Lecture 7. The classification of fuels. Methods of processing of solid fuels (gasification, carbonization).
The device coke ovens. Processing of coke oven gas.

Fuel is something consumed to produce energy, especially:

a. A material such as wood, coal, gas, or oil burned to produce heat or power.
b. Fissionable material used in a nuclear reactor

Anything that is capable of producing energy in a form that is useable for producing power is called fuel.

Types of fuels

General Grouping	Primary/Natural Fuels	Secondary Fuels
Solid Fuel	Anthracite Coal, Bituminous Coal, Lignite, Peat, Wood	Coke, Charcoal, Coke Breeze
Liquid Fuel	Petroleum	Kerosene, Diesel, Tar, gasoline
Gaseous Fuel	Natural Gas	Producer Gas, Coal Gas, Furnace Gas

The various advantages and disadvantages of solid fuels

Advantages	Disadvantages
Easy Transportable	High ash content
Storage convenience	Low thermal efficiency
Production cost is low	Combustion operation not controllable
Moderate ignition temperatures	Burns with clinker formation
Comparatively low S content i.e. low atmospheric pollution	Handling cost is high
	A large excess of air needed
	Calorific values lower than liquid fuels

Solid Fuels: Primary as well as secondary are widely used in domestic and industrial purposes e.g., wood, coal, charcoal and coke.

Wood: Wood has been used as a fuel from ancient times. Due to large scale deforestation, wood is no longer used except in forest areas where wood is available at a low cost.

· Wood when freshly cut contains 25-50% moisture. Normally it is used in air dried condition with 10-15percent moisture content. The calorific value of air dried wood is about 3500-4500 kcal/kg.

When wood burns, the ash content is low but the oxygen content is very high. This makes even dry wood a fuel of low calorific value.

Wood charcoal is obtained by destructive distillation of wood. The major use of wood charcoal is for producing activated carbon.

Coal: coal is regarded as a fossil fuel produced from the vegetable debris under conditions of high temperature and pressure over million of years. The transformation of the vegetable debris to coal takes place in two stages:

(a)Biochemical or peat stage: During this stage, the plant materials were attacked by various micro organisms.

(b)Chemical stage or metamorphism: In this stage, the peat deposit buried under sedimentary deposits lose moisture and volatile components under the effect of high temperature and pressure. The peat gets enriched in carbon whereas its oxygen content decreases. The spongy peat transforms into hard brittle coal gradually. The time required for the formation of young brown coal is of the order of 107 years.

Types of Coal

Type of coal	Percentage (dry, mineral matter free basis)					% moisture	calorific value
	C	H	O	N	VM		
Wood	45-50	5-6	20-40	0-0.5	-	70-90	4000-4500
↓ Peat	45-60	3.5-6.5	20-45	0.75-3	45-75	70-90	4125-5280
↓ Brown Coal	60-75	4.5-5.5	17-35	0.75-2	45-60	30-50	6600-7100
↓ Bituminous coal	75-90	4.0-5.5	20-30	0.75-2	11-50	10-20	6600-8800
↓ Anthracite	90-95	3-4	2-3	0.5-2	3.8-10	1.5-3.5	8470-8800

Carbonization of Coal (Manufacture of Coke)

It is the process of heating the coal in absence of air to a sufficiently high temperature, so that the coal under goes decomposition and yields a residue which is richer in carbon content than the original fuel.

Caking and coking of coals: some coals have a tendency to soften and swell at higher temperatures, to form a solid coherent mass with porous structure. Such coals are called caking coals.

The residue formed is called coke.

If the coke is hard, porous and strong, than the coal, from which it is formed, it is called coking coal. All coking coals are caking coals but all caking coals are not coking coals.

This property is found only in bituminous type of coal. Coals with a high percentage of volatile matter are not fit for coking and are used for gas making. The coals having 20-30 % volatile matter are good coking coals.

Types of carbonization

(a)Low temperature carbonization (semicoking)

(a) High temperature carbonization (coking)

Low temperature carbonization

When the destructive distillation of coal is carried out at temperatures between 500-570 °C .

