

Chapter 2.1: Fuels and Combustion

Part-I: Objective type Questions and Answers

1.	The unit of Density in SI system is ____. a) kg/m ² b) kgf/m ³ c) kg/m ² d) <u>kg/m³</u>
2.	Name the instrument used for the measurement of specific gravity of liquid fuels a) Gravimeter b) <u>Hydrometer</u> c) Bomb calorimeter d) none of the above
3.	The unit of specific gravity in SI system is _____. a) N/m ³ b) kgf/m ³ c) kg/m ² d) <u>no unit</u>
4.	If the liquid fuel is highly viscous, the action required for proper burning in boiler is ____. a) <u>Pre-heating</u> b) <u>cooling</u> c) <u>mixing</u> d) <u>vapourising</u>
5.	“In case of net calorific value (NCV) of any fuel, it assumes that water leaves with the combustion products with fully being condensed”. State True or <u>False</u>
6.	Identify the fuel which has the highest specific gravity. a) furnace oil b) <u>LSHS</u> c) LDO d) HSD
7.	In case of fuel oils, choose the correct answer from the following, which describes the relation between “specific heat” and “specific gravity” a) lighter oil have higher specific heat b) heavier oil have lower specific heat c) <u>lighter oil have lower specific heat</u> d) none of the above
8.	Viscosity of a liquid fluid is very much dependent on a) pressure b) pipe size c) <u>temperature</u> d) colour
9.	Presence of sulphur in the boiler fuel leads to a) <u>corrosion</u> b) erosion c) low heat transfer d) none of the above
10.	For complete combustion of every kg of FO firing, the approximate theoretical quantity of air required is: a) <u>14 kg</u> b) 18 kg c) 21 kg d) 10 kg
11.	Oxygen (O ₂) percentage measurement by volume basis can be done by using: a) ultrasonic tester b) potassium oxide probe c) copper tubes d) <u>zirconium oxide probe</u>
12.	The percentage requirement of excess air for efficient combustion for coal is less than that of natural gas - State True or <u>False</u> .
13.	“Turndown ratio” for burners is the ratio of a) air to fuel

	b) maximum fuel input to actual fuel input c) <u>maximum fuel input over minimum fuel input</u> d) maximum air input over minimum air input
14.	Which is the best suited pump for pumping LSHS? a) vertical turbine pump b) centrifugal pump c) diaphragm pump d) <u>gear pump</u>
15.	State whether following statement is true or false “The proximate” word has meaningful interpretation. While describing “approximate” for a proximate analysis of coal <u>False</u>
16.	The content of solid left in the oven after volatile matter is distilled off (while analysing the composition of coal in a laboratory) is ____. a) only sulphur b) only moisture c) only ash d) <u>mixture of fixed carbon and ash</u>
17.	Large and irregular lumps of coal when fired in a boiler may lead to _____. a) <u>poor combustion</u> b) low excess air c) low unburnt fuel in the ash d) high thermal efficiency
18.	LPG is predominantly the mixture of Propane and ____ . a) methane b) ethane c) <u>butane</u> d) Isopropane
19.	Which one of the following has a high specific gravity a) furnace oil b) HSD c) kerosene d) <u>water</u>
20.	High percentage of carbon monoxide presence in the flue gas of boiler is an indicator of a) high excess air b) complete combustion c) good control of pollutants d) <u>low excess air</u>

Part-II: Short type Questions and Answers

1.	What is 'excess air' and why is it required for 'combustion' in a boiler? For any fuel a fixed amount of theoretical air is required for stoichiometric combustion. In practice theoretical quantity of air is inadequate to mix with the entire quantity of fuel intimately. The problem is sought to be overcome by admitting some quantity of air in excess of the theoretical quantity. This is called excess air.
2.	How to control 'excess air'? Chemical analysis of the gases is an objective method that helps in achieving finer air control. By measuring carbon dioxide (CO₂) or oxygen (O₂) in flue gases by continuous recording instruments or Orsat apparatus or portable fyrite, the excess air level as well as stack losses can be estimated. The excess air to be supplied depends on the type of fuel and the firing system. For example, for optimum combustion of fuel oil, the CO₂ or O₂ in flue gases should be maintained at 14 -15% in case of CO₂ and 2-3% in case of O₂.
3.	Define 'specific gravity' for a fuel. Specific gravity is the ratio of the weight of a given 'volume of oil' to the 'weight of the same volume of water' at a given temperature.

