

FUELS

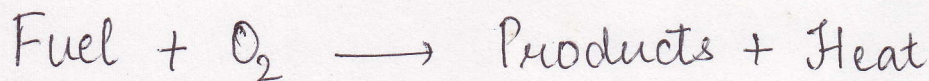
UNIT I A

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INTRODUCTION :-

Fuel is a combustible material containing carbon as the major component which on burning gives large amount of heat that can be used for domestic and industrial purposes. During combustion of a fuel such as coal, the atoms of carbon, hydrogen etc. combines with oxygen to give heat. The energy is released due to rearrangement of valence electrons in these atoms lead to formation of compounds (CO_2 , H_2O etc.). The energy released during the process of combustion is the different of energy and that of products



Therefore the term fuel may be defined as any fissionable material, chemical or any reactant which produces energy in the form of heat that can be used for producing power. A typical example of this is fuel cell.

CHARACTERISTICS OF A GOOD FUEL

The main features of a good fuel are:-

- (i) The fuel should have high calorific value
- (ii) Ignition temperature should be low, so that it can burn smoothly.

- (iii) A fuel should have low moisture level.
- (iv) A fuel should have low content of non-combustible matter because it reduces heating value.
- (v) A good fuel should be readily available in bulk at low cost.
- (vi) A solid should have less ash content.
- (vii) Storage cost of fuel should be low.
- (viii) The combustion velocity should be moderate.
- (ix) Combustion products should be harmless.
- (x) Combustion should be easily controllable.
- (xi) Combustion should not be spontaneous in case of liquid or gas fuel.
- (xii) A good fuel should burn without smoke.
- (xiii) The supply position of the fuel should be reliable.

CLASSIFICATION OF FUELS

The classification of fuels is according to occurrence and state of aggregation. According to occurrence fuel is of natural (primary) or derived (secondary) types and according to state or aggregation the fuels are classified as solid, liquid and gaseous fuels.

Fuel may be classified into two categories

- (i) Primary fuel
- (ii) Secondary fuel

Primary Fuel :- It is also known as natural fuel. Natural fuels are found in nature as such. Natural fuel are directly used for the

function of heat and its technical utilization as such. It may be solid, liquid or gas.

Solid fuels: wood, coal, peat lignite etc.

Liquid fuels: Petroleum.

Gaseous fuels: Natural gases.

Secondary Fuel :- Secondary Fuels are also known as artificial or processed fuels. These fuels are obtained from primary fuel. It may be solid, liquid or gas

Solid fuel: High and low temperature coke, charcoal etc.

Liquid fuel: Kerosine, diesel, gasoline, LPG etc.

Gaseous fuel: Coal gas, water gas, producer gas, biogas etc.

UNITS OF HEAT

- (i) C.G.S System :- The unit of heat on the C.G.S system is calorie which can be defined as the quantity of heat necessary to raise the temperature of one gram of water by 1°C ($15-16^{\circ}\text{C}$)
- (ii) M.K.S System :- The unit of heat on M.K.S System is kilocalorie which can be defined as the quantity of heat necessary to raise the temperature of one kilogram of water 1°C .

$$1 \text{ KCal} = 1000 \text{ Cal.}$$

- (iii) British Thermal Unit (B.T.U) :- The unit of heat on the British system is British thermal unit (B.T.U) which can be defined as the

quantity of heat necessary to raise the temperature of 1 pound of water through 1°F ($60-61^{\circ}\text{F}$).

$$1 \text{ B.T.U.} = 252 \text{ Cal} = 0.252 \text{ K Cal}$$

$$1 \text{ K Cal} = 3.968 \text{ B.T.U.}$$

(iv) Centigrade Heat Unit (C.H.U.) :- This is quantity of heat necessary to raise the temperature of 1 pound of water by 1°C

$$1 \text{ K Cal} = 3.968 \text{ B.T.U.} = 2.2 \text{ C.H.U.}$$

CALORIFIC VALUE

It is the total amount of heat liberated by the complete combustion of one unit of fuel in presence of oxygen.

(i) Higher or Gross Calorific Value (HCV or GCV) :-

When the calorific value of fuel is determined experimentally, hydrogen is converted into steam because hydrogen is present in almost all fuels. If the products of combustion are condensed to room temperature (25°C or 77°C) the latent heat of condensation of steam is also included in the measured heat. The total value of heat is known as higher calorific value and can be defined as the total quantity of heat liberated on combustion of one unit of the fuel and combustion products are cooled to room temperature.

(ii) Lower or Net - Calorific Value :-

Since water vapours escape as such along with hot combustion gases during combustion of fuel, hence a lesser quantity of heat is available. This is known as lower or Net - Calorific Value and can be defined as the quantity of heat liberated

A fine magnesium wire touching the fuel is connected with the electrodes. The bomb is filled with O_2 at 25 atmosphere. The bomb is then dipped in copper calorimeter, having a known mass of water. The stirrer is worked and initial temperature of water is noted. The electrodes are then connected to 6 Volt battery and circuit is completed. The heat is liberated on combustion of the fuel. Uniform stirring of water is continued and the maximum temperature attained is recorded.

OBSERVATION

Weight of fuel taken = x gm
 weight of water in calorimeter = w gm
 Water equivalent of the calorimeter, stirrer, thermometer and bomb = wt. of apparatus \times specific heat
 = w

Initial temperature of water in calorimeter = $t_1^\circ C$

Final temperature of water in calorimeter = $t_2^\circ C$

Let the higher calorific value (HCV) of fuel = L Cal/g

CALCULATION

Heat gained by water = $w(t_2 - t_1)$ Cal

Heat gained by calorimeter = $w(t_2 - t_1)$ Cal

Total heat gained = $w(t_2 - t_1) + w(t_2 - t_1)$
 = $(W + w)(t_2 - t_1)$ Cal

Heat liberated by fuel = xL Cal

Now heat liberated by fuel = Heat gained by water and Calorimeter.

$$xL = (W + w)(t_2 - t_1)$$

$$HCV(L) = \frac{(W + w)(t_2 - t_1)}{x} \text{ Cal/g}$$

Let the % Hydrogen in fuel = H
 Wt. of water produced 1g fuel = $\frac{9H}{100} = 0.09H \text{ g}$