It is practiced for the production of semi coke. Which is also called soft coke. The yield of coke is about 75-80 %.The coke thus produced contains 5 to 15 % volatile matter. The various products of low temperature carbonization are semi coke, low temperature tar, crude low temperature spirit and gas. LTC plants normally use low rank coals. These low rank coals produce excessive smoke on burning. Semi coke from LTC is highly reactive and can be easily ignited into a smokeless flame

The gas which is obtained as a byproduct has higher calorific value of about 6500-9500 kcal/m 3

High temperature carbonization

It is carried out at 900-1200 °C.

First moisture and occluded gases are driven off.

At about 260-270 °C carbon, water, H2S, some low molecular alkenes and alkanes are evolved.

At about 350 °C the decomposition of coal is accompanied by evolution of gases and elimination of vapours takes place.

At about 400 °C, caking coal becomes soft and plastic.

At about 700 °C, hydrogen is evolved.

Above 800 °C, main gaseous products are evolved.

Gases evolved from the plastic mass, expand it to give foam like appearance. At further high temperatures this foam like mass solidifies to form a solid mass with porous structure called coke.

High temperature carbonization is used for the production of pure, hard, strong and porous metallurgical coke containing1-3 % volatile matter.

The yield of the coke is 65-75%.

The byproducts-gas and tar have greater amounts of aromatic hydrocarbons.

The gas which is obtained has lower calorific value of about 5000-6000 kcal/m 3 than that produced in LTC; but the yield of the gas is higher.

The coke obtained is very much harder than the coke obtained from LTC process and hence is called hard coke.

Metallurgical coke: The properties of coke depend on porosity, reactivity and the amount of volatile matter retained by coke during carbonization. Coke is mainly used as a heat source and reducing agent in metallurgy.

Characteristics of good coke in metallurgical process

(1) Purity;

(2)Porosity;

(3)Strength;

(4)Size;

(5) Combustibility;

(6) Calorific value;

(7) Reactivity CO_2 (g) + C (s) ⇔ 2CO(g);

(8)Cost.

Manufacture of Metallurgical Coke

1. **Demerits of Beehive ovens**: The demerits are

•No recovery of byproducts, which are useful chemicals and are allowed to escape.

•Lower coke yield due to partial combustion

•Lack of flexibility of operation

2. **Otto-Hoffmann's oven or By-product Oven:** The beehive ovens have been replaced by chamber ovens which works on regenerative principle of heat economy. All the valuable products are recovered from the outgoing flue gases.

Construction: It consists of no. of narrow rectangular chambers made of silica bricks.

