Chapter 2.6: FBC Boilers

Part-I: Objective type questions and answers

1.	In FBC boilers fluidization depends largely on --------- a) Particle size b) Air velocity c) Both (a) and (b) d) Neither (a) nor (b)
2.	The bed temperature for a FBC boiler ranges between---------- a) 750 – 800°C b) 840 – 950 °C c) 950 - 1000°C d) 1000 - 1200°C
3.	The material used to control SO_2 and NO_x in the FBC boiler is a) Limestone b) Alumina c) Silica d) All of the above
4.	The difference between mean solid velocity and gas velocity in FBC boiler is called ---------- a) Fluidization b) slip velocity c) settling velocity d) None of the above
5.	FBC boiler has an advantage of: a) Burning high quality coal b) Burning variety liquid fuels c) Burning wide variety of coal d) None of the above
6.	The velocity of fluidizing air in atmospheric fluidized bed boiler is in the range of: a) Higher than 4.5 m/sec b) 1.2 – 3.7 m/sec c) Less than 1.2 m/sec d) 4-6 m/sec
7.	The coal particle size used for CFBC boiler is in the range of: a) 5 – 6 mm b) 6 – 12 mm c) 12 – 15 mm d) 15 – 25 mm
8.	In India commonly used power plant boilers are: a) PFBC boiler b) AFBC boilers c) Pulverized coal fired boilers d) Stoker fired boilers
9.	When the boiler bed temperature exceeds beyond 950°C, the result is: a) Low steam temperature b) clinker formation c) Melting of lime stones d) Ash carry over
10.	For even distribution of fluidized air in AFBC boilers, which one of the following is used? a) perforated metal distributor plate b) In bed tubes

	c) Compressed air through nozzles d) Secondary air from sides
11.	In FBC boiler the combustion is carried out at a temperature a) closer to steam temperature b) At adiabatic combustion temperature c) at and above ash fusion temperature d) Below ash fusion temperature of fuel used
12.	The boiler popularly used in modern sugar mills are: a) FBC with under feeding system b) FBC with over feeding c) Pulverised fuel boiler d) PFBC boilers
13.	CFBC is a good choice if a) capacity of boiler is medium to large b) sulphur emission and NOx control is important c) the boiler required to fire low grade fuel or fuel with highly fluctuating fuel quality d) All of the above
14.	Residence time of combustion particles in FBC boiler is many times greater than conventional grate firing. – True or False
15.	Circulating bed systems have better turndown ratio than bubbling bed systems. State whether True or False
16.	The combustion air pressure required for circulating bed systems is a) 3-5 psig b) 1.5-2.0 psig c) 4.0-6.0 psig d) None of the above
17.	For efficient sulphur retention, the temperature of the bed in a fluidized bed boiler should be a) 950°C b) 1100°C c) 850°C d) none of the above
18.	Popular type of boiler used for combined cycle power generation application. a) CFBC b) AFBC c) PFBC d) All the above
19.	Fluidized bed combustion boilers can operate with overall efficiency of------- a) 75 ± 2% b) 80 ± 2% c) 84 ± 2% d) 90 ± 2%
20.	In FBC boilers the percentage of bottom ash to the total ash is about: a) 0% b) 60 – 70% c) 30 – 40% d) 80 – 90%

Part-II: Short Type Questions and Answers

1.	What are the main advantages of FBC over conventional firing? Fluidised bed combustion has significant advantages over conventional firing systems and offers multiple benefits – namely fuel flexibility, reduced emission of noxious pollutants such as SO_x and NO_x, compact boiler design and higher combustion efficiency
2.	What are the parameters which affect the performance of the heat transfer in FBC? i) Bed temperature ii) Bed pressure iii) Superficial gas velocity iv) particle size v) Heat exchanger design, and vi) Gas distributor plate design
3.	Define 'fluidizing velocity' for an FBC boiler? The velocity required to make the particles in suspension in the air stream in a Fluidized Bed combustor is called fluidizing velocity.
4.	In a FBC boiler, when is the bed said to be fluidized state? The bed of solid particles in a FBC exhibits the properties of a boiling liquid and assumes the appearance of a fluid. In this state the bed is said to be fluidized.
5.	What is the principle of CFBC (circulating fluidized bed combustion) boiler? CFBC technology utilizes the fluidized bed principle in which crushed (6 –12 mm size) 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 840-900^{o}C, the fine particles (<450 microns) are elutriated out of the furnace with flue gas velocity of 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).
6.	List the three types of FBC boilers? 1. Atmospheric classic Fluidised Bed Combustion System (AFBC) 2. Atmospheric circulating (fast) Fluidised Bed Combustion system(CFBC) 3. Pressurised Fluidised Bed Combustion System (PFBC).
7.	What is the significance of distributor plate in FBC system? An essential function of the distributor is to introduce the fluidizing air evenly through the bed cross section thereby keeping the solid particles in constant motion, and preventing the formation of de-fluidization zones within the bed.

