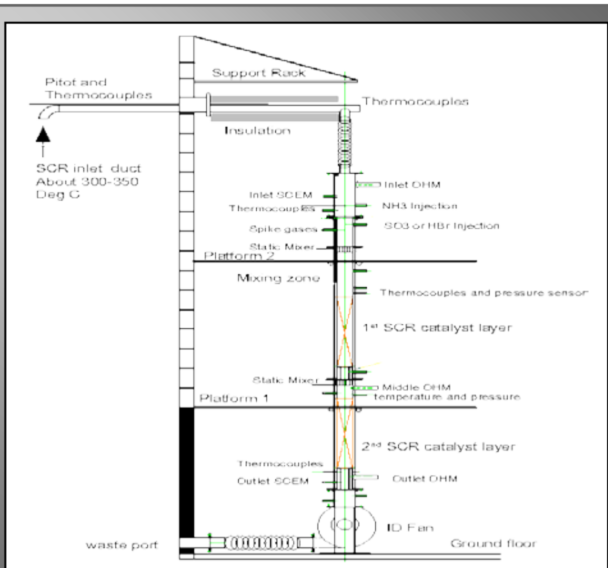

Figure 3 – SCR Slipstream Reactor System

4. Lab-scale Fluidized Bed Combustor, Operation temperature up to 1100^{0}C, Resident time 1-3s **Feed rate 0.20-0.45lb/h**

The fluidized bed co-firing combustor has seven major components. It includes an electrically-heated main body of the fluidized bed combustor; one fuel hopper and one fuel screw feeder; a compressed air delivery line and its metering flow meter; a flue gas cleanup unit including a cyclone and a high temperature quartz filter assembly as well as a wet scrubber. Under the oxygen-firing mode, an oxygen cylinder and flow meter provides oxygen supply and flow control. The outside diameter (OD) of the combustor is about 6.4 cm and 1.6 cm thick. The total height of the combustor is 110 cm. The combustor temperatures are monitored by a platinum-rhodium thermocouple, which is sealed in a stainless steel tube in the combustor. The thermocouple could be moved inside the tube to monitor temperature profile along the height of the combustor. The bed temperature was 850 - 900^{o}C in the main portion of the combustor at the bottom, but gradually started to decrease to 450^{o}C starting at 2/3 of the distance from the combustor's bottom. The fuel mixtures for co-firing are fed into the combustor through a coal feeder on the top of the combustor. The maximum mixing ratios are 50%. The fluidized bed combustor is generally operated at a velocity 3-5 times that of U_{mf} (the minimum fluidization velocity). The excessive air ratio is maintained at about 1.2, while the oxygen concentration at the combustor outlet is about 6.0-8.0%. The flue gas produced with the char residue at the top outlet of the combustor is collected by combining the cyclone and a porous quartz metal filter. The cleaned flue gas is delivered to gas analyzers (O_2, SO_2, NO_x , NH_3 and mercury).

OTHER FACILITIES:

5. 2" I.D. fluidized bed combustor: Operation temperature up to 900℃, Resident time 1-3s Feed rate 0.30-0.50lb/h

6. 1" I.D. fixed bed reactor: Operation temperature up to 1100℃

7. 2" I.D. fixed bed reactor: Operation temperature up to 1200℃

8. 1" I.D. fluidized bed combustor: Operation temperature up to 1000℃, Resident time 1s, Feed rate 0.05lb/h

9. 2" I.D. sorbent injection reactor unit: Operation temperature 150-200℃, Resident time 1-2s, Feed rate 0.10-0.5lb/h

10. Electric boiler: Operation pressure up to 100psi, Feed rate 0.50-4lb/h

11. Chemical looping combustion: Operation temperature 700-900℃, Feed rate 2L/h

12. Horizontal circulating fluidized bed cold and hot model

13. 0.6MW pilot scale of post-combustion CO_2 capture by ammonium bicarbonate system

14. Mercury capture lab-scale test system

15. Mercury re-emission lab-scale system

16. 0.6MW pilot scale of FGD system (Figure 4 - Below)