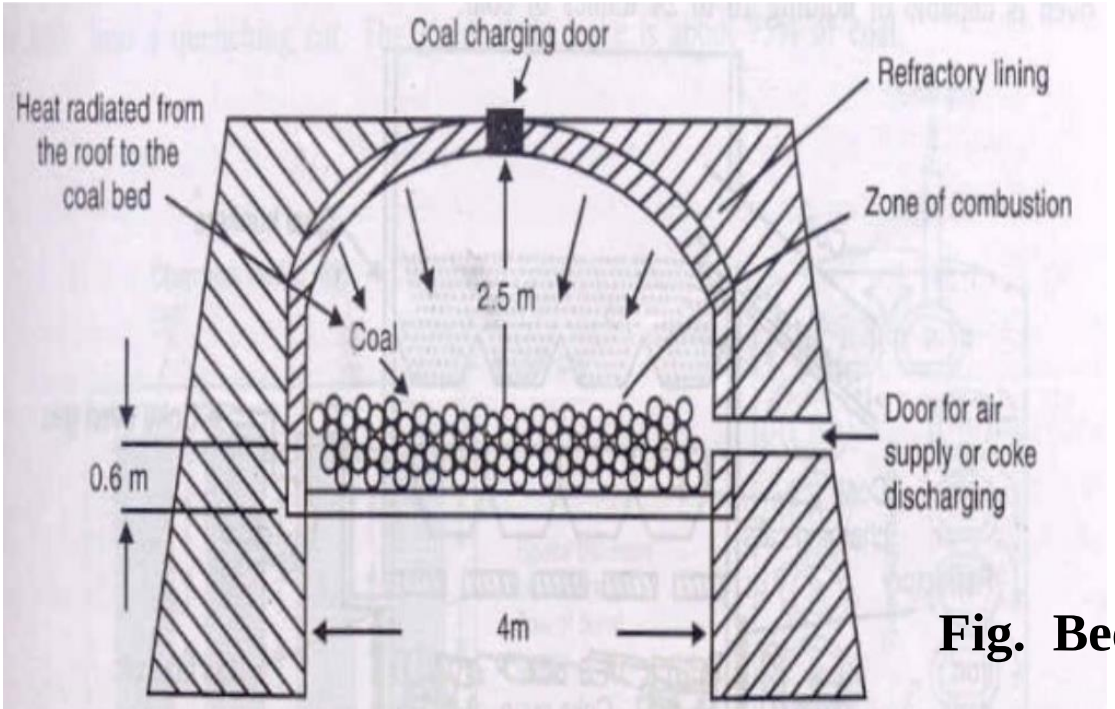


Fig. Beehive coke oven

Working: Coal is charged into the chamber. The coke ovens are heated to 1200oC by burning gaseous fuels. The process of carbonization takes place layer by layer in the coal charge. As the coal adjacent to the oven walls gets heated, a plastic zone is formed which moves away from the walls towards the central zone. As the coal is converted into coke, there is decrease in volume. This is because of the removal of volatile matter in the form of tar and gas at about 500 oC. At further high temperature, the plastic mass solidifies into hard and porous mass called coke. Regenerative principle is employed to achieve as economical heating as possible. Regenerators are built underneath the ovens. The flue gases pass their heat to the checker brick work of regenerators until the temperature rises to 1000 oC. Regenerators work on the principle of alternate heating and cooling cycles. This is achieved by periodically changing the direction of flow of gases through the vertical flues every 30 min or so. Carbonization of a charge of coal takes about 11-18 hours. After the process is complete, red hot coke is pushed outside by means of a ram which is electrically driven. The coke falls into a quenching car. The yield is 75 % of coal.

