

CHEMICAL FUELS

INTRODUCTION:

A chemical fuel is any substance used to produce heat and power by combustion nuclear fuels are also now used. By common usage the term fuel also implies that it can be stored and transported. Fuels are primarily used for heating but they have other very important functions. Eg. Several metallurgical operations, as in a blast furnace, coke not only supplies heat but also acts as a reducing agent.

SURVEY OF FUEL RESOURCES:

To give a general idea, it may be said that the world's gas supplies are likely to last fifteen years, oil eighty years, coal five hundred years, and nuclear fission material two thousand years. India is very well placed in its thorium deposits in which she holds world's monopoly. India has sufficiently large deposits of coal but these are small when compared with some other developed countries. Our best coal which comprises only 13% of the total reserves contains about 17% ash. Major oil fields were found between 1952 and 1964 in Makarkatiya, Cambay, Ankleshwar, Kalol, Rudrasagar and Lakwa. Some of these are drying up. Recently major resource of gas has been the Krishna–Godavari basin.

CLASSIFICATION:

Fuels are classified according to whether they occur in nature (Primary fuel) or are prepared manually and according to whether they are in the solid, liquid or gaseous state.

The classification is summarized as follows:

STATE	NATURAL(PRIMARY)	PREPARED(SECONDARY)
Solid	Wood, peat, lignite coal	Charcoal, coke
Liquid	Petroleum	Petroleum distillates alcoholic tar
Gaseous	Natural gas	Coal gas, coke, producer gas, water gas, blast furnace gas.

1) WOOD:-

In India wood is used to a considerable extent as a domestic fuel. Its uses as an engineering fuel are restricted.

- On a moisture free basis, wood contains about 50% C, 6% H, 4% O₂ and less than 1% ash.
- Freshly cut wood contains 5 to 40% moisture and air dried wood contains about 15% moisture.
- The calorific value of common air dried wood is about 3500cal/g, but in some case it may be as high as 5000 cal/g.
- Bagasse is also important fuel in sugar mills. Its calorific value on 15% moisture basis is 3800 cal/g.

Brazil which is the eleventh largest steel producing country of the world, meets 40% of its energy needs of the steel industry by burning wood. Sweden, meets 60% of energy needs for paper and pulp industries by burning wood.

WOOD CHARCOAL :-

Wood charcoal is obtained by the destructive distillation (heating out of contact with air) of wood. Water and various kinds of volatile matters are expelled.

- Charcoal consists about 20% C, 15% O₂ and N₂, 2% H₂ and 3% ash.
- Its calorific value is high, being 8000cal/g.
- Usually the weight of charcoal obtained does not exceed 20% of the weight of wood. Its volume is 50–75% of the original volume.

Because of its purity and low ash content charcoal was the most important metallurgical fuel.

Because of its low mechanical strength it has become largely replaced by coke.

COAL:

INTRODUCTION:

Coal is a complex substance which originated several million years ago from the various plants that existed profusely on the surface of the earth. The plants were caught up in swamps, buried underground and slowly changed due to heat, pressure and biochemical and chemical processes. The fact that on proper processing it yields gas, oil, fertilizer and chemical which increases its usefulness.

ORIGIN:

Coal has been defined as a stratified rock consisting of the more or less altered remains of plants together with associated mineral matter. This process which

changed plant into coal has taken millions of years.

Geologists have put forward two theories of coal formation.

- 1) "In situ" theory contends that the coal formation took place where the vegetation grow and accumulated.
- 2) "Drift" or "Transportation " theory holds that the trees etc were uprooted and the material drifted or was transported by rivers to lakes and estuaries and deposited there.

The great purity of many coal seems can be better explained by the "in situ" theory and great thickness of coal seems to appears more reasonable on the basis of the "drift" theory.

It is interesting to note that in most cases, although there are some exceptions with the increase in vertical depth, the carbon content increases and volatile matter decreases. Anthracite and graphite are formed under extreme conditions. The stage in the formation of coal from vegetation can be best be summarized thus:

Plant debris – Peat – lignite – brown coal – sub-bituminous coal – bituminous coal – semi-anthracite coal – anthracite coal – graphite.

This series is known as "Peat" to anthracite series.

COAL CLASSIFICATION

The most common method of classification is on the basis of the rank of the coal. Rank represents the extent to which conversion into coal foundation has proceeded or in simple maturity or age of coal. The important ranks are as follows:

PEAT:

In the process of the formation of coal from wood the first stage is the formation of peat. Strictly it is not regarded as coal. One principal difficulty in its use is that peat deposits are associated with large amounts of water, as much as 90% water and only 10% solid. To make it an economical fuel, its moisture content should be reduced to 30% or less. It is not one of the important fuels used in India.

LIGNITES AND BROWN COAL:

In lignite the transformation of wood to coal has taken place to a greater extent than in peat. Lignites are found near the earth's surface and usually in thick seams, sometimes as much as 30m in thickness. These are classified into two groups. The true lignites are those which contain high proportions of relatively unchanged woody matter, have a high % of moisture say upto 60% and have low calorific value.

The other form is commonly known as brown coal. It contains much less

moisture, around 20% and have a higher calorific value. Lignites are usually amorphous and break easily, they are therefore difficult to transport. They burn with long smoky flame. On the basis of 15% the calorific value is about 4500 cal/g. Most important deposits of it are at Neyveli about 200 km South of Madras. The Kashmir lignite is of low calorific value (~2000Cal/g).

SUB BITUMINOUS COALS:

These are black in colour and are more homogeneous and smooth in appearance. The moisture and volatile matters contents are high. These are non-caking coals. The calorific value of sub-bituminous coals on a mineral free basis, is 7000 Cal/g or a little higher. Carbon content varies from 75 to 83% and oxygen content from 13 to 20%.

