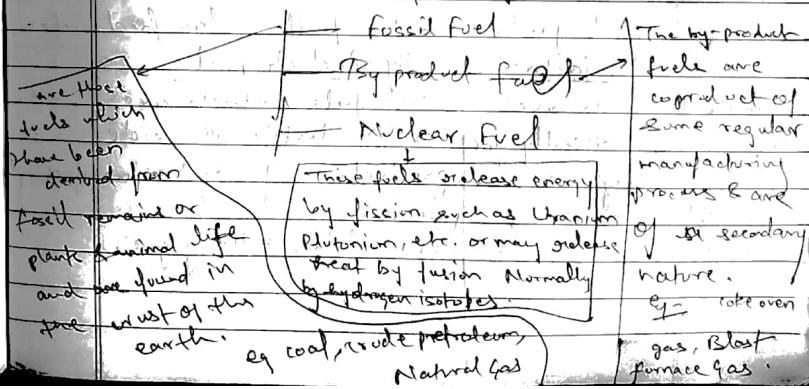


fuel - It is a substance which produce heat. Heat may be produced either by combustion or by nuclear fusion/fission.

Furnace - It is an equipment used to melt metals for casting or to heat materials to change their shape or to change the properties in case of heat treatment or used to extract metals by oxidation/reduction

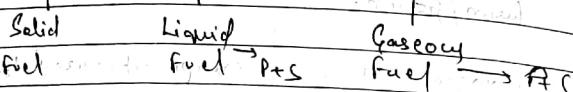
Refractory - Materials which can withstand the action of abrasive or corrosive liquids, liquids or gases at high temp. Such a material is called Refractory.

General Classification of Fuel



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Classification based on its occurrence



Fuels of each above category are further classified as primary & secondary fuels.

Primary fuels - Those fuels which occur in nature such as coal, wood, petroleum, Natural Gas

Secondary fuels - those fuels which are derived from primary fuels such as gasoline, kerosene, coke oven gas, producer gas.

Secondary fuels can be further classified into

Manufactured & By-Product fuel

Those fuels which are specifically for some purpose.

e.g. coffee, gasoline,

producer gas

Those fuels which are co-production or side production of regular manufacturing process.

e.g. coal tar, refinery gas.

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Solid fuels - There are solid materials used as fuel to produce energy and provide heat released through combustion. It includes wood, coal, peat, charcoal.

Liquid fuels - There are in liquid form. Most of LF are derived from fossil fuels, however there are other types of fuels which are called Synthetic Liquid Fuel such as biodiesel, ethanol.

Gaseous fuels - They occur in gaseous form. The most common type of gaseous fuels are NG which are mostly composed of H/C like methane, propane, Hydrogen, CO or their mixture.

Biofuels - These are derived from biomass. It can be solid, liquid or gas. It can be produced from any carbon source that can be replenished rapidly.

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- Merits of Solid Fuel -**
- (1) It is cheap & easily available.
 - (2) It occurs widely.
 - (3) Very easy to handle.
 - (4) No complicated burning mechanism is needed.
 - (5) No special provision to be made for storage like tankers, pipelines.
 - (6) It can be pulverised with flexibility of liquid fuels.
 - (7) Sulphur is comparatively less resulting into reduced atmospheric pollution & corrosion of equipments.
 - (8) Coal ash is free from vanadium which forms corrosive deposits on heat pressure parts of the boiler.
- Limitations or Demerits of SF -**
- (1) Coal deteriorates during storage causing reduction in size & calorific value.
 - (2) It is liable to undergo spontaneous combustion & catch fire during storage.

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- (1) enough space is required for storage.
- (2) It has a clinkering problem in ash & heat is wasted because of that.
- (3) There is a dust nuisance during handling, transportation.
- (4) A lot of labour force is required for moving solid fuel.
- (5) Ash causes further problems
 - (1) Fly ash reduces furnace boilers ability to radiate & erodes super heaters & economiser.
 - (2) Ash handling is a dirty expensive operation, requires lot of space.
 - (3) Coal firing causes heavy wear & tear on grates & refractory lines.
 - (4) Ash reduces drafts on furnace.

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Merits of liquid fuel -

- (1) for equal heat output, LF occupies much less space & has less weight than SF.
- (2) It has slow ash ~~set~~ and clinkering problem.
- (3) Can be handled easily with less labour.
- (4) Oil burner can be designed to burn efficiently over a wide range of heat output.
- (5) Sudden heat demands are met with oil than coal.
- (6) The combustion of LF can be regulated easily.
- (7) Oil can be burned at higher combustion rate, except in the pulverised coal.
- (8) It requires lower amt. of fresh air than SF, resulting in higher thermal efficiency & flame temperature.

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LF can be used in IC engines, it is not liable to spontaneous combustion & deterioration during storage like coal.

- (9) Limitation -
- (1) Special provision for storage like tanks, heaters, lagging of pipelines are needed.
- (2) Risk of fire and explosion during storage or usage exists.
- (3) Vanadium compound present in oil forms corrosive deposits on ~~hot~~ ^{higher} pressure parts of the boiler.
- (4) Sulphur in most of petroleum oil ~~are~~ high compared to coal hence atmospheric pollution & corrosion is a problem.
- (5) Because of comparatively higher H_2 content in liquid fuel than coal, a greater portion of gross calorific value of oil cannot be utilized.

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Merits of Gaseous fuel

- (1) It has ~~SO~~ ash & no clinkering problem, burning in a bushing is quite clean without smoke.
- (2) Requires least amt. of excess air for complete combustion & have high efficiency.
- (3) It is easier to maintain oxidising or reducing atmosphere inside the furnace in case of gaseous fuel.
- (4) It can be used in IC engines.
- (5) It can be easily transported by pipelines at lower pressure drop thus require low pumping power.
- (6) Can be prepared at central place & distributed through pipelines.
- (7) Sulphur compounds from the gas can be removed easily.

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Limitations -

- (1) It occupies larger volume, hence storage is difficult & expensive.
- (2) Some gaseous fuels are highly poisonous and explosive in nature, hence very careful handling is required.

Fuels

General Division	Prime Fuel	Secondary Fuel	
		Manufactured fuel	By-product fuel
(1) Solid	coal, wood, peat, dung	semicoke, coke, charcoal, briquettes, pulverised coal	cokebreeze, wood refuse, charcoal
(2) Liquid	Petroleum	Petrol, alcohol, kerosene, LSHS, Naphthalene, vegetable oil, ethanol	Tar, pitch, benzal
(3) Gaseous	Natural Gas	Producer Gas, Water Gas, Coal gas, LPG, Gobar Gas, Reform Natural Gas,	Blast furnace gas, coke oven gas, refinery gas, LD Gas

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Coalification (Coal Metamorphism)

The process of conversion of peat or lignite to anthracite coal is called coalification or metamorphism of coal.

