



CERTIFIED INDUSTRIAL ENERGY PROFESSIONAL
CIEP TRAINING PROGRAM
FOR INDUSTRIAL ENERGY SPECIALISTS
KRISHNAJI PAWAR, LEED AP BD+C, GSAS CGP, ISO 14001:2015, GCP
ENERGY SPECIALIST CURRICULUM





FUELS, FURNACES, AND FIRED EQUIPMENT
BASICS -1
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WHAT SHOULD YOU LEARN

- Introduction to Fuels
- Properties of Liquid Fuels, Coal and Agro Residues
- Combustion of Oil, Coal & Gas
- Combustion Controls
- Classification of furnaces
- General fuel economy measures in furnaces,
- Excess air, Heat distribution, Temperature control, Draft control, Waste heat recovery.

INTRODUCTION TO FUELS

The various types of fuels like liquid, solid and gaseous fuels are available for firing in boilers, furnaces and other combustion equipments. The selection of right type of fuel depends on various factors such as availability, storage, handling, pollution and landed cost of fuel.

The knowledge of the fuel properties helps in selecting the right fuel for the right purpose and efficient use of the fuel. The following characteristics, determined by laboratory tests, are generally used for assessing the nature and quality of fuels.



PROPERTIES OF LIQUID FUELS

Liquid fuels like furnace oil and LSHS are predominantly used in industrial application. The various properties of liquid fuels are given below.

Density : This is defined as the ratio of the mass of the fuel to the volume of the fuel at a reference temperature of 15°C. Density is measured by an instrument called hydrometer. The knowledge of density is useful for quantity calculations and assessing ignition quality. The unit of density is kg/m³.

Specific gravity : This is defined as the ratio of the weight of a given volume of oil to the weight of the same volume of water at a given temperature. The density of fuel, relative to water, is called specific gravity.



PROPERTIES OF LIQUID FUELS

Viscosity : The viscosity of a fluid is a measure of its internal resistance to flow. Viscosity depends on temperature and decreases as the temperature increases. Any numerical value for viscosity has no meaning unless the temperature is also specified. Viscosity is measured in Stokes / Centistokes. Sometimes viscosity is also quoted in Engler, Saybolt or Redwood. Each type of oil has its own temperature - viscosity relationship. The measurement of viscosity is made with an instrument called Viscometer.

Flash Point : The flash point of a fuel is the lowest temperature at which the fuel can be heated so that the vapour gives off flashes momentarily when an open flame is passed over it. Flash point for furnace oil is 66°C.



PROPERTIES OF LIQUID FUELS

Pour Point : The pour point of a fuel is the lowest temperature at which it will pour or flow when cooled under prescribed conditions. It is a very rough indication of the lowest temperature at which fuel oil is readily pumpable.

Specific Heat : Specific heat is the amount of kCals needed to raise the temperature of 1 kg of oil by 1°C. The unit of specific heat is kCal/kg°C. It varies from 0.22 to 0.28 depending on the oil specific gravity. The specific heat determines how much steam or electrical energy it takes to heat oil to a desired temperature. Light oils have a low specific heat, whereas heavier oils have a high-er specific heat.

PROPERTIES OF LIQUID FUELS

Calorific Value : The calorific value is the measurement of heat or energy produced, and is measured either as gross calorific value or net calorific value. The difference being the latent heat of condensation of the water vapour produced during the combustion process. Gross calorific value (GCV) assumes all vapour produced during the combustion process is fully condensed. Net calorific value (NCV) assumes the water leaves with the combustion products without fully being condensed. Fuels should be compared based on the net calorific value.

Sulphur : The amount of sulphur in the fuel oil depends mainly on the source of the crude oil and to a lesser extent on the refining process. The normal sulfur content for the residual fuel oil (furnace oil) is in the order of 2-4 %.