BITUMINOUS COALS:

This term is used after prefixing caking, noncaking, low volatile, medium volatile, high volatile etc e.g. caking bituminous coals.

- The carbon content varies from 78 to 90% and volatile matter from 20 to 45%.
- Coals of this class are used for making metallurgical coke, coal gas and for domestic heating.
- Calorific value on a mineral free basis goes upto about 9000 Cal/g.
- Bituminous coals are black comparatively hard and brittle and burn easily with a yellow smoky flame.
- The bituminous coals are of two broad types. The caking coals are rich in hydrocarbons. The non-caking are usually called steam coals.

ANTHRACITE COALS:

These are of the highest rank and in them, the coal formation process has proceeded upto the maximum extent.

- The carbon content is 90 to 98% and volatile matter is less than 8%. Therefore they ignite with difficulty.
- Anthracite coals are hard and brittle and produce very little dust.
- They burn without smoke and with a short non-luminous flame giving intense local heating.

INDIAN COALS:

Most of the Indian coals are what is known as "Gondwana coal." Gondwana is a geological term which refers to a certain rock system which is about 200 million years old.

- In India, anthracite coal is found to a negligible extent.
- Coalfields of Bihar and Bengal produce about 80% whereas the coalfields of Madhya Pradesh 10%, Orissa 5% and the rest of the country produce about

5% of the coal.

- The important coalfields of Bihar and Bengal are Barjora, Bokaro, Giridih, karampura, Jharia and Ranigunj.
- A serious disadvantage of Indian coal is that they contain high ash content.
- The Gondwana coal has been classed into the following two broad groups.

RANIGUNJ COAL:

It has greater moisture content (5%) and more volatile matter (30–38%) and therefore burns easily with a long flame. It has low calorific value.

Jharia or Barakar coal

It has less than 2% moisture and volatile matter content is about 28% consequently it burns with a shorter flame. Its calorific value is higher.

GRADING OF COAL:

The objective of grading is fixing coals price for marketing. In India upto June 1975 low moisture coal was graded on the basis of ash content and high moisture coal on the basis of ash and moisture content. Coal containing more than 2% moisture is regarded as high moisture coal. A new grading system has been introduced from July 1975 in which useful heat value of coal has been incorporated in the basis system. As the percentage of ash increases the amount of heat not available increases. Accordingly certain deductions as summarized in the following table are to be made from the gross calorific value for different percentage of ash to obtain the calculated useful calorific value.

TABLE

Deduction to be made from gross calorific value to obtain the useful calorific value of coal.

% Ash	Deduction (kcal/kg)	% Ash	Deduction (kcal/kg)
2	20	30	1030
5	65	35	1200
10	145	40	1370
15	260	45	1540
20	480	50	1710
25	790	–	–

ANALYSIS OF COAL:

The composition of coal may vary widely from one mine to another, hence it is important to analyze and be able to interpret correctly the results. The results are often expressed in terms of the following three bases:

- Basis of fuel as used or as received.
- Moisture free basis and
- Moisture and ash free basis, or on the basis of combustible matter.

Coal analysis is of two types:

- Proximate analysis and
- Ultimate analysis

1. PROXIMATE ANALYSIS:

Proximate analysis gives information which is useful in the practical utilization of coal. It consists in the determination of moisture, ash, volatile matter and fixed carbon.

MOISTURE: Moisture is determined by heating 5gm of finely powdered coal at 105°C for an hour. During transportation freight has to be paid on the increased weight due to the presence of moisture in coal. Therefore the presence of moisture is undesirable.

ASH: Ash determination can be made on the same sample after determining moisture. The sample is burnt at 900–750° in a muffle furnace until a constant weight is obtained. Ash is calculated from the weight of the residue.

For volatile matter Content about 1 g sample is taken in a platinum crucible with a properly fitting cover. It is then heated at $950 \pm 20^{\circ}\text{C}$. for exactly 7minutes. The percent loss in weight minus the percent moisture is reported as the percent volatile matter.

High volatile matter content means that a large portion of the fuel will be distilled and turned as a gas or vapor.

2. ULTIMATE ANALYSIS:

Ultimate analysis includes ash, carbon, hydrogen, sulphur, nitrogen and oxygen. For good comparison and accuracy the calculations should be on an ash free basis. The ultimate analysis is required for establishing a detailed and accurate heat balance for the equipment in which the fuel is used otherwise for most engineering purpose proximate analysis, determination of calorific value, and sometime sulphur content are sufficient.

CARBON AND HYDROGEN: Determination is made by taking 0.2 g coal. It is necessary, therefore to obtain a very representative sample. The sample is burnt in a current of oxygen in the combustion apparatus commonly; used in the organic analysis. As a coal may contain sulphur and also chlorine, it is necessary to use a silver gauze heated to about 800° to retain the oxidation products of these elements.

Carbon and Hydrogen are converted into carbon dioxide and water which are

absorbed in weighed KOH and calcium chloride tubes and the percentage of the elements are calculated from the results.

NITROGEN: It is determined by the kjeldahl method. About 1 g of powdered coal is heated with conc. H_2SO_4 along with potassium sulphate and mercuric sulphate. After the solution has become clear it is treated with caustic alkali and the liberated ammonia is distilled over and absorbed in a known vol. of standard acid solution. From this wt. of ammonia and nitrogen percentage in the coal is calculated.

Sulphur: It is often determined on the washings obtained from a sample of coal used in a bomb calorimeter for the determination of calorific value.

Ash determination is carried on as in proximate analysis. The sum of the percentage of C, H, N, S & ash is subtracted from 100 and recorded as the % of oxygen.

SIGNIFICANCE OF CONSTITUENTS:-

Carbon and hydrogen add directly to the heating value of a fuel and are certainly most desirable. The amount of carbon depends on the type of coal and increase with rank from lignite to anthracite. Hydrogen is mostly associated with the volatile matter and hence it affects the use to which the fuel is put.