Peat → Lignite → Bituminous → Semi-Anthracite

1. $\frac{1}{2} \times 10^3$ kg/m^3 $\times 10^3$ m^3 $\times 10^3$ J/kg
= 5×10^{12} J

Anthracite coal
(Highest Rank)

Carbonisation of Coal — Heating of coal in absence of air at high temp. to produce residue coke, tar and gas is called carbonisation.

Gasification of Coal - Heating of coal with insufficiently less quantity of air plus steam to produce a gas rich in CO and H_2 is called Gasification. This is used to produce gaseous fuel from solid and liquid fuel.

Caking of coal and Coking of coal - when powdered coal is carbonised, it forms an expanded lumpy mass, in some cases such coals are called caking coals. This process is known as caking of coal.

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when the residue after heating is very hard & strong, it is called coke and this process is known as coking of coal.

Non-coking coals - The coals whose carbonization doesn't use to form lumpy mass. such coals are called Non-coking coals.

Rinse Run of Mine :- The crude coal as obtained from mine is called ROM coal.

As Received coals - During the transportation of coal from mines to consumers, a lot of physical and chemical changes occur. Such coals which are ultimately obtained are known as called As Received coals.)

As Received coke and air dried coke are same.

Dry coal - to on the effect of moisture on analytical data is to be completely eliminated, then the coal analysis is called Dry-basic analysis.

Dry ash tree cook (d.a.f.) is also a method.
In this case, effect of ash and moisture is eliminated in the analytical data.

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Any mineral matter free coal (d DMMF)
 In high ash coal, the ~~mineral~~ matter content is ~~more than~~ ~~ash~~ around 10% more than ash content whereas in low ash coal, mineral ~~matter~~ can be considered equal to ash content of coal.

Mineral-metal free - It effect of mineral metal present in coal can be eliminated in reporting data, we call it - mineral metal free analysis (but it includes moisture).

Preliminary Analysis and Ultimate Analysis of Coal
 It means finding out the wt. % of moisture, volatile matter, fixed carbon and ash in coal. The analysis gives the approximate composition of ~~mineral content of coal~~ coal free from moisture and inorganic constituents. This gives elementary constituent of coal & useful in deciding its utilization in specific purpose. Very useful in designing coke oven and other industrial equipments and its auxiliaries.

Combustion - It is an exo. chemical P^r of fuel with oxygen or air at high temp. to liberate heat.

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Calorific Value (CV) - The quantity of heat in kcal liberated by the combustion of unit quantity of fuel is called its CV. Unit is ~~unit~~ kcal/kg. For solid & liquid fuel, and kcal/Nm³ for gaseous fuel.

Gross CV - It is defined as total amt. of heat liberated when 1 unit of the fuel is burnt completely and the combustion products are cooled down to room temp. In this case, latent heat of condensation of steam also get included in the measured heat as H₂ present is converted to steam.

Net CV - It is defined as amt. of heat liberated when 1 unit of fuel is burnt completely & the combustion products are allowed to escape.

Net CV = Gross CV - Latent heat of condensation of steam

Origin of Coal - All coals are of vegetable origin and are remains of prehistoric forests. The factors of time, depth of beds, disturbances of beds, press. and Temp. and intrusion of mineral metals, resulting from such disturbances have resulted into transformation from vegetable fibres to hard coal.

Lignite - is 1st stage of coalification product. It's colour is brown to black. It is friable and occurs in thick seams upto 20 m near earth surface. Moisture is ~~upto~~ about 60%. & CV is around 6000 kcal/kg. It is non-coking coal & burns with bright but slightly smoky flame with moderate heat. On exposure to the atmosphere, brown colour of lignite darkens & moisture content reduces to about 10-20%. On drying, lignite shrinks & breaks up in irregular manner. Hence it is difficult to transport away from mine. It is lightly to ignite spontaneously as it absorbs O₂ from atmosphere immediately hence lignite should not be kept in open.

The major deposits of 'L' in India is in Tamil Nadu (Nawali) and in Gujarat (Waran Shah), in Rajasthan (Palani & Kheri), in Kashmir valley (Nichaham).

Sub-bituminous - This coal is black, homogeneous & smooth mass having high moisture & VM content which breaks into smaller pieces on exposure to air. C content is around 70-80%.

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Sub-bituminous - Coal is around 10-20%. It is non-coking coal. It has CV in around 7000 kcal/kg. like 'L', this coal also disintegrates on exposure to atmos. & is difficult to handle port. It ignites very easily & it is used for steam generation & gaseous fuel production. They are mostly found in Assam, Rajasthan & very few at Kashmir valley.

Bituminous - This coal is black & brittle inure ignites & burns readily with yellow smoky flame. It is denser & harder than 'L' and 'SB' coal. It does not disintegrate on transportation. It has low %M, less than 10%. C content varies from 75% to 90%. & VM varies from 20 to 45%. Depending upon VM content, it is categorized as low volatile coal, medium VC & high VC. CV of ash free is around 7000 kcal/kg. Most of coking coals are bituminous coals only.

Aromatic - It is used for coking for steel making plants,

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power generation, gasification & for domestic heating. Some 'B' coals are also non-coking & they are used for other than coke-making process.

The coking & coking coals form sub-grp. of bituminous coal only. Out of Indian coals found 80% coals are non-coking & out of remaining 20% coals, only 4% is coking coals.

Coals of upper & lower seams of Jharia and upper & lower Karbagwari seams of Giridih are sole deposits of coking coal.

Some coals like dieselguri seam in Panigrahi area, Mahuda in Jharkhand and Petakumri in Assam are highly coking but do not possess high coking properties.

Application

Bituminous coals are used in combustion of domestic ovens, industrial furnaces, boiler, thermal power plants, apart from carbonisation & gasification.

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A typical analysis of Bituminous coal

VM → 20-45% FC → 50-92%

O₂ → 0.5 to 1.5% N → 1.5 to 2.5%

H₂ → 4 to 6%

CV → 7500 to 8900 kcal/kg

Coke. Its properties are (W.W) 'B' and 'A' coal. It is harder than most mature 'B' coal and ignites more easily than 'A' coal. It gives short flame changing from yellow to blue. W.W is 8500 to 8900 kcal/kg, V.D.R is 10-15% & M is 1-2%.

It is non-coking. It is not found in India.

Anthracite is the most mature coal and it has highest ranks. It is very hard & non-coking & burns without smoke with short non-luminous flame.

'C' is 85 to 95%, CV → 8000-8500 kcal/kg,

H₂ → 2.8 to 3.9%, VM → close to 10%

and M → 2-4%. It does not swell

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when burn. It ignites with difficult
because of low V.M. Although highest rank
its CV is lower than bituminous because
of low H₂ content. It is non-coking.
The true A' coal is not found in India.
However, lignite coal found in
Saharan & Jharia Coalfields of
Jharkhand have some deposits.
approaching to the quality of anthracite.

App.
It is used in boilers for steam
production, metallurgical furnaces &
domestic ovens.