PROPERTIES OF LIQUID FUELS

Ash Content : The ash value is related to the inorganic material in the fuel oil. The ash levels of distillate fuels are negligible. Residual fuels have more of the ash-forming constituents. These salts may be compounds of sodium, vanadium, calcium, magnesium, silicon, iron, aluminum, nickel, etc.

Carbon Residue : Carbon residue indicates the tendency of oil to deposit a carbonaceous solid residue on a hot surface, such as a burner or injection nozzle, when its vaporisable constituents evaporate. Residual oil contain carbon residue ranging from 1 percent or more.

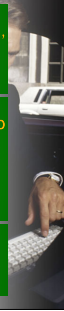
Water Content : Water content of furnace oil when supplied is normally very low as the product at refinery site is handled hot and maximum limit of 1% is specified in the standard.

STORAGE OF FUEL OIL

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.



REMOVAL OF CONTAMINANTS

Removal of Contaminants Furnace oil arrives at the factory site either in tank lorries by road or by rail. Oil is then decanted into the main storage tank. To prevent contaminants such as rags, cotton waste, loose nuts or bolts or screws entering the system and damaging the pump, coarse strainer of 10 mesh size (not more than 3 holes per linear inch) is positioned on the entry pipe to the storage tanks.

Storage Temperature and Pumping Temperature : The viscosity of furnace oil and LSHS increases with decrease in temperature, which makes it difficult to pump the oil. At low ambient temperatures (below 25°C), furnace oil is not easily pumpable. To circumvent this, preheating of oil is accomplished in two ways: (a) the entire tank may be preheated.



PROPERTIES OF COAL

Coal is classified into three major types namely anthracite, bituminous, and lignite. However there is no clear demarcation between them and coal is also further classified as semi- anthracite, semi-bituminous, and sub-bituminous.

The chemical composition of coal has a strong influence on its combustibility. The properties of coal are broadly classified as

1. Physical properties
2. Chemical properties



PROPERTIES OF GASEOUS FUELS

Gaseous fuels in common use are liquefied petroleum gases (LPG), Natural gas, producer gas, blast furnace gas, coke oven gas etc. The calorific value of gaseous fuel is expressed in Kilocalories per normal cubic meter (kCal/Nm³) i.e. at normal temperature (20°C) and pressure (760 mm Hg).

Fuel Gas	Relative Density	Higher Heating Value kCal/Nm ³	Air/Fuel ratio- m ³ of air to m ³ of Fuel	Flame Temp. °C	Flame Speed m/s
Natural Gas	0.6	9350	10	1954	0.290
Propane	1.52	22200	25	1967	0.460
Butane	1.96	28500	32	1973	0.870

PROPERTIES OF AGRO RESIDUES

	Deolled Bran	Paddy Husk	Saw Dust	Coconut Shell
Moisture	7.11	10.79	37.98	13.95
Ash	18.46	16.73	1.63	3.52
Volatile Matter	59.81	56.46	81.22	61.91
Fixed Carbon	14.62	16.02	17.15	20.62

	Deolled Bran	Paddy Husk	Saw Dust	Coconut Shell
Moisture	7.11	10.79	37.98	13.95
Mineral Matter	19.77	16.73	1.63	3.52
Carbon	36.39	33.95	48.55	44.95
Hydrogen	4.15	5.01	6.99	4.99
Nitrogen	0.82	0.91	0.80	0.56
Sulphur	0.54	0.09	0.10	0.08
Oxygen	31.02	32.52	41.93	31.94
GCV (kCal/kg)	3151	3568	4801	4565

The use of locally available agro residues is on the rise. This includes rice husk, coconut shells, groundnut shells, Coffee husk, Wheat stalk etc. The properties of a few of them are given in the table 1.14 and 1.15

COMBUSTION

Combustion refers to the rapid oxidation of fuel accompanied by the production of heat, or heat and light. Complete combustion of a fuel is possible only in the presence of an adequate supply of oxygen.