4.	Comment on blending different qualities of coal feeding the boiler? - Coal having excessive fines, need to be blend with the predominantly lumped coal containing lots of excessive fines. Thus coal blending limits the extent of fines in coal being fired. - Blending of different qualities of coal may also help to supply a uniform coal feed to the boiler.
5.	What is viscosity of liquid fuel oil? The viscosity of a liquid fuel oil is a measure of its internal resistance to flow.
6.	What is the unit of viscosity? Name the instrument used for measurement of viscosity? Viscosity is measured in Stokes / Centistokes. Sometimes viscosity is also quoted in Engler, Saybolt or even Redwood. The measurement of viscosity is made with an instrument called as 'viscometer'.
7.	Why is 'viscosity' a very important parameter for any fuel oil? Viscosity is an important fuel property of any fuel oil specification as it influences the degree of pre-heat required for handling, storage and satisfactory atomization. If the oil is too viscous it may become difficult to pump, hard to light the burner and pre-heating is necessary for proper atomization. This operation may become erratic. In case of poor atomization carbon will be deposited on the burner tips or on the walls.
8.	Define 'specific heat of fuel oil' and also mention its unit of measurement in SI units. 'Specific heat' is the amount of kCal needed to raise the temperature of 1 kg of fuel oil by 1°C. The SI unit of specific heat is kCal/kg °C or KJ/kg°C.
9.	What is the difference between Gross calorific value (GCV) and Net calorific value (NCV)? The difference between GCV and NCV is the latent heat of condensation of the water vapour generated by the combustion process. Gross calorific value assumes all vapour produced during the combustion process is fully condensed. Net calorific value assumes the water leaves with the combustion products without fully being condensed.
10.	What is the main disadvantage of sulphur presence in any fuel? The main disadvantage of sulphur is the risk of corrosion by sulphuric acid formed during and after combustion, and condensing in cool parts of the chimney or stack, air pre heater and economiser.
11.	Name the three main classification of coal? - Anthracite - Bituminous - Lignite
12.	How moisture content in coal derived in a laboratory? A sample of raw coal is crushed until it passes through a 20-mesh screen (20 meshes per linear inch). A definite amount is weighed, placed in a covered crucible, and dried in an oven at about 105°C for 1 hr. Then the sample is cooled to room temperature and weighed again. The loss in weight represents moisture.
13.	What is the laboratory procedure for the measurement of Volatile matter for coal? Fresh sample of crushed coal is weighed, placed in a covered crucible, and heat over a large Bunsen burner until all the volatile gases are driven off. The sample is cooled and weighed. Loss of weight represents moisture and volatile matter. The remainder is coke (fixed carbon and ash).

14.	Give the empirical relationship to convert 'proximate analysis' to 'ultimate analysis' of with regard to coal. Relationship between ultimate analysis and proximate analysis $\%C = 0.97C + 0.7(VM + 0.1A) - M(0.6 - 0.01M)$ $\%H_2 = 0.036C + 0.086(VM - 0.1x_A) - 0.0035M^2(1 - 0.02M)$ $\%N_2 = 2.10 - 0.020 VM$ Where C = % of fixed carbon A = % of ash VM = % of volatile matter M = % of moisture
15.	What is the primary function of a burner application for liquid fuels? The primary function of burner is to atomise fuel to millions of small droplets so that the surface area of the fuel is increased enabling intimate contact with oxygen in air.
16.	What is the important characteristic that distinctly highlights a good burner design? The good burner design is the one that is able to properly mix the air and fuel at the lowest possible excess air.
17.	What are the two ways of preheating the storage tanks used for LSHS? • Bulk heating using steam coils placed at the bottom of the tank • Outflow heater
18.	Define 'density' of a liquid fuel. 'Density' of the fuel is the ratio of the mass of the fuel to the volume at a reference temperature typically at 15°C.
19.	Arrange the following fuels in the ascending order of their 'calorific value'. (HSD, coal, paddy husk) Paddy husk Coal HSD
20.	List out the effect of 'ash content' in liquid fuels? Typical values of ash content in liquid fuels are in the range of 0.03-0.07%. Ash has an erosive effect on the burner tips, causes damage to the refractories at high temperatures and gives rise to high temperature corrosion and fouling of equipments.