Proximate analysis is a physical characteristic
to find out moisture, V.M., FC and
Ash in coal. PA helps to predict
how coal should behave when
handled and burn. The 4 major
characteristics are major in PA
RA, V.M., FC & Ash and it can be
done by simple apparatus in laboratory.

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Moisture
Principle

M?

Loss in wt. of coal caused by heating of
wt. of quantity of coal & sample for 1 hour
at 105°C in the 'n' content of coal.
A known amt. of finely powdered coal
sample is kept in a silica crucible
& heated in a muffle furnace at 105 to
110°C for 1 hour.

~~Then after~~, crucible is taken out,
cooled in a desiccator and then weighed.
The process of heating, cooling & weighing
is repeated a no. of times till a
constant weight of coal is achieved.

$$\% \text{ M} = \frac{\text{wt. of coal sample}}{\text{initially taken}} \times 100$$

V.M.: V.M. is loss in wt. of M free powdered
coal when heated in a silica crucible,
fitted with cover in a muffle furnace
at 950°C for 7 minutes.

$$\% \text{ VM} = \frac{\text{loss in wt. of moisture (M) free coal}}{\text{wt. of M free coal}} \times 100$$

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 After removing the coreg from the crucible - is removed.
 & crucible is heated over the bunsen burner at 750°C until constant wt. is achieved that means all carbon will be burned. The residue is weighed which is the combustible ash.
 $\text{Ash} \% = \frac{\text{wt. of residue ash formed}}{\text{wt. of coal initially taken}} \times 100$

and

$$\text{FC} \% = \frac{100 - \text{M} \%}{\text{V} \% + \text{A} \%}$$

~~FC + NM~~ = Heating value of coal

Ignition property
of the coal.

Ultimate analysis
of coal
 In the VA there are
 C, H, S, N, O

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

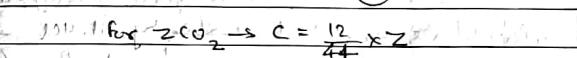
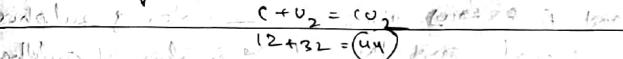
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 (23)
 carbon - A known amt of coal is burned in a current of dry oxygen thereby converting C ~~base~~ of coal to CO and H_2 of coal to H_2O i.e. $\text{C} + \text{O}_2 \rightarrow \text{CO}_2$
 $\text{H}_2 + \frac{1}{2}\text{O}_2 \rightarrow \text{H}_2\text{O}$
 The product of combustion is passed over weighed tubes containing anhydrous CaCl_2 and KOH . The increase in wt. of CaCl_2 represents the wt. of H_2O formed. The increase in wt. of KOH indicates wt. of CO_2 formed.

Suppose x = quantity of coal - example

increase in wt. of CaCl_2 tube

z = increase in wt. of KOH tube

wt. of carbon:



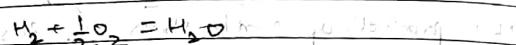
so, % Carbon in coal = $\frac{12}{44} \times z \times 100$

Method of finding heating value of coal

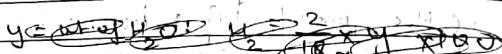
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Hydrogen content:

x = quantity of coal sample
 y = increase in wt. of CaCl_2 tube (wt. H_2O)
 z = increase in wt. of KOH tube (wt. CO_2)



$$2 + 16 = 18$$



$$\therefore \text{H}_2 \text{ in coal} = \frac{2}{18} \times y \times 100$$

of sulphur
 For sulphur, take a known quantity of coal
 coal is burnt completely in a bomb calorimeter
 in a current of O_2 , everything will be burnt

and Ash thus obtained containing sulphur of coal and this will be in form of sulphate which is extracted by dil. HCl and acid extract is treated with BaCl_2 soln to precipitate sulphate as BaSO_4

let x = wt. of coal sample taken

y = wt. of BaSO_4 precipitated

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$$\text{Sulphur in } \text{BaSO}_4 = \frac{32 \times y}{233 \times x} \times 100$$

Nitrogen content in coal (Kjeldahl's method)

A known wt. of powdered coal is heated with concentrated H_2SO_4 in presence of potassium FeSO_4 & CuSO_4 in a long-necked flask called Kjeldahl's flask thereby converting Ns of coal to ammonium sulphate & after the treatment when the clear salt is obtained i.e. all N_2 is converted to $(\text{NH}_4)_2\text{SO}_4$. This is treated with NaOH

NaOH soln. The NH_3 released and the $(\text{NH}_4)_2\text{SO}_4 + 2\text{NaOH} \rightarrow \text{Na}_2\text{SO}_4 + \text{NH}_4\text{OH}$ thus formed is distilled over an absorbed known quantity of H_2SO_4 . The vol. of unused H_2SO_4 is determined by titration, titrating against standard NaOH soln. And thus the amt. of acid neutralised by liberated NH_3 from coal is determined.

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$$\% \text{ N}_2 \text{ in coal} = \frac{\text{Nol. of acid used} \times \text{Normality}}{\text{wt. of coal taken}} \times 100$$

$$\% \text{ of O}_2 \text{ in coal} = 100 - \left(\frac{\text{carbon}}{\text{C} + \text{Ash} + \text{H}_2 + \text{S} + \text{N}_2} \right) \times 100$$

Coking coal - are those coals which have coking properties that make good coke suitable for metallurgical purpose where coke is burnt without coal the burden of coke and flux above it.

Coking coals are classified as:

(1) Prime coking coal (PCC)

(2) Medium coking coals (MCC)

(3) Weak coking coals (WCcC)

~~Under general classification, Coals having coking index more than 24 are PCC and coking index b/w 12 to 23 are MCC and index less than 12 are WCcC.~~

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Coal Reserves in India

As a result of exploration carried out upto to the max depth of 1200m by GSI, CMPDI, SCCL, MECL a cumulative total of 319.02 billion tonnes geological resources of coal have so far been estimated as on 1/4/2018

The Coal Reserves

	Proven	Indicated	Inferred	Total
Gondwana Coals	148194	139065	30174	317433
Tertiary Coals	594	99	895	1588
Total	148787	139164	31069	319020

The coal resources of India are available in older Gondwana formation of Peninsular India and younger Tertiary formation of North Eastern Region. Based on the result of regional or promotional exploration where bore holes are placed b/w 1 to 2 km apart the resources are classified into proven, indicated, and if inferred category.

Subsequent detail exploration in selected blocks where bore hole are less than 400m apart upgrades resources into more proven category

Types & category wise coal produced in India as on 1/4/2018 : -

Type of coal	Proved	Indicated	Inferred	Total
PCC	4649	664	NIL	5313
MCC	13914	11709	1879	27502
Semi coking	919	995	193	1707
Sub Total	19082	13368	2073	37522
Brown coal	129112	125697	28101	282910
Tertiary coal	5945	4999	890	1588
Grand Total	148787	139164	31069	4319024

Storage & Stacking of coal -

Why we store the coal?

