The components of IGCC power plant can be built in modular form and therefore can be integrated into an existing thermal power plant. An IGCC system can also be run on natural gas or oil and can be switched from one fuel to the other. Inlet temperature of 1200°C and a higher exit temperature of 575°C of the gas turbine yields a significant increase in the efficiency of the combined system. The steam turbine normally produces 30 to 40% of the total energy output of an IGCC plant *i.e.* typically 60 to 70% of the power comes from the gas turbine. This results in ultra-low pollution levels and high system efficiencies. IGCC is an expensive system. Recent developments have made this system useful for methanol production, when power is not required, and this is supposed to reduce the cost to some extent.

8.5. FLUIDIZED BED COMBUSTION

The majority of coal available in India is of low quality having low calorific value and high ash content. The conventional grate fuel firing systems have their own limitations and are technically and economically unable to meet the future challenges. Fluidized bed combustion (FBC) has emerged as a viable alternative and has significant advantages over conventional firing systems.

The fuels used in such a system are coal, rice husk, bagasse and other agricultural wastes. Coals with high ash content (62%) and low calorific value (2500 kCal/kg) can also be used in FBC boilers. The output remains unaffected with the low grade of fuel. The special advantage of this type of combustion is that municipal waste, sewage plant sludge, and other high moisture fuels can also be used to generate heat. These fuels can be used either independently or along with coal. The fluidized bed boilers have a wide capacity range from 0.5 T/hr to over 100 T/hr. The benefits of FBC system are compact boiler design, fuel flexibility, higher efficiency of combustion and reduced emission of pollutants such as NO_x and SO_x.

Mechanism of fluidized bed combustion. Fluidization is a new method of mixing fuel and air to obtain combustion. When air is passed through a packed bed of particles, it simply percolates through the interstitial gaps between the particles. As the air flow rate is steadily increased, a point is reached where the pressure drop across the bed becomes equal to the weight of particles per unit area of bed. This critical velocity is called *minimum fluidization velocity* and at this state the bed is said to be *incipiently fluidized*. As the air velocity is further increased, the particles are propped up and are suspended in the air stream. The particles obtain a turbulent fluid like motion. There is a high degree of particle mixing and equilibrium between gas and particles is rapidly established. The bed is now in a fluidized state. The bed of solid particles exhibits the properties of a boiling liquid; bubbles are formed and is known as bubbling fluidized bed. At higher velocities of air, the particles are blown out of the bed and some amount of particles are to be re-circulated to maintain the system stable. Such systems are called "*circulating fluidized bed*". Fluidization depends mainly on the particle size and the air velocity.

A fluidized furnace has an enclosed space with a base having openings to admit air. Above this perforated base is a layer of sand and other inert granular material, through which fluidizing air is passed. The flow of air causes fluidization of the bed of granular material. This results in violent mixing and agitation of bed material. After fluidization of bed, oil or gas is added and ignited. The bed temperature is raised above the ignition point of the fuel to be burnt. Any fuel, solid or liquid, can now be added to the furnace. Solid fuel should be crushed before admitting it to the furnace. The bed normally contains only 1 to 2 percent of burning fuel, so that the inert particles carry the heat away from the burning particles, thus keeping the temperature low. It is essential that the temperature in the furnace does not become more than fusion temperature of granular bed material. A fluidized bed furnace operates at a lower temperature than a conventional furnace. The combustion takes place at about 850°C to 950°C. This temperature is much below the ash fusion temperature. Therefore, melting of ash and associated problems are averted. This also reduces the formation of nitrogen oxides and helps in reducing air pollution. When agro wastes and other similar materials are used as fuel, the heat required to evaporate the moisture in the fuels keeps the bed temperature with in limit. If temperature becomes higher, moisture or air is added. Similarly, if temperature becomes less than desired, additional supplementary fuel is added. When coal and other fuels with high calorific value are used, the temperature may become excessive. The boilers for such fuels have furnace walls made of tubes containing water which absorbs the heat of the furnace.

The agitated bed is helpful in rapid heat transfer. Due to rapid mixing in the fluidized bed and effective extraction of heat from the bed, the coefficient of heat transfer is high. Improved mixing causes evenly distribution of heat at lower temperature. Thus, an FBC system releases heat more efficiently. The high coefficient of heat transfer enables to achieve lower combustion temperature. Therefore, a fluidized bed boiler is smaller than a conventional boiler. The CO_2 content in the flue gas is of the order of 14 to 15% at the full load capacity. Therefore, the FBC boiler can operate with low excess air. In a FBC system, ash flows like liquid from the combustion chamber. The ash produced boilers is non-sticky and therefore, there is no slagging or soot blowing and the removal of ash is easy. The heat of flue gases leaving the furnace is used in heat recovery equipment to improve the heat efficiency. The air or gas velocity is maintained between minimum fluidization velocity and particle entrainment velocity to ensure stable operation of the bed and to avoid particle entrainment in the gas stream. Limestone is used as bed particle to control the emission of sulphur dioxide and nitrogen oxide. This is one of the major advantages of FBC boilers over conventional boilers.

Advantages of fluidized bed combustion system. The advantages of fluidized bed combustion system can be summarized as follows :

1. The overall operating efficiency of FBC boilers is high (approximately 85%).
2. Boiler size is reduced because of high coefficient of heat transfer.
3. A variety of fuels such as flotation slimes, washer rejects, agro waste etc can be

used efficiently.

4. Coals with high ash content and low calorific value can also be used in FBC boilers.
5. The pollution caused by FBC system is less. SO_2 formation by the burning of high sulphur content coals is reduced because of the addition of limestone or dolomite. Also, the low combustion temperature eliminates the formation of NO_x.
6. The erosion and corrosion of the system are reduced because of lower combustion temperature, softness of ash and low velocity of particles.
7. The CO_2 content in the flue gas is of the order of 14 to 15% at the full load capacity.
8. High turbulence in the boiler bed facilitates quick start and shut down.
9. Inherent high thermal storage characteristics provide fast response to load fluctuations.
10. There is no slagging or soot blowing and the removal of ash is easy.
11. Routine maintenance is reduced and high efficiency is maintained for long periods.

Retrofitting of FBC systems. Retrofitting fluidized bed combustion systems to conventional boilers is possible. Conversion of a conventional coal fired boiler system to a fluidized bed combustion system can be executed without effecting major changes and has been done in India also. The important factors which should be considered in retrofitting a FBC system are :

1. Water and steam circulation
2. Clearance between furnace bottom and grate
3. Type of particulate control device
4. Availability of space

But before adopting the conversion, the cost-benefit analysis should be done. Oil fired boilers can also be converted into a coal fired fluidized bed combustion system.

8.6. TYPES OF FLUIDIZED BED COMBUSTION BOILERS

There are three basic types of fluidized bed combustion boilers :

1. Atmospheric Classic Fluidized Bed Combustion System (AFBC)
2. Circulating (fast) Fluidized Bed Combustion System (CFBC)
3. Pressurized Fluidized Bed Combustion System (PFBC).

8.6.1. Atmospheric classic fluidized bed combustion system. Fig. 8.4 shows an atmospheric fluidized bed combustion system. Such boilers are also called *bubbling bed boilers*. Coal is crushed to a size of 1 to 10 mm depending on the grade of coal and the type of fuel feed system. Because of the low combustion temperature, inferior grade