∴ Heat taken by water in forming steam
 = $0.09H \times 587 \text{ Cal}$

∴ LCV = HCV - Latent heat of water
 $LCV = HCV - \frac{9}{100} \times H \times 587 \text{ Cal/gm}$

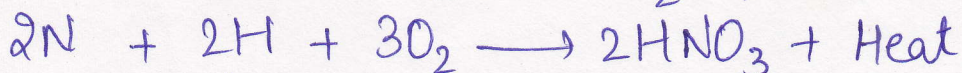
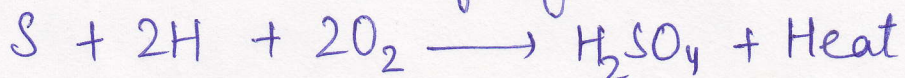
CORRECTIONS

Following corrections are done for accuracy
 (i) Cooling correction :- Rate and time taken for cooling the water in calorimeter from maximum to room temperature must be considered from the state of cooling (dt/mm) and actual time taken for cooling ($t \text{ min}$). The cooling correction of $dt \times t$ is added to the rise in temperature.

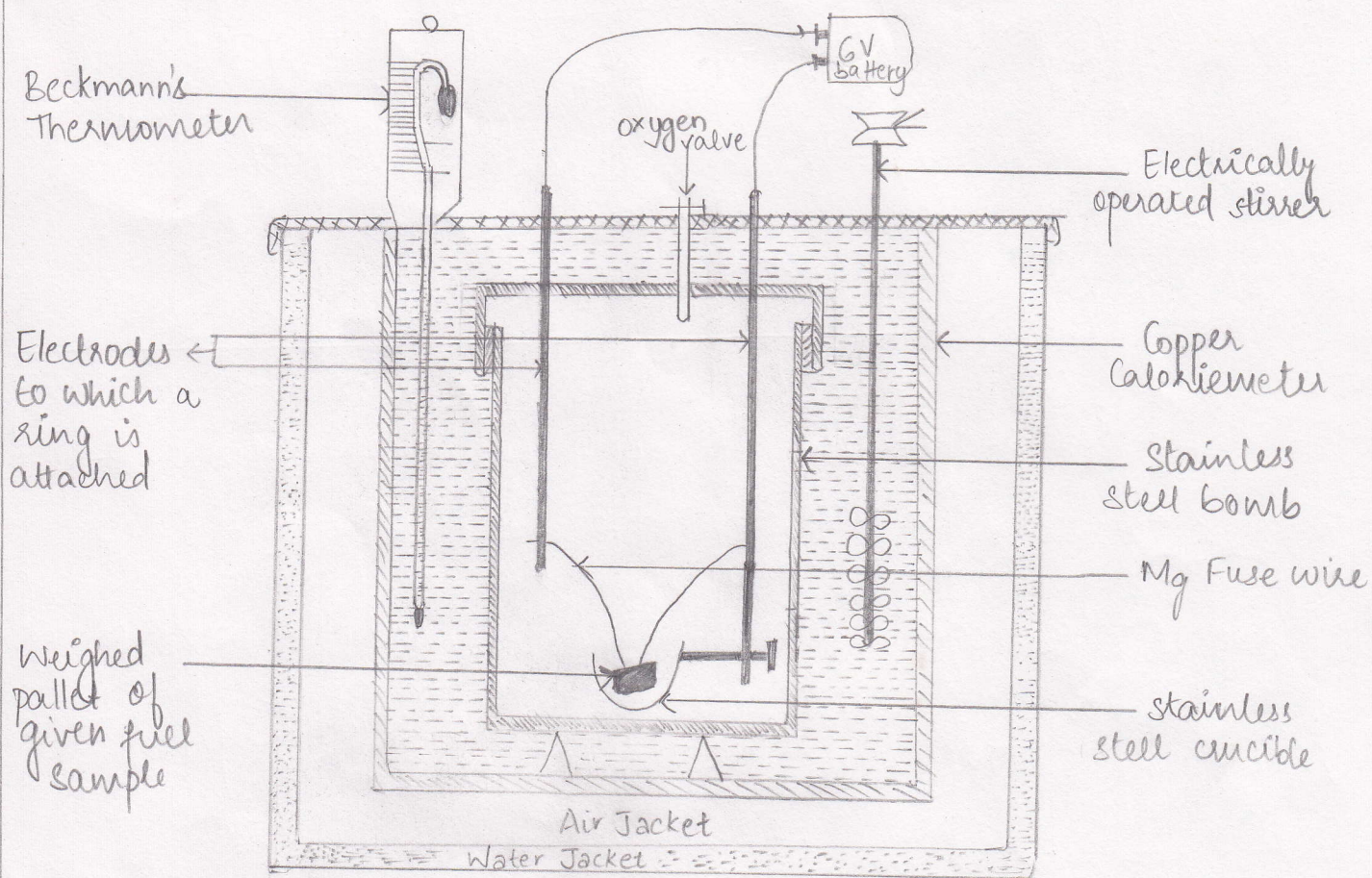
$$\therefore L = \frac{(W+w)(t_2 - t_1 + \text{Cooling correction}) - (\text{Acid} + \text{Fuse} + \text{Thread Corrections})}{x}$$

(ii) Fuse wire correction :- The heat liberated as measured above includes the heat given out by ignition of the fuse wire used.

(iii) Acid correction :- Sulphur and Nitrogen present in fuel are oxidized to H_2SO_4 and HNO_3 with liberation of heat during ignition



So this heat is also included in the measured heat and hence must be subtracted. The quantity of these acids are analysed from washings of bomb by titration, while sulphuric acid is determined by precipitation as $BaSO_4$. Correction for 1mg of S



BOMB CALORIMETER

is 2.25 Cal while for 1ml $\frac{N}{10}$ HNO_3 formed is 1.43 Cal.
(iv) Thread Correction:- The $\frac{10}{100}$ heat liberated also includes the heat given out by ignition of thread.