Nitrogen is found in small amounts only 1% in coal and doesn't contribute any useful property.

Sulphur when present as sulphide contributes to the heating value but it has several undesirable effects. The oxidation products especially when moisture is present have corrosive action on the equipment and also cause atmospheric pollution. Oxygen content decreases as the coal becomes more mature. It is not desirable as it reduces the calorific value.

Phosphorous is undesirable in metallurgical coal because it is transferred to the metal and badly affects the properties of the metal. Moisture reduces the calorific value. It promotes corrosion storage equipments. Volatile matter in coal affects the furnace design. Higher the volatile matter content the larger is the combustion space needed. Coal with lower volatile matter content burns with a shorter flame.

Ash adds to the handling and disposal costs. It prevents complete combustion of carbon. It may be intimately mixed within the mass of coal (called fixed or inherent ash) or may be present in definite layer in the coal (called free or extraneous ash). The inherent ash cannot be removed by washing whereas other one can be.

CALORIFIC VALUE:-

The gross or higher calorific value of fuel is the amount of heat, expressed in calories per gram which is liberated when the fuel is completely burnt in an enclosed vessel at constant volume in the presence of excess of oxygen the products of combustion having been cooled to the room temperature.

The net or lower calorific value is the gross calorific value minus the latent heat of the water vapor. One of the formulas which Dulong proposed for the calculation of the calorific value from chemical composition is

$$\text{Gross C.V.} = 1/100 \times (8080 C + 34500(H-O/8) + 2240 S) \text{ Cal/g.}$$

Calorific value can easily be converted from one unit to another as follows.

$$1 \text{ Cal/g} = 1 \text{ Kcal/kg} = 1 \text{ C.H.U/lb} = 1.8 \text{ B.Th.U/lb.}$$

THE BOMB CALORIMETER:-

The simple sketch given below shows only the bomb of a calorimeter used for determining the calorific value of solid and liquid fuels.

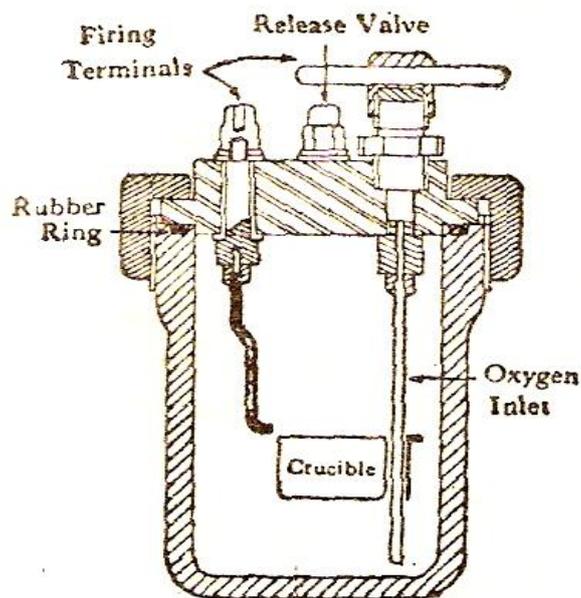


Fig-1 Bomb

Construction:-

The calorimeter has a carefully made, strong cylindrical bomb in which the combustion takes place. It is made of stable austenitic steel which is resistant to corrosion and can withstand a pressure of at least 50 atm. Two stainless steel electrodes are fitted to the cap. One of these is a tube through which oxygen is introduced.

A small ring is attached to this electrode on which the crucible containing the fuel is supported. A valve for releasing the pressure is also provided. Capacity of bomb is 300 ml. Calorimeter in which bomb is placed, is surrounded by an outer layer/jacket to prevent heat loss. A stirrer is provided for stirring water.

Procedure:-

About 1 g of the fuel is weighed into the crucible and a weighted piece of firing wire is stretched between the electrodes in such a manner that it is in close contact with the fuel so that it may be ignited. 2 ml of water is poured in the bomb so that the products of combustion of sulphur and nitrogen may be absorbed in it. The cap is screwed down on the bomb and oxygen is filled in up to a pressure of about 25 atmosphere.

The bomb is then placed in a weighed amount of water taken in the calorimeter. Electrical connections are made, stirring is started and temperature reading is taken with a thermometer, reading to 0.01° C. When the thermometer shows a steady temperature reading the electrical contact is made to fire the fuel and temp readings are continued for 5 minutes after the maximum temperature is attained. Water is stirred during process.

The bomb is then removed and allowed to stand so that the acid mist may settle down. The pressure is slowly released and the contents of the bomb are carefully washed, the washings are collected and analyzed for sulphuric & nitric acids formed. As S & N do not give sulphuric acid and nitric acid in actual practice, correction needs to be made for the heat given out in their formation.

Calorific value is then calculated from following formula:-

$$\text{Calorific Value} = \frac{(T + t) \times (W + w) - \text{corrections}}{\text{Wt. of fuel in g.}} \text{ cal/g}$$

T= observed rise in temp; t = radiation correction; W = weight of water; w=water equivalent of calorimeter.

Correction includes heats of formation of nitric and sulphuric acids and heat given out by the fuse wire while igniting the fuel.

CALORIFIC INTENSITY OR THEORITICAL FLAME TEMPERATURE:-

This is defined as the temperature that would be attained if the fuel burned completely in the theoretical amount of air and the heat produced was totally utilized in heating the products of combustion. This temperature is never attained in actual combustion, but it represents the maximum temperature to which a material could be heated under ideal conditions.

This is important in judging the maximum possible efficiency of an internal

combustion engine (Carnot cycle efficiency), the reactions in metallurgical furnaces and rate of heating in any operation. The calorific intensity is calculated by dividing the heat of combustion of fuel by the heat capacity of the products of combustion.