Oxygen (O₂) is one of the most common elements on earth making up 20.9% of our air. Rapid fuel oxidation results in large amounts of heat. Solid or liquid fuels must be changed to a gas before they will burn. Usually heat is required to change liquids or solids into gases. Fuel gases will burn in their normal state if enough air is present.

Most of the 79% of air (that is not oxygen) is nitrogen, with traces of other elements. Nitrogen is considered to be a temperature reducing dilutant that must be present to obtain the oxygen required for combustion.

3 T'S OF COMBUSTION

The objective of good combustion is to release all of the heat in the fuel. This is accomplished by controlling the "three T's" of combustion which are

- (1) Temperature high enough to ignite and maintain ignition of the fuel,
- (2) Turbulence or intimate mixing of the fuel and oxygen, and
- (3) Time sufficient for complete combustion.

Commonly used fuels like natural gas and propane generally consist of carbon and hydrogen. Water vapor is a by-product of burning hydrogen. This robs heat from the flue gases, which would otherwise be available for more heat transfer.

Natural gas contains more hydrogen and less carbon per kg than fuel oils and as such produces more water vapor. Consequently, more heat will be carried away by exhaust while firing natural gas.

COMBUSTION OF OIL

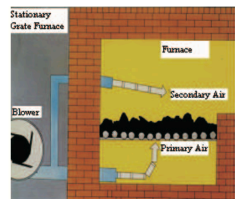
Heating Oil to Correct Viscosity : When atomizing oil, it is necessary to heat it enough to get the desired viscosity. This temperature varies slightly for each grade of oil. The lighter oils do not usually require pre-heating. Typical viscosity at the burner tip (for LAP, MAP & HAP burners) for furnace oil should be 100 Redwood seconds-1 which would require heating the oil to about 105°C.

Rules for combustion of oil

1. Atomize the oil completely to produce a fine uniform spray
2. Mix the air and fuel thoroughly
3. Introduce enough air for combustion, but limit the excess air to a maximum of 15%
4. Keep the burners in good condition

COMBUSTION OF COAL

1 kg of coal will typically require 7-8 kg of air depending upon the carbon, hydrogen, nitrogen, oxygen and sulphur content for complete combustion. This air is also known as theoretical or stoichiometric air.



If for any reason the air supplied is inadequate, the combustion will be incomplete. The result is poor generation of heat with some portions of carbon remaining unburnt (black smoke) and forming carbon monoxide instead of carbon dioxides.

COMBUSTION OF GAS

The stoichiometric ratio for natural gas (and most gaseous fuels) is normally indicated by volume. The air to natural gas (stoichiometric) ratio by volume for complete combustion vary between 9.5:1 to 10:1

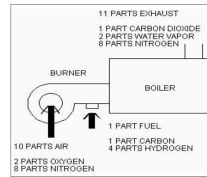


Figure 1.6 Combustion of Natural Gas

Natural gas is essentially pure methane, CH_4 . Its combustion can be represented as follows: $\text{CH}_4 + 2\text{O}_2 = \text{CO}_2 + 2\text{H}_2\text{O}$. So for every 16 kgs of methane that are consumed, 44 kgs of carbon dioxide are produced. (Remember that the atomic weights of carbon, oxygen and hydrogen are 12, 16 and 1, respectively.) Methane burns, when mixed with the proper amount of air and heated to the combustion temperature. Figure 1.6 shows the process with the amount of air and fuel required for perfect combustion.

DRAFT SYSTEM

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.

Natural Draft :

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.

DRAFT SYSTEM +

Mechanical Draft It is draft artificially produced by fans. Three basic types of drafts that are applied are :

✓ **Balanced Draft:** 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 pressure is maintained between 0.05 to 0.10 in. of water gauge below atmospheric pressure in the case of boilers and slightly positive for reheating and heat treatment furnaces.

✓ **Induced Draft:** 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.

✓ **Forced Draft:** 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.

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:

On/Off Control :

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. Various types of combustion controls in use are:

COMBUSTION CONTROLS

High/Low/Off Control :

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.

Modulating Control :

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.

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