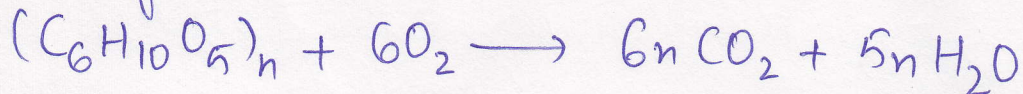
CHARACTERISTICS OF GOOD FUEL

A good fuel should have following properties.

- (i) High Calorific Value:- A fuel should have high calorific value depends on the heat liberated by fuel.
- (ii) Moderate Combustion Temperature or ignition temperature
It is the lowest temperature necessary for combustion of a fuel. Low ignition temperature of fuel is dangerous for storage and transport because it can cause fire hazard. High ignition temperature is unfavourable for starting fire. So an ideal fuel must have moderate ignition temperature.
- (iii) Low moisture:- Moisture reduces the heating value of a fuel so it should be low.
- (iv) Low non-combustible matter:- Non-combustible matter reduces the heating value of a fuel and after combustion of fuel remains as a fuel. A good fuel have low quantity of non-combustible matter.
- (v) Moderate combustion:- Burning of fuel should be moderate for uniform heat supply.
- (vi) Highest pyrometric effect:- The highest temperature obtained with the fuel have high pyrometric effect.
- (vii) Transportation:- The Transportation of fuel should be easy and of low cost. It is easy to transport solid and liquid fuels. while gaseous fuels it is costly hazardous.

SOLID FUELS

1. Wood:- Wood consists of cellulose $(C_6H_{10}O_5)_n$, lignite, resins, inorganic substances and nearly 60% of water. Its calorific value varies from 3000 - 4000 Kcal/kg of air dried wood. Wood has got low ash content (0.3 - 0.6%). On burning wood gives carbon dioxide and water



2. Coal:- Coal is primary fuel and is highly carbonaceous matter being formed as a result of alteration of vegetable matter under favourable condition. It is composed of C, H, N and O. besides some non-combustible inorganic substance.

Various types of Coal commonly recognized on the basis of rank or degree of alteration from parent material wood are

Wood \rightarrow Peat \rightarrow lignite \rightarrow Bituminous Coal \rightarrow Anthracite

(i) Peat is brown fibrous jelly like mass. This is regarded as the 1st stage in coalification of wood. It may contain 80 - 90% water. The average composition of air dried peat is C = 57% H = 6%
O = 35%.

ash = 2.5 - 6%. Its calorific value is about 5400 Kcal/kg.

(ii) lignite is brown coloured intermediate stage between the peat and bituminous coal. It is compact in texture containing 20 - 60% moisture and dried lignite contains C = 60 - 70% O = 20%. lignite burns with long smoky flame. Its calorific value is about 6500 - 7100 Kcal/kg

- (iii) Bituminous Coal (Common Coal) is compact black substance and is most widely used of all the mineral coals. They are further classified as
- (a) Sub-bituminous Coals are black in colour and are more homogeneous and smooth in appearance. The carbon content varies from 75-83% and oxygen content from 10-20%. The calorific value is about 7000 Kcal/Kg.
 - (b) Bituminous Coals have banded appearance and carbon content varies from 78-90% and volatile matter 20-45%. The calorific value is about 8000-8500 Kcal/Kg. These are used for making metallurgical coke, coal gas and for steam generation.
 - (c) Semi bituminous Coals are rich in carbon (90-95%) and have low volatile matter. They are used in coke manufacture. The calorific value is about 8500-8600 Kcal/Kg.
- (iv) Anthracite is a class of highest rank coal containing highest percentage of carbon (92-98%) & has lowest volatile matter and moisture content. The calorific value is about 8,650-8700 Kcal/Kg. They are used for steam generation for household purposes and as a metallurgical fuel. In India anthracite is found in Kashmir and in eastern Himalayas.

ANALYSIS OF COAL

For assessment of quality of coal the following

(A) Proximate Analysis of Coal

The proximate analysis gives information regarding the practical utility of coal. This involves the following steps.

① Moisture :- About 1g of finely powdered air dried Coal sample is weighed in a crucible. The crucible is placed inside an electric oven maintained at 100°C for 1hr. The crucible is then taken out cooled in a desiccator and weighed. The loss in weight is reported as moisture on percentage basis.

$$\% \text{ Moisture} = \frac{\text{Loss in weight}}{\text{Weight of Coal taken}} \times 100$$

② Volatile matter :- Dried sample of coal left in crucible (1) is then covered with a lid and placed in a muffle furnace maintained at 950°C for 7 minute. The crucible is then taken out cooled in air, then in a desiccator and weighed the loss of weight is reported as volatile matter on percentage basis.

$$\% \text{ Volatile matter} = \frac{\text{Loss in weight due to volatile matter}}{\text{wt. of coal taken}} \times 100$$

③ Ash :- The residual coal in the crucible is then heated in a muffle furnace at $700 - 750^{\circ}\text{C}$. The crucible is then taken out, cooled in air and then in a desiccator and weighed. The experiment is repeated to get a constant weight of residue. The residue is reported as ash on percentage basis.

$$\% \text{ ash} = \frac{\text{wt. of ash left}}{\text{wt. of coal taken}} \times 100$$

④ Fixed Carbon :- This is determined by deduction as follows $\% \text{ C} = 100 - \% (\text{Moisture} + \text{Volatile matter} + \text{ash})$.

High percentage of fixed Carbon is desirable.

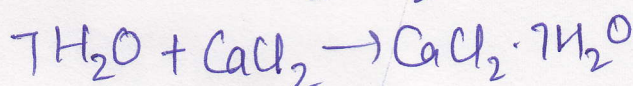
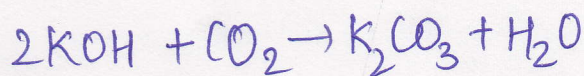
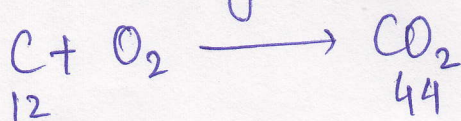
B) Ultimate Analysis

Ultimate Analysis is the elemental analysis of coal which deals with the determination of Carbon, hydrogen, nitrogen, oxygen, sulphur and ash contents. These determination as given below.