Part–III: Long type Questions and Answers

1.	Write short notes on 'combustion control' for boiler. Also describe the different types 'combustion controls'? 'Combustion controls' assist the burner in regulation of fuel supply, air supply, (fuel to air ratio), and removal of gases of combustion to achieve optimum boiler efficiency. The amount of fuel supplied to the burner must be in proportion to the steam pressure and the quantity of steam required. The combustion controls are also necessary as safety device to ensure that the boiler operates safely.
----	---

	Various types of combustion controls in use are: <i>On/Off Control:</i> The simplest control, ON/OFF control means that either the burner is firing at full rate or it is OFF. This type of control is limited to small boilers. <i>High/Low/Off Control:</i> Slightly more complex is HIGH/LOW/OFF system where the burner has two firing rates. The burner operates at slower firing rate and then switches to full firing as needed. Burner can also revert to low firing position at reduced load. This control is fitted to medium sized boilers. <i>Modulating Control:</i> The modulating control operates on the principle of matching the steam pressure demand by altering the firing rate over the entire operating range of the boiler. Modulating motors use conventional mechanical linkage or electric valves to regulate the primary air, secondary air, and fuel supplied to the burner. Full modulation means that boiler keeps firing, and fuel and air are carefully matched over the whole firing range to maximize thermal efficiency.																
2.	Mention the means of storage of furnace oil in any industry. Also mention the safety precautions to be taken during storage. It can be potentially hazardous to store furnace oil in barrels. A better practice is to store it in cylindrical tanks, either above or below the ground. Furnace oil, that is delivered, may contain dust, water and other contaminants. The sizing of storage tank facility is very important. A recommended storage estimate is to provide for at least 10 days of normal consumption. Industrial heating fuel storage tanks are generally vertical mild steel tanks mounted above ground. It is prudent for safety and environmental reasons to build bund walls around tanks to contain accidental spillages. As a certain amount of settlement of solids and sludge will occur in tanks over time, cleaning should be carried out at regular intervals-annually for heavy fuels and every two years for light fuels. A little care should be taken when oil is decanted from the tanker to storage tank. All leaks from joints, flanges and pipelines must be attended at the earliest. Fuel oil should be free from possible contaminants such as dirt, sludge and water before it is fed to the combustion system.																
3.	Calculate the Stoichiometric (kg) amount of air required for the following liquid fuel.																
	<table> <tr> <th>Constituents</th><th>% By weight</th></tr> <tr> <td>Carbon</td><td>85.9</td></tr> <tr> <td>Hydrogen</td><td>12</td></tr> <tr> <td>Oxygen</td><td>0.7</td></tr> <tr> <td>Nitrogen</td><td>0.5</td></tr> <tr> <td>Sulphur</td><td>0.5</td></tr> <tr> <td>H₂O</td><td>0.35</td></tr> <tr> <td>Ash</td><td>0.05</td></tr> </table>	Constituents	% By weight	Carbon	85.9	Hydrogen	12	Oxygen	0.7	Nitrogen	0.5	Sulphur	0.5	H ₂ O	0.35	Ash	0.05
Constituents	% By weight																
Carbon	85.9																
Hydrogen	12																
Oxygen	0.7																
Nitrogen	0.5																
Sulphur	0.5																
H ₂ O	0.35																
Ash	0.05																
	GCV of fuel : 10880 kCal/kg																
	Calculation for Requirement of Theoretical Amount of Air Consider a sample of 100 kg of fuel. The chemical reactions are:																