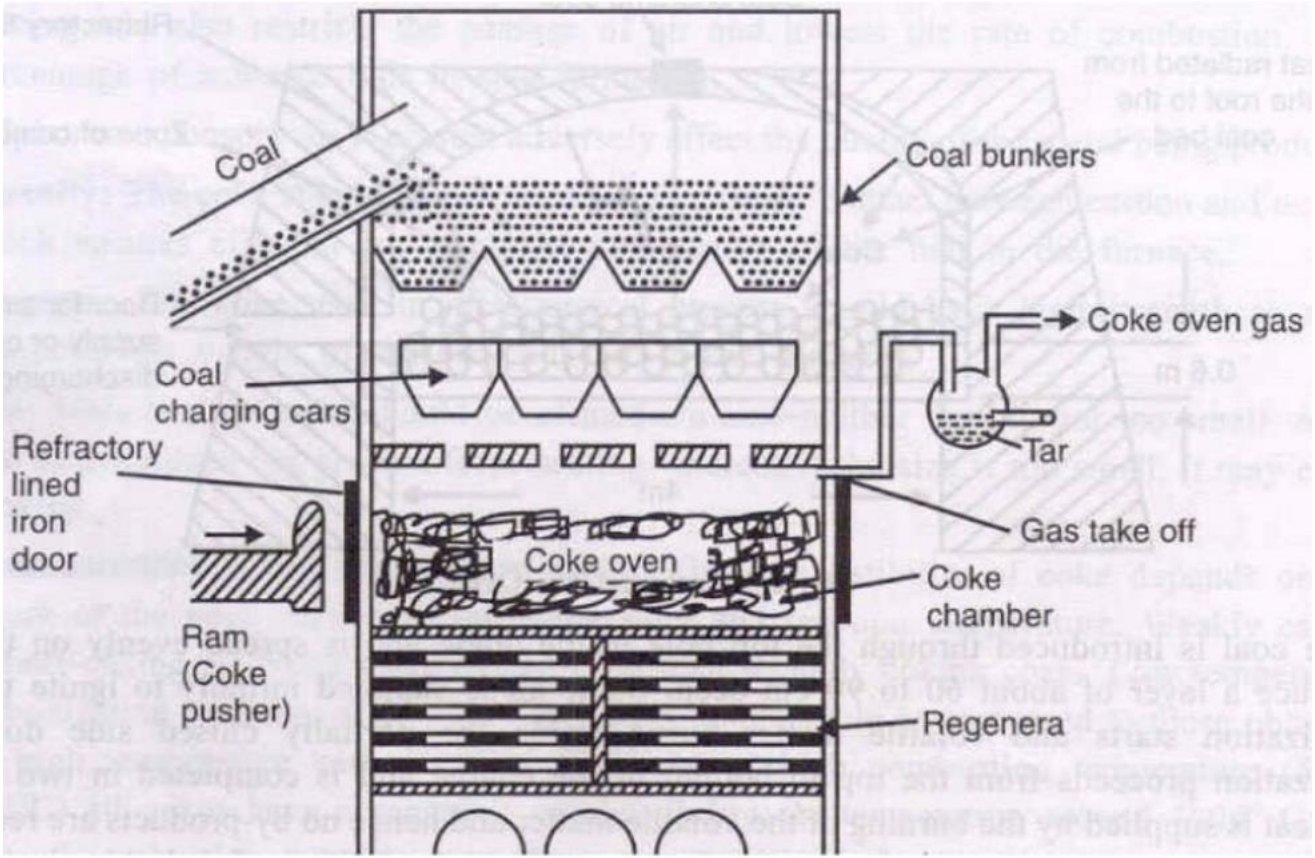
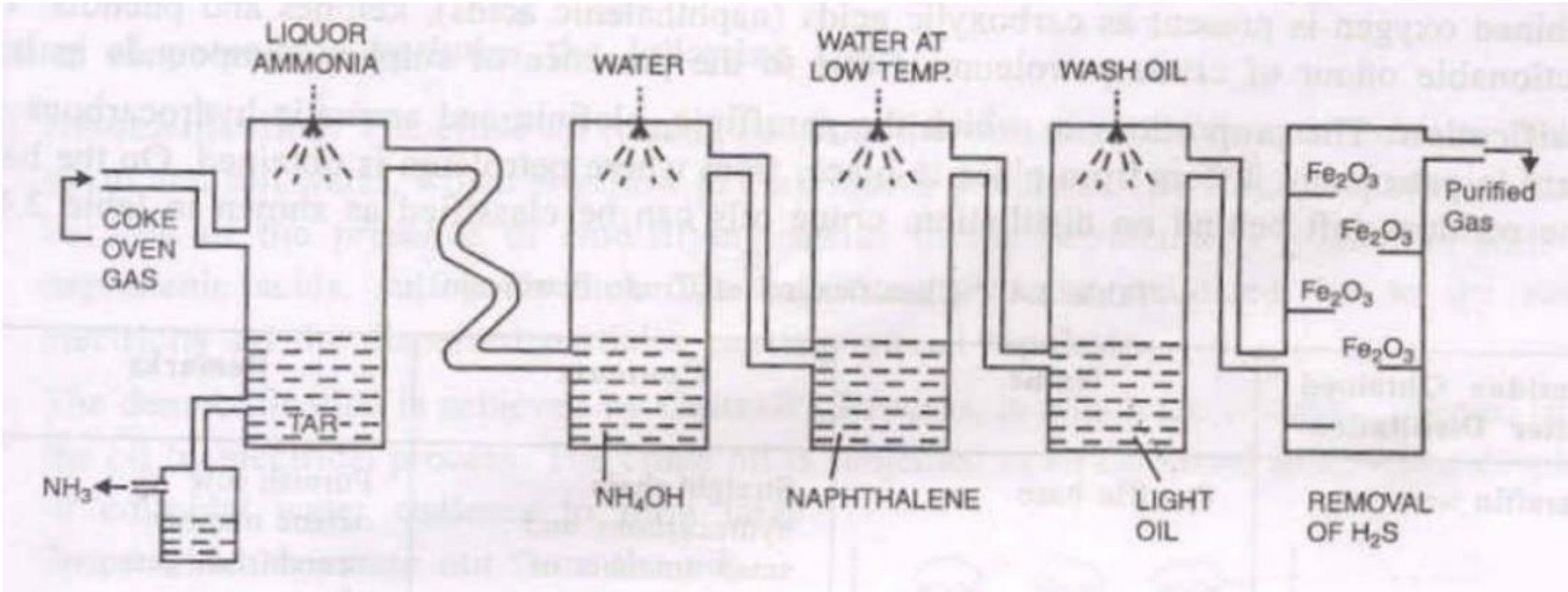