(i) Carbon and Hydrogen:-

About 1-2g of accurately weighed coal sample is burnt in a current of oxygen in a combustion apparatus. C and H of coal are converted into CO_2 and H_2O respectively. The gaseous products are absorbed in KOH and CaCl_2 tubes of known weights.

The increase weights of these are determined.



$$\% \text{C} = \frac{\text{Increase in weight of KOH tube} \times 12 \times 100}{\text{Wt. of coal sample taken} \times 44}$$

$$\% \text{H} = \frac{\text{Increase in weight of } \text{CaCl}_2 \text{ tube} \times 2 \times 100}{\text{Wt. of coal sample taken} \times 18}$$

(ii) Nitrogen:-

About 1gm of coal sample is heated with concentrated H_2SO_4 along with K_2SO_4 as catalyst in a long necked flask called Kjeldahl flask. After the solution becomes clear it is treated with excess KOH and liberated ammonia is distilled over and absorbed in a known volume of standard acid solution. The unused acid is determined by back titration with standard NaOH. From the volume of acid used by ammonia liberated the % N in coal is calculated.

$$\% N = \frac{\text{Vol. of acid used} \times \text{normality} \times 1.4}{\text{wt. of coal sample}}$$

(iii) Sulphur :- This is determined from the washings obtained from the known mass of Coal used in bomb calorimeter for determination of Calorific Value. During this determination of Calorific value S is converted into sulphate. The washings are treated with BaCl_2 when BaSO_4 is precipitated. This precipitate is filtered, washed and heated to constant weight.

$$\% S = \frac{\text{wt. of } \text{BaSO}_4 \times 32 \times 100}{\text{wt. of Coal taken in bomb} \times 233}$$

(iv) Ash :- This is done as in proximate Analysis

(v) Oxygen :- It is calculated by deduction

$$\% O = 100 - \% (C + H + N + S + \text{ash})$$

FUELS

CARBONISATION

When coal is heated strongly in absence of air it loses volatile matter & converted into white, lustrous, dense, strong, porous & coherent mass known as coke. This process of converting coal into coke is called carbonisation. The coal having a tendency to soften, swell & stick together during combustion can be converted into coke. Only bituminous coal can be coked. There are two types of carbonisation of coal.

① LOW TEMPERATURE CARBONISATION: In this process heating of coal is carried out at $500-700^{\circ}\text{C}$. The yield of coke is 75-80% containing 5-15% volatile matter. It is not mechanically strong hence cannot be used as metallurgical coke. However it burns easily giving a smokeless, hot & radiant fire & hence is an ideal fuel for domestic purposes. The gaseous product of this process has high calorific value (6500 kcal/m^3) & is therefore a valuable fuel.

DISCO PROCESS: By this process strongly coking coals are carbonised at low temperature. Coal is fed to roasters which are cast iron plates heated from below. Coal is stirred over these plates till it attains a temperature of 60°F. When coal is strongly coking, air is passed over it to destroy to some extent its agglutinating properties. However to destroy if coal is weakly coking no air is required for its oxidation. After roasting coal is allowed to fall into the raised end of a kiln type of carboniser. This carboniser consists of two concentric cylinders. The inner cylinder rotates while the outer is stationary. Heat is applied in the annular spaces between these two cylinders, by hot combustion gases at 140°F from a furnace. The by products in low temperature carbonisation are tar, ammonia, etc.