The temperature actually attained in the furnace depends upon several factors like the weight of air supplied, heat losses and the specific heat of the products. Temperature can be increased by supplying heated air.

PULVERIZED COAL:-

The combustion rate can be increased by increasing the rate at which air is forced in but this means a supply of excess air resulting in waste of heat.

The combustion rate can also be increased by finely powdering or pulverizing the fuel so that air and fuel easily come in close contact.

Pulverized fuel has some of the advantages over liquid or gaseous fuels.

- A lower percentage of excess air is necessary for obtaining complete combustion; thus there is less waste of heat higher temperature are obtained and thermal efficiency is higher.
- The rate of combustion can be changed as easily as in the case of a liquid or gaseous fuel.
- Low grade coal with high ash content can be used.
- Labour charges are lower.

The main disadvantage of pulverized coal is the cost of pulverization and as the ash is in a finely divided state, about 75% of it goes along with the flux gases and is discharged on the surrounding area. On the whole the advantages are greater than the disadvantages.

SELECTION OF COAL:

Broadly the use of coal can be divided into the following categories on the basis of uses:

- Power production
- Direct or indirect heating
- Manufacturing of other fuels, mostly manufacturing of coke and coal gas.

For the selection of coal for other uses the following are the main factors.

- **CALORIFIC VALUE:** It should be high so that a small quantity of coal can give a large quantity of heat, thereby reducing handling and storage cost also.
- **ASH:** Its content should be low. Each percent of ash means a heat loss of 1.5%. For most purposes the ash should not have a low melting point.

- **MOISTURE:** It should be as low as possible because it is paid for at the same rate as coal.
- **SIZE:** It should be as low as possible, as it facilitates handling and regulation of combustion.
- **CAKING:** These properties are undesirable except for making coke.
- **QUALITY :** of coal received in various installments should be as uniform as possible so that its behavior while burning does not change

CLEANING OF COAL:

Importance of coal cleaning is clear from the fact that each percent rise in ash content decreases the output of a blast furnace by 3 to 4%. Due to use of highly mechanized mining methods coal of inferior quality gets mixed-up. India coking coals contain 26 to 28% ash whereas the metallurgical industry requires coking coal with not more than 15 to 17% ash.

Due to large reserve of coal of very poor quality, other large consumers like the thermal power plants, railways and cement factories have started considering the use of washed coal.

Thus need for coal washing i.e. removal of ash from raw coal by physical, physio-chemical or mechanical treatments has increased. The first coal washery in India was installed at Kargali, Dist. Hazaribagh (Bihar) in 1958.

Two other new washeries set up are at Monidih and Ramgarh. These are designed to produce washed coal with 17% ash content. The only non-coking coal washery in the country was set-up by associated cement companies at Nowrazabad in 1961 with 0.7 million tones annual capacity. In washing coal, advantage is taken of the difference in specific gravity between clean coal and mineral matter. The average specific gravity of good coal is about 1.5, of average coal is 1.65 and of waste coal is 25 to 50%, combustible matter is about 2.

One method for separation is to treat coal of proper size in a Baum Jig in which pulsation is created in water by air under pressure. Coal with less ash content forms the upper layer and moves out through the coal outlet. Coal of inferior quality forms the lower layer.

The gravity separation method is more common An aqueous solution of calcium chloride or a suspension of a solid, such as sand magnetite etc. is made in water. Coal is agitated with the solution so that the clean coal floats and dirt sinks. The inferior coals which have a large amount of finely dispersed ash are treated in cyclone washer.

The coal is crushed to size below 1cm and subjected to strong centrifugal force in the cyclone washers. Froth floatation process has also been adopted. In all these cases coal has finally to be washed with water.

STORAGE OF COAL:

Coal should be stored for the minimum period necessary because, besides locking up of the capital and deterioration in quality, there is the danger of spontaneous combustion leading to outbreak of fire.

The primary cause of the self-heating of coal is oxidation. It is advisable to keep coal for about six weeks before transporting it to the consumers. The oxidation process is exothermic and if heat is not removed the temperature rises with the consequent increase in the rate of reaction and a point comes when the coal begins to burn. This process is known as spontaneous combustion and is helped by the following factors:

- **FINENESS OF THE COAL:** The finer the coal the larger is the surface area exposed on which oxidation can take place.
- **SULPHIDES:** Sulphides are easily oxidized giving heat. The oxidation products occupy more volume therefore the coal is broken into smaller pieces. This increases the surface area, thereby promoting further oxidation.
- **TEMPERATURE:** At higher temperature the oxidation proceeds faster. Immediate attention should be paid if the temperature has gone up to say 90°. Coal should not be stored against walls which get heated like the walls of the boiler house.

The best way of storing coal is to store it under water or in airtight bins so as to exclude oxygen. Coals may be stored in open space in piles not higher than 2metres. Care should be taken not to mix fine coal with bigger lumps.

It has been suggested that sized hard coal can be piled upto 7metres and anthracite coal upto 10metres without undue risk.

COKING COALS:

Coals which on heating soften become plastic and fuse together giving large coherent masses are known as coking coals. If the residue, i.e. the coke, is porous and strong it can be used on an industrial scale; then the original coal is known as coking coal.

All coking coals are caking but all caking coals are not coking coals. Coals which have little or no fusing action are called 'free burning coals'. In India coke is manufactured mainly for the iron and steel industry.

Caking coal should have as low ash (<17%) sulphur and phosphorus contents as possible. It is noteworthy that coke in most cases will come in direct contact with the metal, hence its impurities are likely to be transferred to the metal, especially sulphur and phosphorus which badly affects the properties of the metal.

The best results are said to be obtained with coals having 83 to 90% carbon content.