Fig. A single chamber of Otto Hoffmann's oven

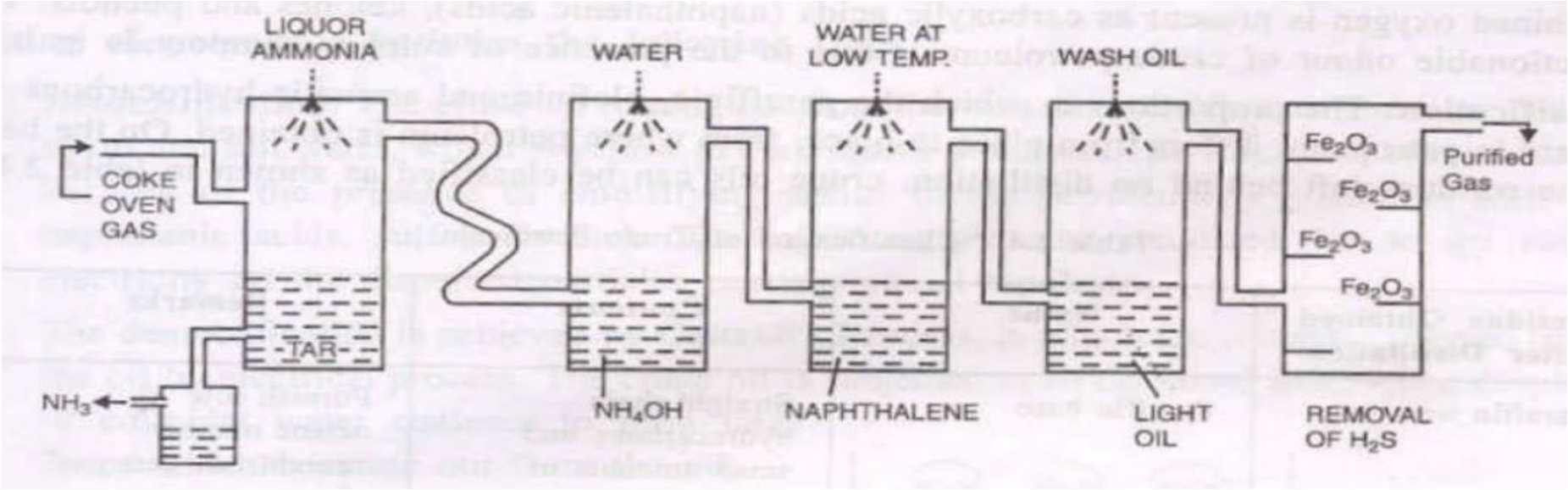
Coke-Oven gas treatment plant



Recovery of byproducts: The gases and vapours evolved on carbonization in coke ovens are not allowed to mix with the combustion and are collected separately. The coke oven gas is treated separately for the recovery of the valuable byproducts.

1.Recovery of Tar: The gas from the coke ovens is passed through a tower in which liquor ammonia is sprayed. Tar and dust get collected in a tank. The tank is provided with a heating coils to recover back ammonia.

2. Recovery of Ammonia: The gases are then passed through a tower where water is sprayed to recover ammonia. The ammonia can also be recovered by dissolving it in H2SO4 to form (NH4)2SO4, which is then used as a fertilizer.



3. Recovery of Naphthalene: The gases are passed through a cooling tower, where water at a low temperature is sprayed. The gas is scrubbed with water until its temp. reduces.

4. Recovery of Benzole: The gases are then introduced into a light oil or benzol scrubber, where benzene along with its homologue is removed and iscollected at the bottom.

5 Recovery of H_2S and other S compounds: are removed from the coke oven gas after the light oil has been separated out. $Fe_2O_3 + 3H_2S \rightarrow Fe_2S_3 + 3H_2O$

- $2Fe_2S_3 + 4O_2 \rightarrow 2FeO + 3SO_2$
- $4FeO + O_2 \rightarrow 2Fe_2O_3$

The SO_2 obtained can be used for the manufacturing of sulphuric acid, which can be used to absorb NH_3

Gasification

Gasification is a process that converts carbonaceous materials, such as coal, petroleum, or biomass, into carbon monoxide and hydrogen by reacting the raw material at high temperatures > 700 °C with a controlled amount of oxygen (partial combustion).

The resulting gas mixture is called synthesis gas or syngas and is itself a fuel.

Gasification is a very efficient method for extracting energy from many different types of organic materials, and also has applications as a clean waste disposal technique.