Heat radiated from roof to coal bed

Refractor lining

Zone of combustion

Door for air supply or coke discharging

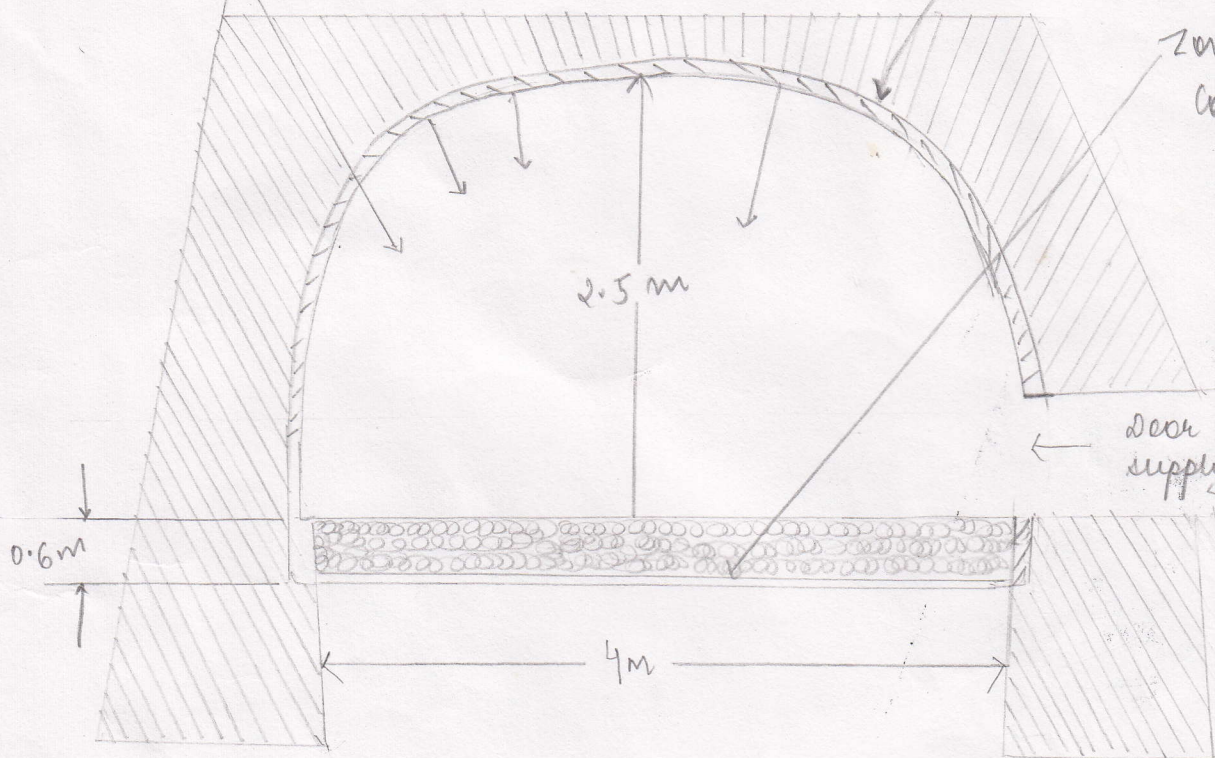


Fig. (i) Beehive coke oven

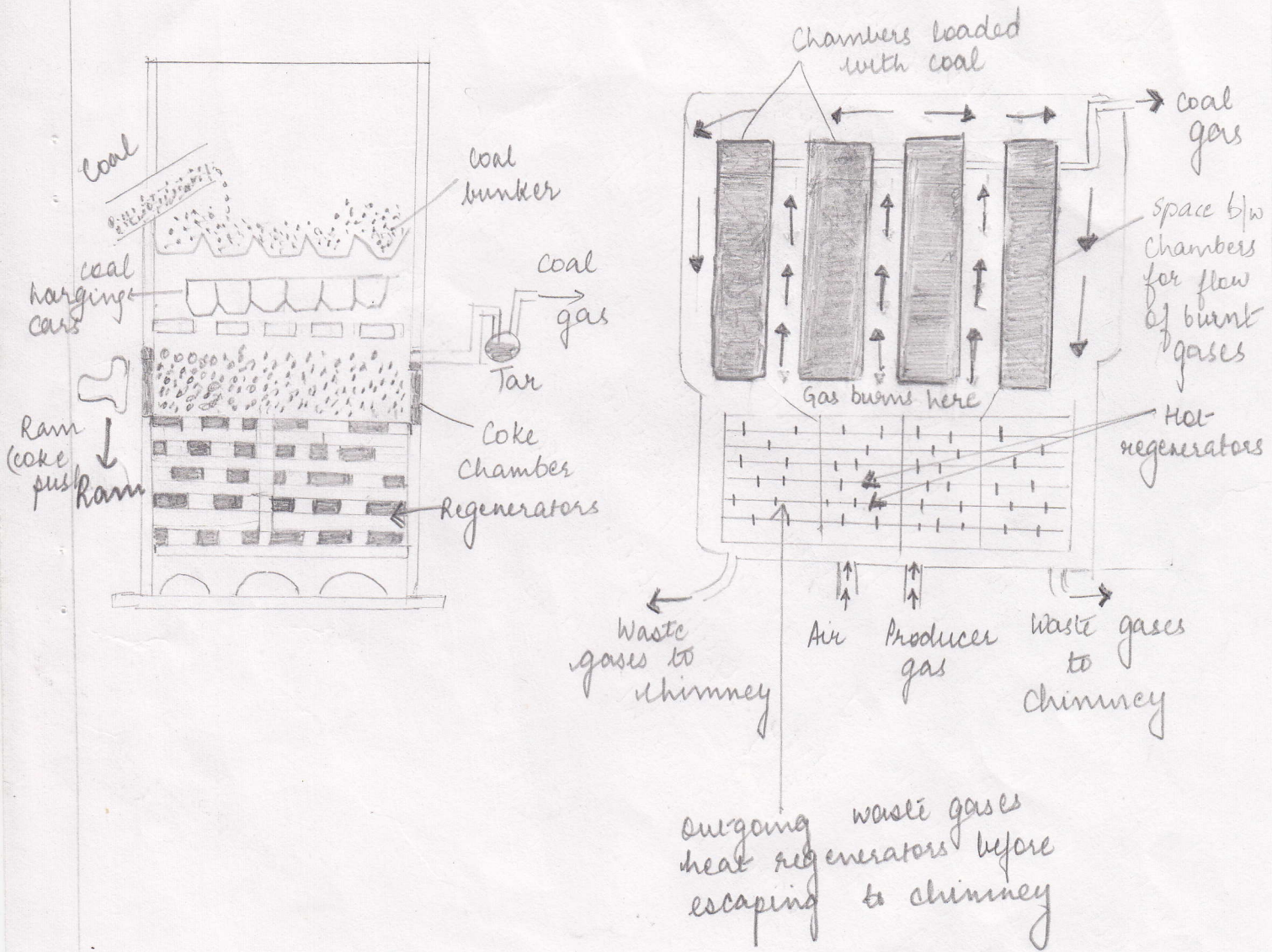


Fig : (ii) Otto Hoffmann's by product coke oven with regenerators.

② HIGH TEMPERATURE CARBONISATION:

In this process heating of coal is carried out at high temperature ($900 - 1200^{\circ}\text{C}$). The yield of coke is about 65-75% containing about 1-3% volatile matter. The coke obtained by this process porous, hard, pure compact & strong & thus can be used in metallurgy. The gaseous by-product of this process is although high in volume but its calorific value is low ($5400 - 6000 \text{ kcal/m}^3$).

High temperature carbonisation of coal is carried out in coking ovens in either of the following two types:

(A) BEEHIVE OVEN: It is earliest & cheapest process for the carbonisation of coal (Fig 1). The Beehive oven is a dome shaped structure made of bricks. It is about 4m wide & 2.5m high. It is provided with the openings one at the top for charging of coal and the other on a side for discharging the coke/supplying air. These openings can be opened or closed as desired.

Coal is charged through the top opening & levelled evenly to produce a layer about 0.6m deep. Air is supplied through the side door & coal is ignited. The volatile matter escapes or burns inside the side doors. The carbonisation takes 3-4 days. The hot coke is quenched with water & raked out through

the side door. The yield of coke is 80% of the charged coal & about 5-6 tonnes of coke per firing.

(B) OTTO HOFFMANN PROCESS :

Ottohoffmann developed modern by product coke oven which has the advantage that the valuable by products are recovered. Here heating is done on the principle of "regenerative system". of heat economy i.e. utilising the waste flue gases for heating the checker work of bricks.