COKE:

PROPERTIES OF METALLURGICAL COKE:

Coke is the residue left on heating bituminous coal out of contact with air. Its largest industrial use is in the metallurgical industry, especially in the blast furnace. For such purpose the important properties are the following:

- **PURITY:** Ash, sulphur and phosphorus contents should be as low as possible. Ash has to be removed as slog,. It is estimated that 2% of coke is required for the removal of 1% of ash.
- **POROSITY:** Coke should be porous so that oxygen can easily come in contact with the carbon of the coke and the rate of combustion becomes higher.
- **STRENGTH:** During handling and also while dropping into the furnace if coke breaks into fine particles, the flow of gases will be retarded.
- **COMBUSTIBILITY:** Obviously coke should burn quickly. Coal does not possess as much porosity and strength as coke. If coal is used in a blast furnace it will be crushed under the load, by coking much of the sulphur is removed but the ash content increases, because of these reasons coke is preferred to coal for a blast furnace.

CARBONISATION PROCESS:

Carbonization means heating or distilling coal out of contact with air.

This produces a solid residue, called coke and liquid and gaseous products of distillation. This process is known as coking. Carbonization is carried out mostly for making metallurgical coke. Carbonization is also used to make smokeless fuel for domestic purpose. Ammonia liquor crude benzene and crude tar are the other by-products of carbonization.

On heating out of contact with air when the temperature of bituminous coal reaches a little over 100°C, water and absorbed gases are given off. First oxygen is removed in the form of carbon-monoxide and carbon dioxide, the hydrogen sulphide and olefins gases are liberated followed by the appearance of oily products.

Around 350° the active decomposition of coal begins and evolution of plenty of gas and tarry vapors can be seen. This process is completed when temperature reaches 450°. At this stage the mass is in a plastic state and the escaping gases bubble through it and thus the mass solidifies into a porous structure which is a characteristic of coke.

Coke is bad conductor of heat. Therefore movement of the plastic zone slowly occurs from the heated surface to interior. It is reported that there may be a temperature drop of 200 across a centimeter thick layer of coke. Due to higher temp of the coke further decomposition occurs giving various organic compounds. The quality of coke is influenced by various factors, the main factors being the quality of the coal carborized, the rate and the temperature of carborization.

A mixture of two kinds combines the advantages of both besides helping to overcome the shortage of coking coals. Low temperature coke contains 5 to 15% volatile matter and is weak for metallurgical purposes. High temperature carbonization gives coke which is strong can withstand load and abrasion in a furnace.

MANUFACTURE OF COKE:-

1) Beehive Coke Ovens:-

Especially where the consumption of coke is not very large, it is made in beehive coke ovens. The shape of the oven is like a dome. It is made of brick work and has an opening at the top for charging the coal. A door is provided at the side to remove coke.

A number of such ovens are operated in series so that the heat of each oven helps to heat the adjoining ovens. The evolved heat is sufficient to distill the volatile matter and also to fuel the coal. The time taken for completion of the entire operation is about 3 days. The coke is cooled by spraying water and then taken out through the side door.

2) By-product coke oven practice:-

A modern coke oven is a long, narrow, rectangular chamber made of silica bricks, about 10 to 12 meter long, 3 to 6 meter high and 40 to 45 cm wide. It tapers slightly (about 4 to 10 cm) towards the discharge and so that coke can be easily pushed out. Mechanically operated cast iron doors lined with fire bricks are provided at both ends.

The oven is provided at the top with an ascension pipe connected to a collecting main. There are 3 or 4 openings at the top as shown in fig below through which blended coal of the proper size (0.5 to 0.3) is fed.

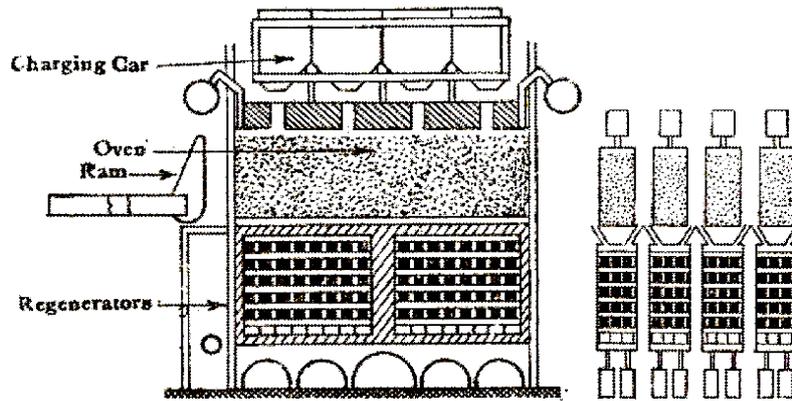


Fig-2 Coke oven

Every oven is separated from its neighboring one by a vertical flue in which gases burn. Thus each oven is heated from both the sides. The ovens are built in a block, consisting of ovens with alternating flues for heating. Such a block is known as a coke oven battery and has 20 to 100 ovens.

The time taken for coking varies from 12 to 20 hours and the temperature is 1100° or more.

Underneath the battery there is a regenerator system which consists of chambers filled with a chequer work of firebricks. The hot gas leaving the flues heats a set of chambers while air and fuel gas pass through other chambers which have already been heated. After sometime the directions are reversed. From this waste hot gas heats other chambers.

Thus the sensible heat of the waste gas is recovered and instead of the fuel gas burning in air at atmospheric temperature hot fuel gas burns in hot air, thereby producing a higher temperature and increasing the efficiency of the process.

The gas (generated from the ovens) is of high calorific value and can be transported to distant places.

After carbonization both the doors of the oven are opened and red hot coke is pushed out by a pusher into a coke car. The car takes the coke to a quenching station where a spray of water cools it. Excess water is allowed to evaporate and the coke screened into different sizes.

DISTILLATION OF COAL TAR:-

Coal tar is a black, thick oily liquid obtained by destructive distillation of coal. Tar obtained by high temperature carbonization is darker colored (black), whereas tar obtained by low temperature carbonization is dark brown liquid.