8.	List some of the features of bubbling bed boiler? (i) Distribution plate through which air is blown for fluidizing. (ii) Immersed steam-raising or water heating tubes which extract heat directly from the bed. (iii) Tubes above the bed which extract heat from hot combustion gas before it enters the flue duct.
9.	Define minimum fluid velocity for a FBC boiler? The minimum air/gas velocity which gives rise to bubble formation, vigorous turbulence and rapid mixing of the bed of solid particles which exhibits the properties of a boiling liquid and assumes the appearance of a fluid is called as minimum fluid velocity.
10.	In the context of FBC boiler, what is slip velocity? What are its advantages? The mean solids velocity increases at a slower rate than does the gas velocity. The difference between the solids velocity and the gas velocity is called as slip velocity.
11.	Define entrainment velocity for FBC boilers? With higher air velocities, the bed particles leave the combustion with the flue gases so that solids recirculation is necessary to maintain circulating fluidized bed. The minimum velocity at which this phenomenon takes place is called as entrainment velocity.
12.	What is the advantage of Pressurised Fluidised Bed Combustion System (PFBC) system over Atmospheric classic Fluidised Bed Combustion System (AFBC)? The PFBC system can be used for cogeneration or combined cycle power generation. By combining the gas and steam turbines in this way, electricity is generated more efficiently than in conventional system. The overall conversion efficiency is higher by 5% to 8%.
13.	List the advantages of CFBC boilers over AFBC boilers. • Higher processing temperature because of high gas velocity through the system. • Lower combustion temperature of about 870 ^{o}C can be achieved constantly, which results in minimal NOx formation. • The combustion air is supplied at 1.5 to 2 psig rather than 3 to 5 psig as required by bubbling bed combustors. • Higher combustion efficiency. • Better turndown ratio. • Erosion of heat transfer surface in the combustion chamber is reduced, since the surface is parallel to the flow. In AFBC system, the surface is generally perpendicular to the flow.
14.	List the factors that are important for efficient heat transfer in the bed. • Bed pressure • Bed temperature • Superficial gas velocity

	• Particle size • Heat exchanger design • Gas distribution plate design
15.	Describe how pressurised fluidised bed boiler (PFBC) can be used in a cogeneration system. In PFBC, the bed vessel is operated at pressure upto 16 ata. The off-gas from the fluidized bed combustor drives the gas turbine. The steam turbine is driven by steam raised in tubes immersed in the fluidized bed. The condensate from the steam turbine is pre-heated using waste heat from gas turbine exhaust and is then taken as feed water for steam generation.
16.	What are the advantages of using PFBC system for cogeneration or combined cycle power generation than the conventional system? • The overall efficiency is higher by 5% to 8%. • The potential reduction in boiler size is considerable due to increased amount of combustion in pressurized mode and high heat flux through in-bed tubes.
17.	State the important aspects to be considered in retrofitting conventional boilers with FBC? a) Water/steam circulation design b) Furnace bottom-grate clearance c) Type of particulate control device d) Fan capacity e) Availability of space
18.	For FBC boiler, a statement is made to read as “A fluidised bed of solids behave in many ways like a liquid”. Justify. The following points substantiate the statement: • Sand particles resting on a mesh become fluidized when air is blown through and take on the appearance and some of the properties of a boiling fluid. • Granular solids remain in layers when one is poured on to another. Rapid mixing occurs on fluidisation • A bed of stationary particles supports objects whatever their density. On fluidisation, an object of lower density floats and of higher density sinks • In a bed of stationary particles, heat is transferred slowly and there are big differences in temperature. In a fluidized bed, rapid mixing ensures uniformity of temperature
19.	What modifications are required to retrofit a conventional stoker fired water tube boiler to fluidised bed combustion? Retrofitting of a fluidised bed combustor to a conventional stoker fired water tube boiler may involve: • The replacement of grate by a distributor plate with short stand pipes for admitting air from the wind box located underneath.

	• Installation of stand pipes to remove ash from the bed. • Provision of horizontal hair pin tubes in the bed with a pump for forced circulation from the boiler drum. • Modification of crusher to size the coal/limestone mixture for pneumatic under bed injection of the mixture.
20.	What are the important aspects to be considered for retrofitting a conventional boiler to FBC technology? The important aspects to be considered in retrofit projects are: • Water/steam circulation design • Furnace bottom-grate clearance • Type of particulate control device • Fan capacity • Availability of space.

Part-III: Long Type Questions and answers

1.	Explain the mechanism of fluidized bed combustion. When an evenly distributed air or gas is passed upward through a finely divided bed of solid particles such as sand supported on a fine mesh, the particles are undisturbed at low velocity. As air velocity is gradually increased, a stage is reached when the individual particles are suspended in the air stream. Further, increase in velocity gives rise to bubble formation, vigorous turbulence and rapid mixing. The bed of solid particles exhibits the properties of a boiling liquid and assumes the appearance of a fluid. In this state the bed is said to be fluidized. The furnace combustion takes place at about 840^{O}C to 950^{O}C. Control of sulfur dioxide and nitrogen oxide emissions in the combustion chamber without the need for additional control equipment is one of the major advantages over conventional boilers. The fluidized bed is a system in which the air distributed by a grid or distribution plate, is blown through the bed solids developing a "fluidized condition." Fluidization depends largely on the particle size and the air velocity. At low air velocities, a dense defined bed surface forms and is usually called a bubbling fluidized bed. With higher air velocities, the bed particles leave the combustion with the flue gases so that solids recirculation is necessary to maintain circulating fluidized bed. The mean solids velocity increases at a slower rate than does the gas velocity. Therefore, a maximum slip velocity between the solids and the gas can be achieved resulting in good heat transfer and contact time with the limestone, for sulphur dioxide removal.
2.	Explain the main features with reference to fuel feeding system, air distribution system for a FBC boiler. • Fuel Feeding For feeding fuel and sorbent like limestone or dolomite, usually two methods are followed as explained below: Under Bed Pneumatic Feeding