The byproduct coke oven consists of narrow silica chambers separated by interspaces for burning gas. Each silica chamber is about 10-12m long, 3-4m high and 0.40-0.45m wide. Each chamber is provided with a charging hole at the top, a gas off take & a refractory lined cast iron door at each & for discharging coke (fig ii.)

finely crushed coal is charged into chambers & chambers are closed. The ovens are heated to 1200°C by burning gaseous fuel on regenerative principle to achieve economical heating. Flue gas produced during combustion are passed to the regenerators whose brick work takes up the heat & get heated to 1000°C. The waste gases then go to the chimney. The checker work of bricks. The byproduct coke oven consists of narrow silica chamber separated by interspaces for burning gas. Each silica chamber is about 10-12 m long

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When the coke is formed, a massive ram pushes the red hot coke outside. It is quenched by a water spray. In dry quenching the red hot coke is cooled by inert gas like nitrogen. The coke obtained by dry quenching is cheaper, drier, clean & stronger than wet quenched coke. The yield of coke is \approx 75% of coal charged.

RECOVERY OF BY-PRODUCTS :

The volatile matter coming in the form of gas known as coke oven gas is composed of ammonia, hydrogen sulphide, naphthalene, benzene, etc. These product are separated from each other.

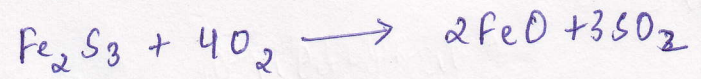
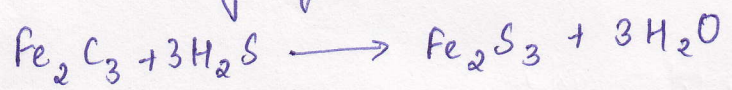
(1) RECOVERY OF TAR: The coke oven gas is passed through a tower where liquor ammonia is sprayed. Here dust & tar gets collected in a tank which is heated by steam coils to recover back ammonia. The ammonia is used again.

(2) RECOVERY OF AMMONIA: The gas is free from tar is passed through a tower in which water is sprayed. Here NH_3 goes into a solution as NH_4OH .

(3) RECOVERY OF NAPHTHALENE: The gas is then passed through a tower in which water is sprayed at very low temperature when naphthalene is condensed.

(4) RECOVERY OF BENZOL: The gas is passed through a tower in which petroleum is sprayed. Here benzene & its higher homologues are removed.

(5) REMOVAL OF H_2S : The gases are passed through purifiers containing ferric oxide.



Sulphur is removed as SO_2 .

METALLURGICAL COKE :

Among the solid fuels coal is used in metallurgical process. A good coke used in metallurgical process should possess following characteristics :

(1) PURITY : A metallurgical coke should have minimum possible amount of moisture, ash, sulphur & phosphorus. Presence of moisture in coke reduces its calorific value. Excess of ash hinders the heating and also helps in slag formation. Presence of S & P in coke on burning forms SO_2 , P_2O_3 & P_2O_5 which adversely affect the quality of metal to be produced. Presence of S in coke makes it brittle.

(2) STRENGTH : Coke is used in metallurgical furnace should be compact, hard & strong such that it can withstand the load of overlying solids (ore + flux).

(3) POROSITY : Coke should be porous enough so that oxygen can easily come in contact with the carbon such that complete combustion at high rate takes place.

(4) SIZE : Metallurgical coke should be of medium size.

(5) RATE OF COMBUSTION: A good metallurgical coke has low rate of combustion because lower the state of combustion of a coke higher will be its calorific value & hence better the quality of fuel.

(6) COMBUSTIBILITY: There should be no difficulty in burning of coke.

(7) COST: It should be cheaply available.

(8) CALORIFIC VALUES: It should be high.

LIQUID FUELS:

The liquid fuels have low flash point, high calorific value, low viscosity at ordinary temperature & low moisture & sulphur contents.

PETROLEUM: As it is found in rocks it is called petroleum. derived from the latin *petra* (rock) & *oleum* (oil). Thus petroleum means rock oil. Petroleum is often called liquid gold because modern civilization has found it to be more valuable than gold. Petroleum or crude oil is a dark greenish brown viscous oil found deep in earth's crust.

The average composition of crude petroleum is

$C = 79.5 - 87.1\%$ $H = 11.5 - 14.9\%$ $S = 0.1 - 3.5\%$

$H+O = 0.1 - 0.5\%$

CLASSIFICATION OF PETROLEUM

Petroleum is classified into three categories according to its composition

- (1) Paraffin base petroleum: It contains hydrocarbons of the paraffin series. These paraffin hydrocarbons are branched or straight.
- (2) Asphaltic base Petroleum: It contains hydrocarbons of naphthalene series.
- (3) Mixed Base Petroleum: It contains both paraffinic & asphaltic hydrocarbons & are generally rich in semi solid waxes.

ORIGIN OF PETROLEUM;

Modern Theory: According to modern theory petroleum has resulted from the partial decomposition of marine animals & vegetable organisms of prehistoric forest. Changes in earth (volcanoes etc) has buried these materials underground. During course of time under favourable conditions biological matter decomposed into petroleum. This theory explains presence of urine coal, N & S compounds chlorophyll & haemin & also optically active compounds in petroleum.

MINING OF PETROLEUM :

Mining of petroleum is done by drilling holes in the earth's crust & sinking pipes upto oil bearing porous rocks. Usually oil pushes out itself due to hydrostatic pressure of natural gas but as the pressure of gas subsides, air pressure is applied through pumps to force the oil out of the well.

REFINING OF PETROLEUM :

Petroleum is a viscous, dark coloured and foul smelling liquid. It is always found mixed with considerable amount of water and earth particles & it is also known as crude oil. It is a complex mixture of hydrocarbon & so it becomes necessary to separate these things in order to make each fraction available for appropriate use. It can be separated into a number of useful fractions with different boiling ranges is called refining of petroleum. The process of refining involves the following steps:

- (1) Separation of Water : The crude oil is an emulsion of oil & salt water (brine). The process of separating water from oil consists of allowing the crude oil to flow between two highly charged electrodes. The colloidal water droplets form large drops which separate out from oil.

(2) Separation of sulphur compounds : This involves the treatment of oil with copper oxide. A reaction takes place with sulphur compounds which results in the formation of copper sulphide which then removed by filtration.

(3) Fractional Distillation : The crude oil is then heated to 430°C in an iron retort where by all volatile components are evaporated. The compounds like tar and asphalt do not vapourise & they settle at the bottom of the column. The hot vapours are then passed through a distillation column.