Tar obtained by low temperature carbonization contains paraffins, naphthalene, alkylated aromatic compounds, cresols, xylenole, and higher phenol. The amount of benzene, naphthalene and other aromatic is low in low temperature tars. The

composition of high temperature tar does not vary much, while that of low temperature tar varies widely.

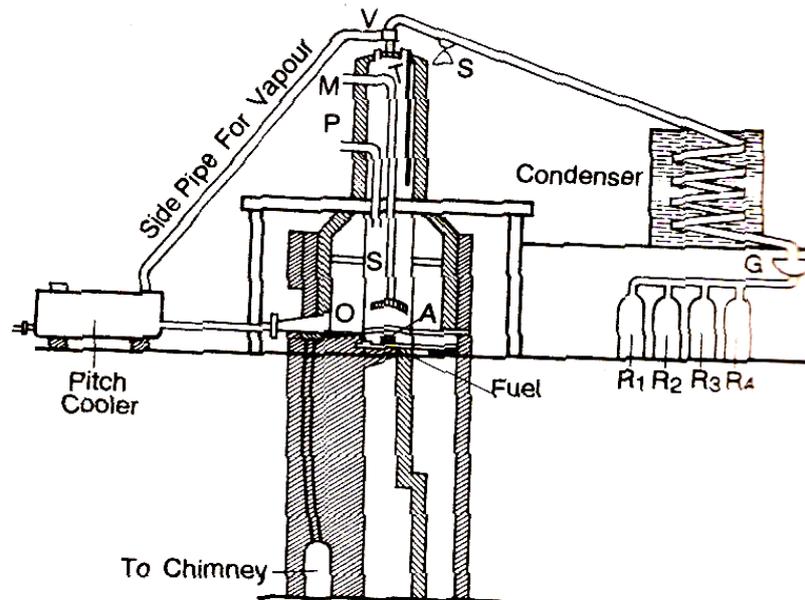


Fig- 3 Distillation of coal tar

FRACTIONAL DISTILLATION OF COAL TAR:-

Tar obtained by destructive distillation of coal still contains some ammoniacal liquor. This is separated by dehydrating the tar by heating. Distillation is carried out in batch still by heating dehydrated tar in a cast iron cylindrical horizontal plate tank. Main hole M is provided at the top.

The vapor pipe V is joined to the water cooled condenser. The cylinder is set in a brick built furnace. The brick work arc A protects the bottom coming in direct contact with the flame.

The fuel may be coal, oil or gas. Usually tar is agitated by blowing the superheated steam through the steam; coil S1 to reduce the temperature of distillation and hence to facilitate the distillation of heavy oils.

Specific gravity of various fractions can be noted occasionally in pot G, before passing them to receivers. Tar is allowed to pass into the still through the inlet pipe P, while it is already hot from the previous operation where the still is half full. It is then heated in the still carefully till the cracking noise in the still ceases. It indicates water is not present in tar now.

Dehydrated tar is heated at a higher temperature so that the distillates at different temperature range are collected separately in receivers R1, R2, R3 etc at the rate of about 4.6 gallons per minute. The soft pitch is then collected in coolers and then in storage.

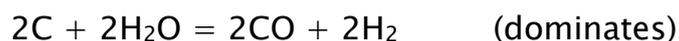
The following fractions are obtained as a result of distillation.

FRACTION	TEMP OF DISTILLATION	CHIEF CONSTITUENT
1) Light oil	80–170°C	Benzene, toluene & xylene
2) Middle oil	170–230°C	Phenol, naphthalene
3) Heavy oil	230–270°C	Phenol, cresol naphthalene
4) Pitch	270–300°C	Anthracene.

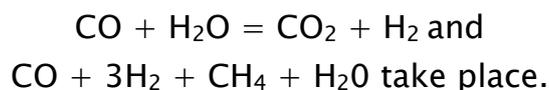
GASIFICATION OF COAL:-

Coal gasification is commercially proven for example they may be directed towards producing either high energy fuel gas which is rich in methane, or synthesis gas for chemical production.

In some well-known processes the coal in a suitable form, plus steam and oxygen enter the gasification reactor where they undergo a complex series of reactions, the balance between these depends on the temperature employed. Thus at high temperature, i.e. 1000°C.

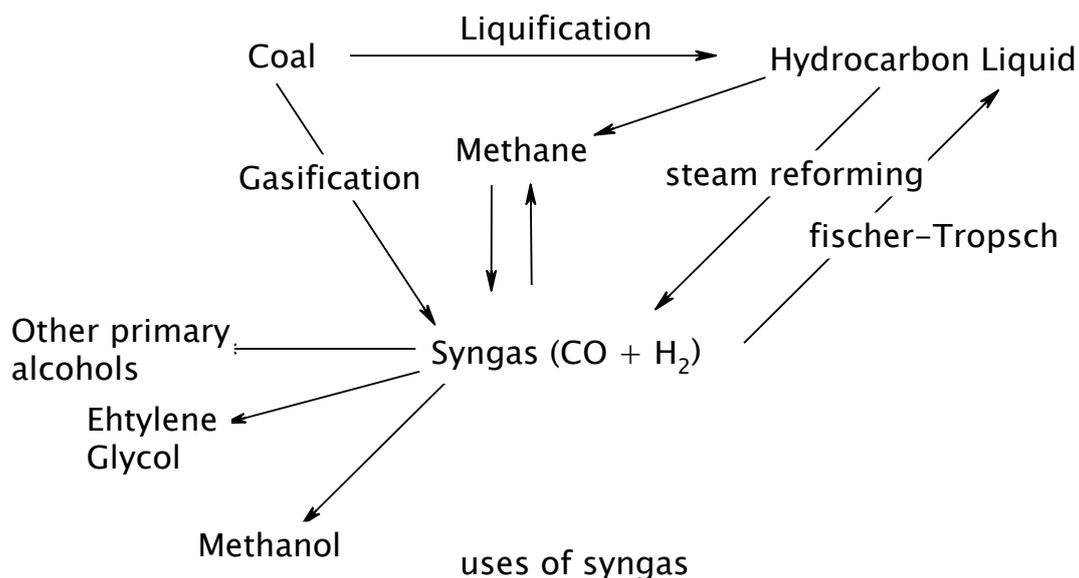


At lower temperature competition with



Hence higher temperatures are used to produce predominantly mixtures of carbon monoxide and hydrogen or synthesis gas. Small amount of alcohols and esters are produced in the Fischer-Tropsch process.