Decrease in demand of coal in market

To be ready for ~~water~~ bottle neck caused by shippage which may occur in production.

(3) To meet consumers demand without interruption

(4) To decrease moisture content of coal.

(5) To feed thermal power stations continuously with coal of specified properties.

(6) To minimize defects which may occur in working plant. (power plant).

Problems faced during storage -

Freshly mined high volatile coals when stored in bulk undergoes low temp. ~~oxidation~~ atmospheric oxidation due to presence of methane rather volatile matter on the surface. This exothermic oxidation causes

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rise in temp of coal and if the heat generated is not removed, a stage will come when coal begins to burn. This phenomenon is called Spontaneous Combustion.

low temp. atmospheric oxidation

↓
burning of coal

↓
Spontaneous Combustion

and this SC may lead to outbreak of sudden fire in the coal heap and if the temp. rise due to oxidation does not exceed a critical value.

For lignite coal, critical value for SC → 100°C
For bituminous coal, 80°C

It will affect the quality of coal even though the critical value has not reached.

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SC occurs usually within 1-4 months of ~~mine~~ mining. Coal already stored for longer than 6 months with exposure to air are not usually liable for SC

Losses liable to occur during coal storage
① Oxidation Loss of Coal - the moment coal is mixed out, it starts absorbing Oxygen from atmosphere and this affects deterioration in the coal quality

② Wind Loss of Coal - Due to blowing of wind, it has been seen that a lot of coal is lost

③ Carpet Loss - Storing coal on the ground causes mixing of bottom coal with soil and this causes CL.

④ Losses due to Spontaneous Combustion - Due to SC, considerable amt of coal is lost.

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Safe Storage

Here are ~~the~~ the guidelines -

- (1) Removal of coal dust - Dust to be separated & disposed off as early as possible.
- (2) Ventilation - Ventilation to be reduced by compacting the coal.
- (3) Location - Storage area should be away from external source of heat.
- (4) Height of coal heap - Height of heap should ~~not~~ not be more than 3m.
- (5) Conical heap - Conical heap of coal to be avoided. It increases the exposed area and promotes entry of fresh air into heap.
- (6) Smaller heap - The dissipation of heat in smaller heap is faster & hence, a no. of smaller heaps are preferred.

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- (7) Flow of Stock - the stationary coal to be moved out fast to common to make room for fresh coal. Storage of coal for longer period should be avoided.

- (8) Pod test - At least once a week, the temp. in the different places in the coal stock should be observed by pod test upto 2m ~~test~~ depth.

- (9) Fire Hydrant - Point should be provided near the stock.

Precaution -

- (1) If there is a fire ~~in~~ in the heap, we should drench the burning coal with lot of water. Sprinkling of H_2O to be avoided as it may form CO and H_2 .

Solution → The floor should be concreted.

(2) To prevent entry of air to the coal stock, sides of heap should be tightly packed by building wall. Normally, the coal stack height should be 2m for mixed size, upto 5m for sized coal and 6m for sized hard coal and upto 9m for anthracite coal.

Preparation of Coal - coal

The technology of coal preparation is applied to produce specific desirable coal products from the Run-of-Mine coal without change of the physical identity. This results in high economic value of ROM coal.

The purpose of coal preparation is to improve the quality of coal by cleaning to remove inorganic impurities i.e., mineral matter & sizing for further handling process combustion & reduction requirement.

relative density, friability, hardness of different elements in the coal matrix are key parameters for mechanical cleaning or washing for preparation.

The specific gravity of coal ranges from 1.23 to 1.72 depending upon rank of coal, moisture & ash content.

mineral matter within coal matrix have higher specific gravity & this quality is employed in various washing & separation technology.

Coal preparation includes blending and homogenization, step reduction, grinding, screening and handling. The most important step in the coal preparation is coal washing or beneficiation.

The cost of coal preparation depends upon method used & also on the

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degree of beneficiation which is greatly determined by market demand.

The coal preparation process

The typical steps in coal preparation of are -

Crushing



Scalping



Destoning



Sizing



Washing



Dewatering



Thermal drying



Blending

(a) Washing of coal represents the most important

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The main objective of coal washing is to recover products of some specified quality as required by the customer & these objectives are -

- (1) Washing reduces ash content.
- (2) washing " sulphur & phosphorus content as these are required by metallurgical coal.
- (3) Washing increases the CV.
- (4) washing also improves Coking property of coal.
- (5) It increases fusion pt. of ash.
- (6) It reduces clinkering tendency of coal.

~~Principle of washing~~

- The specific gravity of pure coal varies from $1.23 - 1.72$ and that of the mineral matter from $1.34 - 1.79$ $1.7 - 4.9$

If the avg. SG of pure coal is 1.3 and it is suspended in a liquid called washing medium of SG 1.5 then the impurities being heavier will sink in it. whereas the pure coal will float. thereby the

SG = Specific Gravity

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pure coal & impurities can be separated by using this difference in SG

~~Procedure~~

(W.C.)

The washability characteristics of coal is the most important step or criteria to determine the extent to which a coal can be cleaned. The ~~wash~~ W.C. is ascertained by float-sink tests.

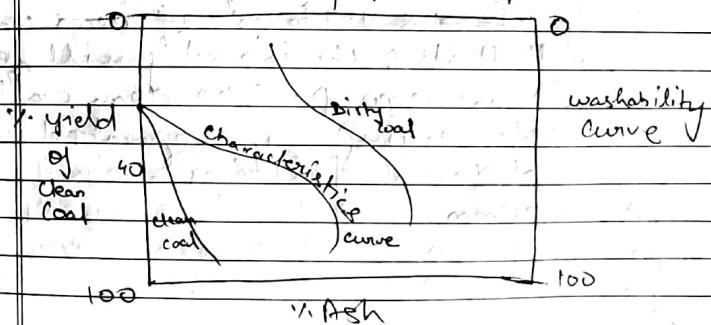
Liquids of different SG from 1.3 to 1.8 increasing in steps of $\frac{1}{10}$ are prepared either by mixing organic liquids in different proportion or by making inorganic solutions of different concentrations. In industry normally, suspension of fine ground coal or magnetic ore in H_2O are used. In lab, organic mixtures of C_6H_6 or salt of ZnCl_2 are used. These liquids are taken in tall jars and arranged in the order of increasing SG . The coal sample of particular ash content & size fraction is first used in the lowest SG liquid.

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The coal fraction lighter than the liquid floats & heavier will sink. The portion which floats on a particular SG is known as float fraction at a particular SG & the portion which sinks is known as sink fraction at a particular SG .

This is then placed in a next higher SG liquid. Here again, float & sink portion will be separated. like this float fractions and weighed. Float & sink fractions of diff. SG are collected from all jars and weighed separately. P.A. of ash are carried out for all float & sink fractions, mostly for ash and the data collected are tabulated and graphs are plotted:-



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Float & sink characteristics of a particular size fraction of coal are obtained in laboratory. For this, it is necessary to have representative sample of coal ~~as per size~~ with specific top size and the crushed top size is determined by market demand.