Element		Molecular Weight kg / kg mole	
C		12	
O ₂		32	
H ₂		2	
S		32	
N ₂		28	
CO ₂		44	
SO ₂		64	
H ₂ O		18	
C	+	O ₂	→ CO ₂
H ₂	+	O	→ H ₂ O
S	+	O ₂	→ SO ₂
Constituents of fuel			
C	+	O ₂	→ CO ₂
12	+	32	→ 44
12 kg of carbon requires 32 kg of oxygen to form 44 kg of carbon dioxide therefore 1 kg of carbon requires 32/12 kg i.e. 2.67 kg of oxygen			
(85.9) C + (85.9 x 2.67) O ₂ → 314.97 CO ₂			
2H ₂	+	O ₂	→ 2H ₂ O
4	+	32	→ 36
4 kg of hydrogen requires 32 kg of oxygen to form 36 kg of water, therefore 1 kg of hydrogen requires 32/4 kg i.e. 8 kg of oxygen			
(12) H ₂ + (12 x 8) O → 108 H ₂ O			
S	+	O ₂	→ SO ₂
32	+	32	→ 64
32 kg of sulphur requires 32 kg of oxygen to form 64 kg of sulphur dioxide, therefore 1 kg of sulphur requires 32/32 kg i.e. 1 kg of oxygen			
(0.5) S + (0.5 x 1) O ₂ → 1.0 SO ₂			
Total Oxygen required		=	325.57 kg
(229.07+96+0.5)			
Oxygen already present in			
100 kg fuel (given)		=	0.7 kg
Additional Oxygen Required		=	325.57 – 0.7

	$= 324.87 \text{ kg}$ Therefore quantity of dry air required = $(324.87) / 0.23$ (air contains 23% oxygen by wt.) $= 1412.45 \text{ kg of air}$ Theoretical Air required = $(1412.45) / 100$ $= 14.12 \text{ kg of air / kg of fuel}$
4.	What is the function of 'draft' in a boiler? Enumerate the different types of draft available for a boiler? The function of draft in a combustion system is to exhaust the products of combustion into the atmosphere. The draft can be classified into two types namely Natural and Mechanical Draft. <i>Natural Draft:</i> It is the draft produced by a chimney alone. It is caused by the difference in weight between the column of hot gas inside the chimney and column of outside air of the same height and cross section. Being much lighter than outside air, chimney flue gas tends to rise, and the heavier outside air flows in through the ash pit to take its place. It is usually controlled by hand-operated dampers in the chimney and breeching connecting the boiler to the chimney. Here no fans or blowers are used. The products of combustion are discharged at such a height that it will not be a nuisance to the surrounding community. <i>Mechanical Draft:</i> It is draft artificially produced by fans. Three basic types of drafts that are applied are: <i>Balanced Draft:</i> Forced-draft (F-D) fan (blower) pushes air into the furnace and an induced-draft (I-D) fan draws gases into the chimney thereby providing draft to remove the gases from the boiler. Here the furnace is maintained at from 0.05 to 0.10 in. of water gauge below atmospheric pressure. <i>Induced Draft:</i> An induced-draft fan draws enough draft for flow into the furnace, causing the products of combustion to discharge to atmosphere. Here the furnace is kept at a slight negative pressure below the atmospheric pressure so that combustion air flows through the system. <i>Forced Draft:</i> The Forced draft system uses a fan to deliver the air to the furnace, forcing combustion products to flow through the unit and up the stack.
5.	Describe the working of an oil fired burner covering the following points. a) atomization of fuel b) primary and secondary air circuit c) burner turndown ratio
	The burner is the principal device for the firing of fuel. The primary function of burner is to atomize fuel to millions of small droplets so that the surface area of the fuel is increased enabling intimate contact with oxygen in air. The finer the fuel droplets are atomized, more readily will the particles come in contact with the oxygen in the air and burn.

	Normally, atomization is carried out by primary air and completion of combustion is ensured by secondary air. Burners for fuel oil can be classified on the basis of the technique to prepare the fuel for burning i.e. atomization. An important aspect to be considered in selection of burner is turndown ratio. Turndown ratio is the relationship between the maximum and minimum fuel input without affecting the excess air level. For example, a burner whose maximum input is 250,000 kCal and minimum rate is 50,000 kCal, has a 'Turn-Down Ratio' of 5 to 1.
--	---