The distillation column is a cylindrical structure of steel 31m high & 3m diameter. There are horizontal plates or trays are filled inside the column at short distance (25-50m). In each tray there is a bubble cap and an upgoing short tube (Fig iii). As the vapours go up they begin to cool & condense in fractions, at different height of the column. Higher boiling point fraction condenses first; while lower & lower boiling fractions condense one after the other. For this reason aviation petrol (a liquid with lower boiling pt) is collected in the upper most tray & fuel oil (a liquid with highest boiling pt) is collected in the lowest tray.

Brajshwara

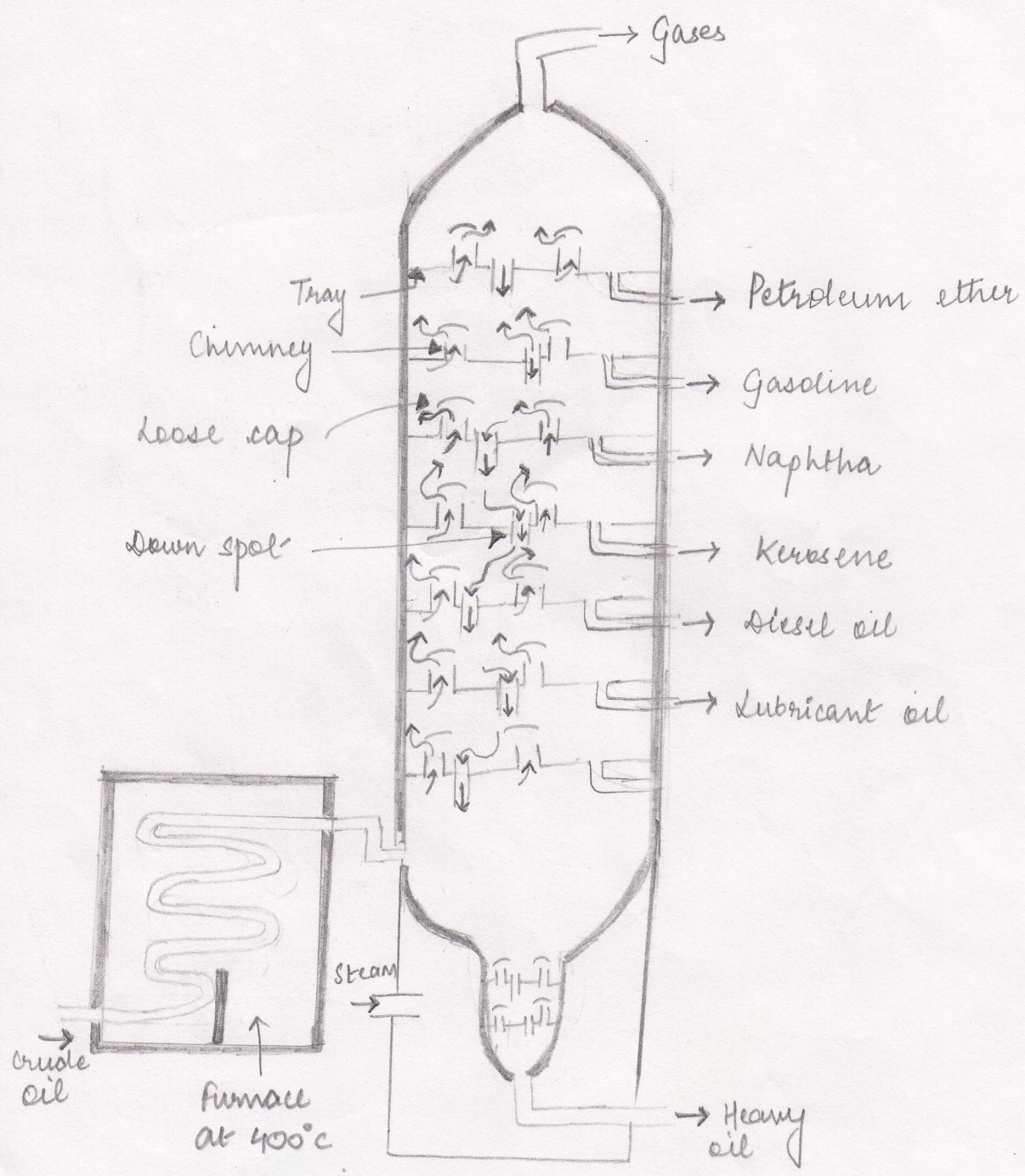


Fig (iii) : Fractional Distillation of Crude petroleum.

DIFFERENT FRACTION OF CRUDE OIL DISTILLATION

Name of fraction	Approx composition	Boiling range	Uses
Uncondensed gases	C ₁ -C ₅	upto 30°C	LPG, synthesis of organic compounds, production of carbon black
Petroleum ether	C ₅ -C ₇	30°-70°C	As a solvent for oil, varnish
Petrol	C ₅ -C ₁₀	40°-120°C	Fuel for IC engine, automobiles, aeroplanes, solvent & dry cleaning
Naptha	C ₉ -C ₁₀	120°-180°C	As solvent & dry cleaning
Kerosene	C ₁₀ -C ₁₆	180°-250°C	Illuminants, fuel for stoves
Diesel oil	C ₁₀ -C ₁₈	250°-320°C	Fuel for diesel engines
Heavy oil on refraction gives	C ₁₇ -C ₃₀	320°C-400°C	Lubrication
(a) Lubricating oil			Lubricants, cosmetics
(b) Petroleum jelly			Medicines
(c) Grease			Lubricant
(d) Paraffin wax			Candles, floor polish, wax paper, tarpaulin cloth
(e) Petroleum coke	C ₃₀ & above	<400°C	water proofing of roofs, road making, as a fuel.

KNOCKING :

Although theoretically the power output of an internal combustion engine increases with increase in the compression ratio, in actual practice it rapidly falls after a certain compression ratio. Compression ratio is the ratio of the cylinder volume at the end of the down stroke to the volume at the end of the up stroke of the piston.