~~Dry & wet~~
~~washing~~

In DW, run-of-mine is crushed & screened ~~& coal size~~ above 75 mm size is crushed to size less than 75 mm of size and the crushed & screened coal is feed to a Barn-Jig Washer having a slurry of sand & water of SG. ~~+ 1.7 to 1.8~~ clean coal will float & the impurity will settle and are removed. The clean coal after drying is separated in 3 different fractions

- (1) 25-75 mm
- (2) 6-25 mm
- (3) -6 mm

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Coal below 6 mm is not washed further as it has lower ash content. The other 2 fractions are further washed in a slurry of SG 1.5 which gives an yield product of clean coal ^{drying} 17-19% ash, coal middling 17-35% ash and rejects more than 50% ash, 35-50% ash

Post
washing
Treatment

→ washed coal is associated with considerable moisture. The ~~coarse~~ constituent fraction of coal are dewatered by oscillating screen ~~the~~ or drainage banks ~~the~~ the final fraction which forms elutriation are dewatered by thickness & filters

Blending - is defined as the integration of a no. of raw coal from diff. sources with diff. physical or chemical properties to create a required specification or blend. The aim is to achieve a fixed product from 2 or more coal types

DATE _____

obligations
Agglomeration



that has a well-defined chemical composition in which elements are evenly distributed.

Objective: Depending upon the target blending of blending if this operation can be employed to

- (1) to reduce the fuel variability.
- (2) to combine different raw coals into useful fuel products.

The coal blending is being used by growing no. of consumers to gain more control of fuel characteristics while maintaining the fuel cost.

Blending can be resorted into 2 types -

- (1) Bed Blending
- (2) Belt Blending

Bed Blending :- Coal is sequentially layered by a travelling linear stacker. Each subsequent layer completely covers the previous

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Conveyed belt
blended

layer. Thus forming a V-shaped cross-sectioned pile. These multiple layers are simultaneously re-claimed from base of stock pile to the surface. Thus, variability of all layers is thereby blended by each re-claimed slice of cross-section.

Belt Blending: Bed Blending provides a reliable & repeatable methodology to reduce the variability of coals. These methods are normally employed in coal plants.

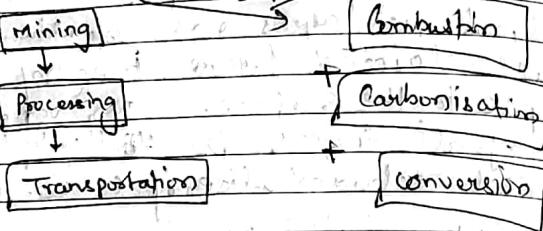
Belt Blending: Belt Blending combines the characteristics of 2 or more diff. grades of coal. Each grade is individually stock piled and physically segregated. During re-clamation, these stock piles are proportionally combined most commonly by either volume or by weight. For this, weighing feeders or weigh beams belt scales are used.

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Application of Coal -

3 applications

Pathway



Combustion - Combustion involved burning of coal in air to liberate thermal energy i.e. heat. The heat is used as such for domestic comfort or to carry out many industrial processes that require high temp. It is also used to generate steam for use in power plant boilers for production of electricity.

Carbonisation - It is heating of coal to high temp in absence of air for production of coke for metallurgical industry.

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Conversion - It uses various chemical processes to transform coal into gaseous or liquid fuels called synthetic fuel like biodiesel, GTL.

Uses of Coal -

generation
for electricity - 68% of coal is used
for Iron and Steel - 7%

Cement - 4%

Other industries - 8%

Heating - 3%

Other uses - 10%

① Generation of Electricity - Coal is pulverised and combusted in a furnace i.e. boiler to produce high press. steam which is used to spin turbines and in turn, turbine produce Electricity through turbo-generator.

② Conversion to produce metallurgical coke to be used in BF as reducing agent & also as a fuel -

valuable
Some carbonisation process produce
~~valuable~~ by-product like coal tar
 NH_3 , ~~light oil~~, coal gas; ~~gasification~~

(3) Coal Gasification - It is used to produce synthetic gas which is a mix of CO , H_2 and N_2 . The synthetic gas can be converted into transportation fuel such as gasoline, diesel.

(4) Liquification - Coal can also be converted into synthetic liquid fuel which is equivalent to gasoline or diesel by conversion process.

(5) Production of Chemicals - NH_3 and urea are product of coal to chemical process for use in fertilizer.

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Coke Making

- (1) Beehive Coke making
- (2) By Product coke making

75% \rightarrow BF

The caking behavior of coal is critical to coke making as caking coal if heated in absence of air/oxygen, it passes through the regions where it becomes very plastic & soft and after that, it swells and then re-solidifies. The re-solidified residue is cellular coke mass. Non-caking coal on heating do not form any coke but will simply form a non-coherent ~~char~~ char.

In the coke making process, bituminous coking coal is fed into a series of ovens which are shield and subsequently heat at high temp. of about 1200°C in an oxygen deficit atmosphere. Typically in a cycle lasting for 24-36 hours.

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Beehive Coke Making

~~Plants~~ Beehive coke ovens are called due to the beehive shape of sh. of ovens in the coke battery. These are non-masonry type in which there is no provision for recovery of various valuable products from coke oven gases. All coke oven gases are burnt off to the atmosphere as flue gas and coke breeze and coke are only by-product in these type of plants.

coke	25 to 80 mm	→ BF coke
	15 to 25 mm	→ pearl coke
	0-15 mm	→ coke breeze

Coke ovens are made of fire bricks with an arched roof having a shape of beehive. There is a circular opening at the top for coal charging & the opening for releasing the flue gas out of ovens. There is a side door through which coke is discharged after cutting.

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Typical dimension: height is 2m, base diameter 3.5m and capacity → 5 to 7 tons of coal.

~~process~~ Heat for carbonisation is supplied by burning of VTM or coal and partly by coal itself. Evolved gases burn with the air introduced through an opening at the top of closed door. The carbonisation process starts from the bottom of coal charge. At the end of carbonisation, the door is opened & coke is quenched with lot of H_2O & then removed manually or by machine.

Units in Beehive coke oven Plants

(1) Washing facility

Input -

(2) Crushing & Screening Facility (0-6 mm coal)

(3) Feeding & Charging Facility

(4) Carbonisation

(5) Discharge & Quenching

For coke
Crushing & Screening

25 to 80 mm → BF coke
15 to 25 mm → pearl coke
0-15 mm → coke breeze
↓
G-15 Nut coke

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Merits & Demerits

Merits

- (1) Strong blocking coke having ~~good~~ ^{good} reactivity are produced.
- (2) It produces hard coke for foundry.
- (3) Beehive oven is low capital & low operating cost.
- (4) Coke oven can be shut down without any damage to refractory.
- (5) Simple to construct ~~the~~ beehive oven.
- (6) No extra fuel required for heating up in case of by-product ovens.