	If the fuel is coal, it is crushed to 1-6 mm size and pneumatically transported from feed hopper to the combustor through a feed pipe piercing the distributor. Based on the capacity of the boiler, the number of feed points increases as it is necessary to distribute the fuel into the bed uniformly. Over-Bed Feeding The crushed coal, 6-10 mm size is conveyed from coal bunker to a spreader by a screw conveyor. The spreader distributes the coal over the surface of the bed uniformly. This type of fuel feeding system accepts over size fuel also and eliminates transport lines, when compared to under-bed feeding system. • Air Distributor An essential function of the distributor is to introduce the fluidizing air evenly through the bed cross section thereby keeping the solid particles in constant motion, and preventing the formation of de-fluidization zones within the bed. The distributor is normally constructed from metal plate with a number of perforations, in a definite geometric pattern. The perforations may be located in simple nozzles or nozzles with bubble caps, which serve to prevent solid particles from flowing back into the space below the distributor.
3.	What are the major performance features of the CFBC boiler (circulating fluidizing bed combustion boiler)? The major performance features of the CFBC boiler (circulating fluidizing bed combustion boiler) are: a) It has a high processing capacity because of the high gas velocity through the system. b) The temperature of about 870^{o}C is reasonably constant throughout the process because of the high turbulence and circulation of solids. The low combustion temperature also results in minimal NOx formation. c) Sulphur present in the fuel is retained in the circulating solids in the form of calcium sulphate is removed in solid form. The use of limestone or dolomite sorbents allows a higher sulphur retention rate, and limestone requirements have been demonstrated to be substantially less than with bubbling bed combustor. d) The combustion air is supplied at 1.5 to 2 psig rather than 3-5 psig as required by bubbling bed combustors. e) It has high combustion efficiency. f) It has a better turndown ratio than bubbling bed systems. g) Erosion of the heat transfer surface in the combustion chamber is reduced, since the surface is parallel to the flow. In a bubbling bed system, the surface generally is perpendicular to the flow.
4.	Describe in detail about retrofitting of FBC systems to conventional boilers? Retrofitting fluidized bed coal fired combustion systems to conventional boilers have been carried out successfully both in India and abroad. The important aspects to be considered in retrofit projects are: a) Water/steam circulation design b) Furnace bottom-grate clearance c) Type of particulate control device

	d) Fan capacity e) Availability of space. Retrofitting of a fluidized bed combustor to a conventional stoker fired water tube boiler may involve: a) The replacement of grate by a distributor plate with short stand pipes for admitting air from the wind box located underneath. b) Installation of stand pipes to remove ash from the bed. c) Provision of horizontal hair pin tubes in the bed with a pump for forced circulation from the boiler drum. d) Modification of crusher to size the coal/limestone mixture for pneumatic under bed injection of the mixture. It may be emphasized that conversion of a conventional coal fired system to a fluidized bed combustion system can be accomplished without effecting major changes, after making a cost-benefit analysis. Oil fired boilers can also be converted to coal fired fluidized bed combustion systems. However it has to be examined on a case to case basis.
5.	Explain at least six advantages of fluidized bed boilers? **i) High Efficiency** FBC boilers can burn fuel with a combustion efficiency of over 95% irrespective of ash content. FBC boilers can operate with overall efficiency of 84% + 2%. **ii) Reduction in Boiler Size** High heat transfer rate over a small heat transfer area immersed in the bed result in overall size reduction of the boiler. **iii) Fuel Flexibility** FBC boilers can be operated efficiently with a variety of fuels and these can be fed either independently or in combination with coal into the same furnace. Even fuels like flotation slimes, washer rejects, agro waste can be burnt efficiently. **iv) Ability to Burn Low Grade Fuel** FBC boilers would give the rated output even with inferior quality fuel. The boilers can fire coals with ash content as high as 62% and having calorific value as low as 2,500 kcal/kg. Even carbon content of only 1% by weight can sustain the fluidized bed combustion. **v) Ability to Burn Fines** Coal containing fines below 6 mm can be burnt efficiently in FBC boiler, which is a very difficult proposition in conventional firing system. **vi) Pollution Control** SO_2 formation can be greatly minimized by addition of limestone or dolomite for high sulphur coals. The amount of like stone addition is about 3% for every 1% sulphur in the coal feed. Low combustion temperature eliminates NO_x formation.