If the fuel air mixture is compressed beyond this point two difficulties arise. firstly, because of the high temperature the fuel may ignite spontaneously even before the spark functioned. This is known as preignition. The second difficulty arises if after the start of the combustion and the flame proceeding at a particular rate, the last portion of fuel burns spontaneously. This instantaneous combustion, causes a shock wave to be setup. This is known as 'knocking' 'spinking'. 'Detonation'. It depends on the characteristics of the fuel besides design factor.

Knocking tendency decreases in the order
 n alkanes > mono substituted alkane > cycle alkanes >
 alkenes > Poly substituted alkenes > aromatics & for
 straight chain hydrocarbons. the tendency to knock
 increases with molecular weight and boiling point
 eg. n hexane > n pentane > n butane.

Aromatic hydrocarbons have higher anti knocking properties than paraffins & olefins

Octane Number: The most common way of expressing knocking characteristics is by octane number. It has been found that n-heptane knocks very badly & its antiknock value has arbitrarily taken as zero & iso-octane gives very little knocking and its antiknock value has been taken as 100. The octane number is the percentage by volume of iso-octane in a mixture of iso-octane & n heptane which just matches the knocking characteristics of the fuel. Thus if a sample of petrol gives as much knocking as a mixture of 80 parts of iso-octane & 20-parts of n-heptane, its octane number is 80. Nowadays fuels with an octane number above 100 & also available and the value is determined by extrapolation

The maximum permissible power increases with increase in the octane number. Based on experimental results graphs have been drawn to show the relationship. Another unit known as performance number, is now being used to enable direct deduction of the power output that can be expected of a fuel.

Cuprous chloride in liquor ammonia. It can absorb CO_2 , O_2 & CO .

CETANE NUMBER :

The knocking characteristics of a diesel engine is expressed in terms of octane number. Octane ($C_{16}H_{34}$) has a very short ignition lag and its number is taken as 100 & that of α -methyl naphthalene ($C_{11}H_{10}$) which has a very long lag as zero. The cetane is defined as percentage of cetane in a mixture of cetane & α -methyl naphthalene which just matches the ignition quality of fuel under test. Oils for high speed, medium speed and low speed diesel engines should have cetane number not less than 45, 35 and 25 respectively. Knocking in a diesel engine is due to the oil not igniting in time.

The cetane number can be improved by adding substances like ethyl nitrate, acetone peroxide & iso-amyl nitrate which helps in starting ignition. These substances are known as dopes and are added in a small amount (1-1.5 ml).

Knocking in a petrol engine and in a diesel engine is due to two different reasons. In a petrol engine it is due to sudden spontaneous combustion of the last part of the oil & in a diesel engine it is due to delay in the spontaneous combustion of the 1st part of the oil.

The result is that an oil of high octane number has low cetane number and vice-versa.

Therefore a petroleum cutude, which gives petrol of high octane gives diesel oil of low cetane number. Cetane number depends on the nature & composition of its hydrocarbon n-alkane > naphthalene (cycloalkanes) > alkenes > branched alkanes > aromatics (i.e. cycloalkanes).

Flue Gas Analysis By Orsat Apparatus

It has been already stated that if theoretically minimum air is supplied in a furnace the combustion reaction will not be complete & there will be considerable wastage. In common furnaces 50-100% excess air is generally supplied. In practice it is difficult to measure the air supplied. For proper control & economy, it is also necessary to know the actual state of combustion i.e. whether or not complete combustion is taking place. How much CO is being formed how much of free oxygen goes in the gases etc. Orsat Apparatus used for fuel gas analysis is one of the best examples.

Orsat apparatus consists of capillary glass tubes manifold connected at one end to a gas burette B & to the three way stop cock, d, at the other end. The manifold has three side tubes connected to three stopcocks, a, b & c. through which are connected three absorption pipettes P₁, P₂ & P₃. each of which has two bulbs as shown in figure. Just below the necks there are marks to show the levels of solutions. The gas burette is surrounded by a water jacket so that temperature of gas remains unchanged during the experiment. The lower end of the burette is connected by a rubber tube to an aspirator bottle, P, filled with water

The pipettes are usually filled with glass tubes so that the surface area of contact between the gas and solution is increased. The three pipettes P_1, P_2, P_3 have solutions for the absorption of CO_2, O_2 and CO respectively. P_1 has KOH solution and absorbs only CO_2 . P_2 has pyrogallol and KOH and can absorb CO_2 & O_2 . P_3 contains cuprous chloride in liquor ammonia. It can absorb CO_2, O_2 & CO .

Hence it is necessary that the fuel gas is passed first through the pipette P_1 , where CO_2 is removed then through P_2 , where O_2 will be removed & finally through P_3 where only CO will be removed. The whole apparatus is readily available in compact wooden cabinets. The orsat apparatus is simple and easy to work. It gives valuable information for regulating combustion in furnaces. If there is a large amount of free O_2 it shows a large excess of air. Both CO & excess O_2 should not be present together.

Fuels

bottle to two-thirds with water
orange to the liquid in the le
noting of the burette reading.

Take out the rubber stop
three absorbent solutions in
openings at the back until
stoppers.

Close the stop-cock 'a',
sphere. Raise the aspirator
water but does not enter the
stop-cock 'd' and open the
Now, water from the burette
from the apparatus which is
pipette, P_1 , the back limb of
the solution in P_1 starts risin
 M_1 , close the stop-cock 'a'.
pective absorbent liquids, by

Test the apparatus for
cock 'd' to atmosphere and
by raising the aspirator L
whether the level of the
aspirator L is kept at higher
in the water level in the bu
air tight.

Now, proceed with th
'd' to the atmosphere and
with water. Connect the st
glass wool U-trap of the ap
ing and lower the aspirator
burette. Again open the st
the gas out by raising L. I
that all the air in the app
burette completely with th
the atmosphere and carefi
of the water in it is same
mark. Now, the burette h
pheric pressure. Now clo
'a' and raise the aspirator
contains the KOH solutio
back in the burette. Send
the same procedure and
complete absorption of C
lower the aspirator L till
mark, M_1 and then clo
water in the burette B, a
decrease in the volume o
present in 100 ml of th
of O_2 and CO present in
ing the experiment and
tes P_2 and P_3 .

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