Demerits

- (1) No by-product recovery.
- (2) Lower coke yield due to partial combustion of coal.
- (3) Blend of inferior coal cannot produce ~~good~~ coke.
- (4) Lack of flexibility of operation.
- (5) Long coking time upto 2-3 days. Hence production rate is low.

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- (6) Beehive CM is obsolete in India. However, in North eastern region, there are under operation.

Pollution in beehive COP

The coking process emits various air pollutants like particulate matters, volatile organic compounds (VOCs), polynuclear aromatic Hydrocarbons (methane, CO, H₂S, and NH₃, etc.). Besides SOX and NOX

In non-recovery beehive plants, the above pollutants are released to the atmosphere directly.

These coke oven plants are considered to be major air pollution industry. Most of these plants

still operate without any air pollution control measures. Some of the BOP have been installed with wet scrubber before the gas are released to the atmosphere.

These measures have been effective in such coke making plants in controlling emission or controlling pollution.

Guidelines by Government

Pollutants

New Units	PM ₁₀	Emission Limit 150 mg / Nm ³
Exist in Plant	PM ₁₀	Emission Limit 350 mg / Nm ³

- (1) Unit setup after 2nd April, 1996 are considered as new plants.
- (2) A m/f stack height of 20m shall be provided in new units.
- (3) Emissions from coke oven plant will be channelled through a tunnel and finally emitted through a stack.
- (4) The ~~the~~ ~~nozzles~~ damper adjustment feature shall be fixed to have optimum heat utilisation & also to control emission of unburnt carbon particles & combustion flue gases.
- (5) wet scrubbing facility or make heat recovery system shall be installed in each COP.
- (6) And after 1st April, 2000 all existing units shall have to comply with these guidelines otherwise they'll face the closure.

By product coke oven plant

It consists of a rectangular refractory chamber of length 13 to 15 m, height 4 to 5 m & width 400 mm with removable door at both ends to enable the hot coke to be pushed out with a ~~scrap~~ ram. The width of the coke discharge side is slightly more about 3-4 cm than the pusher side.

A large no of ovens with heating flues in bw is arranged in a battery with regenerators for heat exchange w/ hot flue gas & combustion air placed below. The oven walls are made of silica bricks. The high temp strength of " " ensures also long life for ovens & enables oven walls to be built up thin for high heat transfer rate through them.

Operation
Coking coal blending is introduced by top charging ~~to~~ holes. Each pair of ovens which is separated by a ~~re~~ system of vertical flues can be heated by coke oven gas or mixed gas. Air for combustion is preheated in a regenerator.

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The mixed gas can also be pre-heated but coke oven gas when directly in use cannot be pre-heated as the H/C present in the gas may crack. The flame temp in the heating chamber is maintained at 1200-1300°C & carbonisation time (coking time) for 22 tons weight coal is about 16-18 hours.

Ovens are charged & discharged as per schedule decided to maintain uniform temp. over all oven walls to avoid thermal damage to the battery. Uniform temp. is also maintained by reversing the flow of combustion gas through the flues & regenerators every 30 minutes.

Ends of ovens are shielded with bricks ^{line} close to stop flame or heat coming out from the ovens which will reduce the temp.

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During coking, gas & tar are taken off via an essential ~~ex~~ extraction pipe & passed into gas collecting main called hydraulic main.

The coke ~~out~~ when fully carbonised is taken by a ram cart out of the oven into the quenching car & taken to the quenching tower for cooling.

During carbonisation, coal swells ~~at~~ first but shrinks as temp. rises. This puts some press. on walls & ovens. Therefore, should not be pushed until the ^{coal} has shrunk clear of wall.

For this, coal blending should be proper.

Waste heat ovens & regenerative ovens are similar in operation & differ only in the proportion of coke oven gas available for outside use.

BF coke
Pearl coke
Nut coke
Coke breeze

Gross coke yield - 77% of dry coal charge
 BF coke yield - 87% of Gross coke
 Coke oven gas yield - $290 \text{ m}^3/\text{t}$ of dry coal charge
 Ammonia - 3 kg/t of dry coal
 Tarr - 30 kg of dry coal
 Benzol - 7 Lit / dry coal

Coke oven Gas composition

H_2 - 58%	CO - 8%
CH_4 - 25%	CO_2 - 2.5%
C_6H_6 - 2.5%	N_2 - 3.7%
	O_2 - 0.3%

$\text{CV} = 4200 \text{ to } 4300 \text{ kJ/Nm}^3$

Specific Heat consumption - 0.6 G cal / t of dry

Improvement of Coke Quality

- 1) Dry quenching of coke
- 2) Steam charging of coal

Modern coke making Practice

- 1) Dry quenching of coke
- 2) Stamped charging of coal

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- (1) Use of coal Briquets.
- (2) Pre-heating of coal charge
- (3) Blending of coking coal
- (4) Reduction in Ash in coal
- (5) Addition of coking agent
- (6) Use of taller ovens

Dry quenching of coke - Hot coke is discharged from coke oven at over 900°C , about 30-40% of energy consumed in coke making is wasted as sensible heat of waste coke while if it is quenched with phenolic water as the steam generated cannot be used becoz of its highly corrosive nature. ~~therefore~~ Dry quenching of coke aims at ~~recovery~~ the sensible heat of hot coke. In this process, inert gas i.e. N_2 is circulated in a close circuit which takes up the heat of coke & that heat is used to generate steam in waste heat boiler. The coke temp. is thus brought down by N_2 cooling from 900°C to 200°C & finally this quenched by water spray cooling.

About 450 kg of steam per ton of coke can be generated by this process.

Reactant \rightarrow Product
Coal \rightarrow coke

out of which, 50 kg may be consumed for driving inert gas circulation fan & remaining steam can be used to generate power.

Inert gas remaining is used in coke oven plants of RINL, Vishakhapatnam.

Stamping of coal - In gravity charging coke oven plants, coal particles are loosely packed inside oven. In stamping charging coal is first pressed mechanically, and then charged into the oven.

Stamping is a means of increasing the bulk density of coal. SC enables the utilisation of larger proportion of inferior coking coal.

Stamping of high ranks, low fixed coals produce max. improvement in coke quality. 20-30% of non-coking coal can be used by SC process.

By this, coke of better quality is produced from inferior grades of coal. Stamp charge coke is denser & larger in size since about

coke making time.

12-16% moisture is required for binding of coal during stamping hence in SC coke oven, coking time is 15-20% more becos of high moisture & high charge quality.

Parameter	Top Charging Ovens	Stamped Charging ovens
(1) oven charge	100%	130 to 135%
(2) carbonization time	100%	15 to 20% more
(3) coke productivity	\propto	10 to 12% more
(4) increase in B.F. coke yield		4 to 5% more
(5) use of non-coking coal		20 to 25% more
(6) Bulk density of coal charge	0.75 t/m^3	2.10 t/m^3

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use of taller ovens - Most of coke ovens all over the world is 4 to 5m tall. use of taller ovens increases the throughput of oven & hence production rate.