Methanol is readily obtained from syngas and its conversion to hydrocarbons over a metal oxide catalyst is well known. However, this gives a wide range of hydrocarbons and the catalyst's lifetime is relatively short. ZSM-5 zeolite catalysts, which are much more selective, have longer lifetimes and can produce ethylene as well.



PROCESS	CONDITIONS	TYPICAL PRODUCTS (VOL %)				COMMENTS
		CH ₄	H ₂	CO	CO ₂	
Lurgi	Fixed bed reactor ~1000°C, 30 atm.	12	37	18	32	Production of by product heavy tar (1%) restricts coal to non-caking types.
Koppers-Totzek	Entrained bed reactor 1800°C; 1 atm	-	34	51	12	Can handle all coals; high temperatures destroy heavy organic tar.
Winkler	Fluidized bed reactor ~900°C; 1 atm	3	42	36	18	High pressure process (15 atm) development.
Texaco	Entrained bed reactor ~1200°C ; 80 atm	N.A.				Commercially successful process for partial oxidation of fuel oil to synthesis gas being developed to handle coal as coal/water or coal/oil slurries.

GASIOUS FUELS

Advantages

- Combustion is under better control. Gases burn instantaneously and the rate of burning can be changed very easily. Oxidizing or reducing atmosphere can be easily maintained. All these gives fuel economy.
- Heat from hot flue gases can be removed and gaseous fuel can be pre-heated in regenerative furnaces, as is done in steel making by the open hearth process.
- Gaseous fuels may be prepared at a central place and distributed over a wide area through pipelines.
- Neither smoke nor ash is produced. Thus gaseous fuels are very clean.
- There is no problem of storage if the supply is obtained from a public supply.

The principal disadvantage of gaseous fuels is that they occupy large volume, therefore storage is difficult.

COAL GAS AND COKE OVEN GAS :-

Coal gas and coke-oven gas, both are obtained from the destructive distillation of coal and their composition and calorific values are similar. Coal gas is made in horizontal or vertical retorts by heating coal rich in volatile matter and gas is the main product.

The average calorific value is around 5000 K Cal/m³. Coal gas has a slightly higher calorific value than coke-oven gas. It has about 50% H₂, 30% hydrocarbons, 5% CO and smaller amount of other gases. As temperature of carbonisation is increased the yields of gaseous products increase and the yield of liquid product decreases. The volatile products obtained from the retorts of coke-ovens are drawn off through ascension pipes connected to a collecting main which runs horizontally along the entire row of ovens or retorts.

Here the volatile matter gets slightly cooled and some of the tar and water is condensed. The tar is led off to a tar well. The hot gas passes up the condensers into tar and ammonia liquor layer. The gas is then washed by a spray of water or sulphuric acid to remove the remaining ammonia. The cooled gas is finally washed with oil and benzol is recovered.

The gas has HCN, H₂S, CS₂ as impurities. It is passed through purifiers which consist of a series of chambers having several shelves loosely packed with ferric hydroxide which retains H₂S.



Hydrogen cyanide also gets removed as ferric cyanide. Iron sulphide is exposed to air when sulphur separates and is recovered. Presence of CS₂ is undesirable

because on oxidation, it forms corrosive oxides of sulphur. This is removed by passing the gas over heated nickel catalyst when some of the hydrogen of the gas reduces carbon disulphide and carbon.

The gas is stored in huge gas holders floating on water.

PRODUCER GAS:-

Producer gas is essentially a mixture of carbon monoxide and nitrogen but often steam is blown along with air, thereby giving some hydrogen also. A typical procedure giving the reaction, illustrated in the following figure.

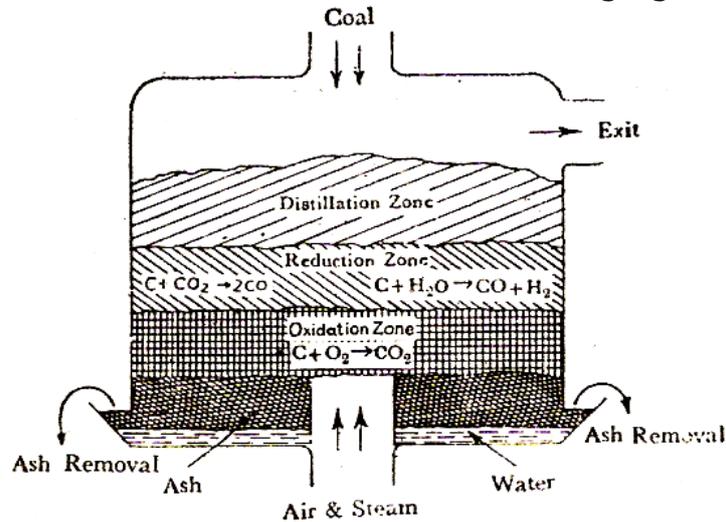


Fig-4 Producer gas plant

The procedure contains of an air tight cylindrical furnace made of steel plate lined with fire clay bricks. There is water-seal at the base which helps the removal of ash. Air or a mixture of air and steam, is blown through a pipe at the base. At the top there is an inlet for coal and also an outlet for the gas generated. Coal of high ash content or coke is generally used for making producer gas. Bituminous coal gives gas of higher calorific value.