At many places in abroad, 7m tall batteries have been built and are in operation successfully. In India too, 7m tall batteries are working in Vizag Steel Plants and SAIL. They are also installing 7m tall battery. Taller ovens have got horizontal burners.

Pore-heating of coal charge - Pre-heating of CC increases its bulk density, resulting into increased productivity of ovens besides lowering time of carbonisation & also reduction in heat consumption for carbonisation. The coal charge can be preheated by hot flue gas coming out from coke oven regenerators.

The residual heat in the waste flue gas can be recovered to some extent by pre-heating coal charge.

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CV
The pre-heating of CC upto 250°C causes increase in its FC & heating value.

Note -

1. Reductior in coke ash reduces the ~~coal~~ consumption in BF by 20-25 kg/t of hot metal.

use of coal briquets

Addition of coking agents

Low coking power of some weakly coking coals can be improved by the addition of CA like tar, pitch, etc. and it helps in use of non-coking coal upto 5%.

coke quality for BF

The moisture in metallurgical coke should not be more than 1.5%. If 1% additional coke is added in BF will increase the ^{coke in instead} coke in BF will increase the ~~the~~ in metallurgical coke. Ash should be less.

The moisture in metallurgical coke should not be more than 1%. If 1% coke moisture is increased then it requires 1-2% coke consumption. Addition of 1% additional ash will increase 2% coke consumption and slag rate will increase.

How much Hardness & Strength?

The Hardness & Str. of Bf coke can be measured through MIMUM test. MIMUM value M40 should be 80% min.

& M10 value in Bf coke should not be more than 10

50kg of coke of 50mm size is rotated in the MIMUM drum for 4 minutes at the rate of 25 rotations per minute. MIMUM drum is a cylindrical steel drum where length & diameter both are 1m each. Each fitted lengthwise 4 iron rods 10mm by 20mm by 10mm and they are fitted 90° apart. Then ~~reaction~~ after rotation coke fractions are taken out and screened to 60, 40, 20 & 10mm.

Strength of coke during reduction - (2)

Reactivity is defined as ability of coke to react with O_2 , CO_2 & steam. For industrial fuel, reactivity to

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O_2 is most important & for domestic fuel, ease of ignition and high reactivity are important. Formation of CO on the surface of Bf is promoted by high reactivity of coke. For Cupola, high temp. oxidation is large hence ~~smaller~~ unreactive coke in large piece are preferred. Coke of high reactivity ignites easily & gives rapid pick-up of fuel bed temperature. Low reactivity coke gives higher fuel bed temp. than highly reactive coke. Low reactive coke is desired in Cupola operating to produce high hearth temp. and reduce scale, dose reaction. Modern methods of expressing reactivity & strength of coke is (1) Coke Reactivity Index - CRI value, (2) coke strength after reaction CSR value. ~~CRI vs CSR~~ value should not be more than 20% & CSR values should be more than 65%.

~~Coke volatile determination~~

To determine (RI value of coke, 2000) of coke sample of size 20mm to 25mm is taken in a stainless steel tube & heated in an electric furnace to 1100°C . CO₂ gas at 5 kg/cm² pressure is passed through the coke bed for 2 hours. The coke forms by PT with C is burnt in a burner and the gas is exhausted out. Carbon of coke reacts with CO₂ depending upon reactivity level of coke & thereby a loss of wt. of coke depending upon its reactivity. More is loss in wt. of coke, more is reactivity % and thus less in wt. of coke is reported as CPI value of coke.

The Ideal CPI value of coke should be around 20% but it may go up to 28-29%

~~CSF~~
value?

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left over coke from CPI test is rotated for 60 rotations in MICUM screen. 1-8 of coke retained on 10mm screen is reported as CSF value.

Stronger the coke, more is the CSF value.

Ideal CSF value would be 60-65%.

Sulphur in coke should be less than 1% & more sulphur will cause brittleness in steel.

Phosphorus should also be min. More P causes cold ~~softness~~ softness.

Graphitization of coke takes place in the high temp. zone which reduces the abrasion resistance of coke. Graphitization is catalyzed by FeS in coke cause more.

DR process-

- (1) coal based
- (2) gas based

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Liquid Fuel

- (1) Natural Liquid Fuel
- (2) Manufactured or Artificial Liquid Fuel

Natural Liquid fuel - Crude petroleum is a basic Natural LF. It is naturally occurring in deep in earth's crust - or onshore / offshore.

Crude oil is obtained from earth's crust either by natural seepage or by drilling wells to various depths. The ^{average} composition of crude petroleum is -

typical composition of crude/ petroleum	C → 84 to 87%
	H ₂ → 11 to 15%
	N ₂ → 0.1 to 1.5%
	O ₂ → 0.3 to 1.8%
	S → 0.1 to 3%

The crude petroleum is graded acc. to their following properties -

Grading Criteria of Crude Petroleum

(1) Specific Gravity	(6) Moisture & Sediment content
(2) Calorific value	(7) Specific heat or coefficient of expansion
(3) Flash point or Ignition point	
(4) Viscosity	
(5) Sulphur content	

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The chemical nature of the crude ~~is~~ vary to the part of the world in which they occur.

Classification of Crude Petroleum

Depending upon the nature of H/C present in crude, the petroleum is classified as -

- (1) paraffin base type crude oil
(residue left on distillation is paraffin wax)
- (2) Naphthenic base type crude oil
(residue left on distillation contains Naphthenic + a little of wax)
- (3) Asphaltic base type crude oil
(residue left on distillation contains Asphaltic material (Asphalt - looking black like tar))
- (4) Mixed Base type
(residue left on distillation contains paraffin + Naphthenic and some asphalt)

Indian Crude oil is mostly mixed base type containing approx. 40% paraffin, 25% Naphthenic 35% asphalt.

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Manufactured Liquid Fuel -

MLF include gasoline, diesel oil, kerosene oil, heavy oil, Naphtha, lubricating oils.

All these oils are obtained after the fractional distillation of crude petroleum.

Salient features of Refining -

Refining is done through fractional distillation of crude petroleum in a cylindrical fractionating column where pre-treated crude oil is heated in pipes placed in a furnace & vapours are passed from bottom to top. The higher b.p. fractions ~~cool~~ condense towards the ~~upper~~ lower part of column and lower b.p. fractions towards upper part.

The primary distillation is carried out first under atmospheric pressure & recoveries fractionate upto gas oil and residue is then distilled under vacuum & recoveries vacuum gas oil, now ~~raw~~ Lubricating oil ~~and~~ and other products like asphalts, ~~tar~~ and bitumen.