The producer is filled with the fuel and the fuel is ignited. Air is forced in through the hot fuel and in the lower zone known as the oxidation zone, carbon burns to give CO₂. The reaction is strongly exothermic.



CO₂ passes upwards through the bed of coal and is reduced to carbon monoxide.



In the uppermost part of the fuel bed there is fresh coal which gets pre-heated and volatile matter distills. Gas goes out through the outlet and ash is removed through the water-seal. An efficient plant producer gas contains about 33% CO, 64% N₂ and the rest is carbon dioxide and hydrogen.

DIFFICULTIES FACED:- In working of the producer of this type, some serious difficulties are faced. The combustion of carbon in air heats the lower part with

the result that the ash forms clinkers which are difficult to remove. The fire bars, on which the coal rests and the refractory lining of the plant get heated by which their lives are reduced.

To reduce these difficulties some steam about 0.35 kg per kg of coal is blown in along with the air. In the reduction zone, steam reacts with carbon producing CO & H₂;



The calorific value of producer gas is about 900 k cal/m³.

WATER GAS OR BLUE GAS:-

This consists essentially of a mixture of carbon monoxide (40%) and hydrogen (50%) along with some CO₂ & N₂. It is manufactured in similar manner as producer gas. The change in the method is that first only air is passed through the coal bed when carbon burns to CO₂ and the entire bed gets heated to 1000° or more.

The outgoing gas which is a mixture of CO₂ & N₂ is not used as a fuel but is used to preheat the incoming air and steam. Steam is blown through red hot coal when CO & H₂ are produced and are collected. Reaction is endothermic.

Water gas is also called "blue gas" because both CO & H₂ burn with a blue flame. Its calorific value is about 2700 kcal/m³. Calorific value can be increased by mixing oil gas. Thus carbureted water gas is obtained which contains about 35% each of CO & H₂, 70 % of various lower hydrocarbon gases and 10% of CO₂ and N₂. Its calorific value is 4500 Kcal/m³.

BLAST FURNACE GAS:-

It contains about 25% CO and has a calorific value of 800kcal/m³. The quantity of gas produced is very large but cal value is so low that it can't be used for many purposes nor can it be supplied to distant places.

The gas is passed through dust catchers where the heavier particles drop down. Then washed with a spray of water and passed through electrical precipitator to remove remaining particles.

Gas purification is important because the dust is deposited in the pipelines, burners and furnaces. The use of blast furnace gas for heating coke oven makes available a larger quantity of coke-oven gas which has higher calorific value. This has resulted in saving on fuel cost in steel plants.

NATURAL GAS:-

Almost every petroleum well gives out some gaseous product consisting mostly of methane along with some ethane, propane and other hydrocarbons.

The gas is given the name "natural gas". Natural gas is wet as it contains

hydrocarbons which could condense in the pipeline. These are removed by compression and cooling or by absorption in liquid oil.

The dry gas so obtained contains over 80% methane, the balance being mostly ethane. Its calorific value is about 10,000 Kcal/m³.

Easily condensable hydrocarbons like propane, isobutane and butane are liquefied at room temperature by compression.

DETERMINATION OF CALORIFIC VALUE:-

Junker's Calorimeter:-

The following figure illustrates a gas calorimeter originally designed by Junker. It consists essentially of an inner combustion chamber in which the gas burns.

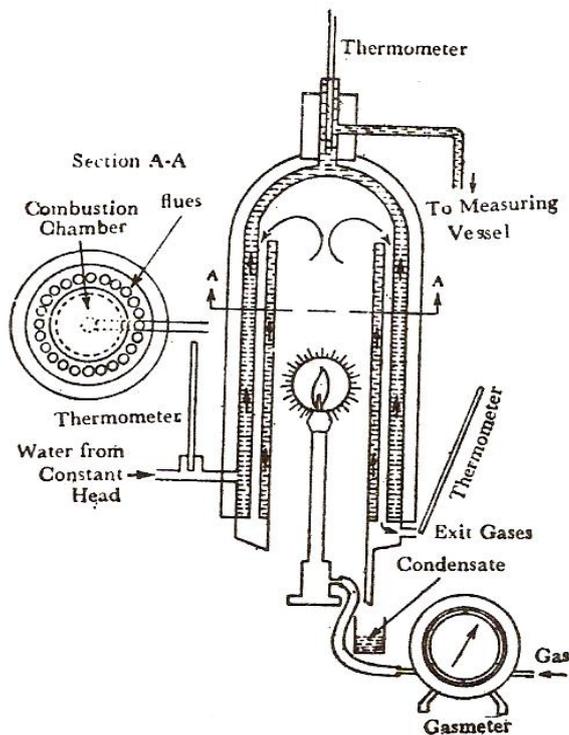


Fig-5 Junker's gas calorimeter

The chamber is surrounded by a water jacket through which a number of tubes, called flues pass. The gas on combustion heats the water jacket and then passes down the flues in the water jacket, thus complete transfer of the heat of combustion to water is ensured.

Water enters the calorimeter through a constant head and its temperature is noted by a thermometer. The gas whose calorific value is to be determined, passes through a gas meter, which records its volume and burns in a burner as shown.

The hot products of combustion move upwards in the chamber and then downward through the flues provided in the water jacket and escape through the

exit. Water, moving in a direction opposite to that of the gases in the flues goes out from the upper portion. Its temperature and volume are recorded.

The volume of gas burnt during the experiment is converted to volume at 15° and 760 mm Hg pressure. Knowing the vol. of the water flowing and the rise in its temperature the heat given out by the gas is known.

For obtaining the net calorific value, the condensed water is weighed and the weight multiplied by the latent heat of vaporization of water. This is subtracted from the total heat and the result is then divided by the corrected volume of the gas.