Application Uses of petroleum products -

- (1) LPG → It is used as cooking gas in domestic areas.
 - Used as industrial fuel for heating purpose,
 - LPG is also called refinery gas. It is mainly mixture of ~~methane~~ propane and butane with a small % of unsaturated H/C. It is obtained in liquified form. LPG is also used for cutting, welding and soldering.
- (2) Gasoline/Petrol →
 - It is used as fuel for spark ignition, internal combustion engines, dry cleaning of clothes.
- (3) Naphtha → It is used for production of hydrogen through steam reforming which is in turn used for making nitrogenous fertilizers. It is also used as fuel gas in steel plants. It is also used as a solvent, paint thinner. Sometimes also used ~~for~~ blending with motor fuel.
- (4) Kerosene oil → It is mostly used as domestic illuminant, tractor fuel.

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- (5) Diesel oil - It is used in compression ignition engines.
- (6) Jet fuel - Fuel for aviation turbine engines and jet plants.
- (7) Gas oil - It is gasified for fuel oil production. It is fuel for industrial furnace, used as blend for heavy fuel oil.
- (8) Lubricating oil - It is used as lubricants for machines & engines.
- (9) Petroleumum - Lubricant used ~~as~~ as base material for production of grease.
- (10) Light fuel oil - used as a fuel in industrial furnace.
- (11) Heavy fuel oil - Also used as furnace fuel after blending with light fuel oil or naphtha to reduce its viscosity and increase fluidity & for atomization furnace.

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Characteristics of Liquid fuel

(1) Flash point

Pour point

(2) Viscosity

(3) Knocking

(4) Flash point →

It is the lowest temp. at which liquid fuel can be heated so that vapors form gives off flashes momentarily.

Pour point →

It is the lowest temp. at which the liquid fuel will flow or pour when cooled under prescribed condition. It is very rough indication of lowest temp. at which liquid fuel is ready to be pumped.

Viscosity → It is a measure of its internal resistance to flow. Viscosity depends on temp. and decreases as the temp. increases. It is measured in stokes or centi-strokes. Each type of oil has its own temp.-viscosity relationship.

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Knocking → When fuel air mixture undergoes fast combustion inside the combustion chamber of an IC engine, the rattling sound develops from combustion chamber due to uneven, unsteady & uncontrollable combustion. This sound is called Knocking and is denoted by octane number of fuel.

If an IC engine is operated at high load & slower speed, Knocking results.

- Gasoline
 - Naphtha
 - Diesel
 - LPG
- (Making, Characteristics + Utilisation)

Gasoline Fuel

Synthetic liquid fuel

This is another type of liquid fuel manufactured from coal, natural gas and biomass by synthesis process and is called synthetic liquid fuel. Synthesis is a process which is called conversion process. Important commercially established fuels are

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- (1) GTL fuel (Gas to Liquid fuel)
- (2) DME (Diamethyl Ether)
- (3) Methanol
- (4) Bioethanol
- (5) Biodiesel (BDF) fuel

Application

GTL fuel is normally used in power generation, diesel engine, gas turbine.

DME & Methanol → transportation vehicle, boilers for steam generation, and also as a replacement of LPG.

GTL fuel, DME, Methanol.

They are produced from coal or natural gas through conversion process.

Bioethanol and Biodiesel are produced from biomass.

Conversion processes are →

- ① Indirect conversion
- ② Direct
- ③ Bio fuel process

② Indirect conversion

Fuel $\xrightarrow{\text{synthesis}}$ Gas $\xrightarrow[\text{catalyst}]{\text{conversion}}$ Liquid

Direct conversion

Fuel \longrightarrow Liquid

Biofuel process

Fuel $\xrightarrow{\text{Indirect}}$ Gas \longrightarrow Liquid

Gaseous fuel:-

Gaseous fuels are those fuels which are burnt in gaseous state in air or O_2 to give heat for utilisation in domestic or industrial sectors. A remarkable feature of GF is the absence of mineral impurities, consistency in quality and efficiency in use.

Types of GF -

① Fuels Naturally found in nature -

Natural fuel \longrightarrow Natural Gas
 \longrightarrow CBM (Coal Bed Methane)

② Manufactured Gaseous fuel

\longrightarrow Coal Gas

\longrightarrow Producer Gas

\longrightarrow Water Gas

\longrightarrow BF Gas

\longrightarrow CO gas

\longrightarrow Goben Gas

③ Gases Manufactured from Liquid Petroleum

\longrightarrow LPG

\longrightarrow oil gas

\longrightarrow Refinary Gas

The most commonly used gaseous fuel are Natural Gas, producer gas, water gas, LPG, coal gas, BF Gas & CO gas.

If CV is expressed as kcal/Nm³

Natural Gas - It is a mixture of paraffin H/C in which CH₄ is the main constituent.

It occurs in the gas field under the crust of the earth and is also associated

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with petroleum deposits. It is obtained from well dug in oil bearing regions. After delivery from wells, NG is processed to remove solids. It is then treated for recovery of gasoline & liquefied Natural Gas (LNG). When NG contains very less recoverable condensate, if condensate is less than 15 gm/m³ then it is known as dry NG and if condensate is more than 50 gm/m³ then it is known as wet NG.

The condensate recovered is known as Natural Gasoline which is used as blending for motor fuel.

Dry NG and wet NG

Parameters	Dry Natural Gas	Wet Natural Gas
(1) CH ₄ (methane)	96.91%	77.7%
(2) C ₂ H ₆ (ethane)	1.33%	11.18%
(3) C ₃ H ₈ (propane)	0.19%	5.83%
(4) Other Hydrocarbons	0.07%	3.52%
(5) Other Gases like CO ₂	0.82%	0.8%
(6) N ₂	0.168%	1.39%
Total %	100	100

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wet NG → sweet NG because there is no H₂S

Calorific Value	9000 kcal / m ³	11200 kcal / m ³
CV		
SG	0.574	0.74
Specific gravity		

NG can be liquefied & shipped as LNG and CNG. It can also be compressed to high pressure and cause called CNG used as in transport vehicles.

Uses of NG -

- (1) It is a fuel for cooking in domestic & industrial heating.
- (2) Enrichment of other gaseous fuel of lower calorific value.
- (3) Due to high anti-knocking property, it is used as fuel in IC engines.
- (4) As a fuel in gas turbine.
- (5) Production of synthesis gas for further use for production of methyl alcohol, gasoline or hydrogen for ammonia synthesis.
- (6) For production of CFC by chlorination of methane present

NG is available in India from Gujarat,

Assam & Bombay high oil wells.
Presently, NG lying from Marwar to
Jogdishpur via Bijapur supplies air
to fertilizer plants & thermal power
plants ~~is route~~ which falls in the
route.

(Q8)

Coal Bed Methane - CBM

CH₄ associated with coal in mines
is called CBM.

coal absorbs CH₄ during coalification process.
At the time of mining, CBM is desorbed
or released & it has to be removed
by proper ventilation otherwise it
will cause explosive gas-air mixture.
That's why CBM is recovered by system
through system of drilling operation
and is used as fuel.

Typical composition of CBM -

CH₄ — 93 to 99%

C₂H₆ — 0 to 3%

CO₂ — 0 to 4%

N₂ — 0.2 to 6%

Producer Gas - PG is essentially a mix. of
combustible gases like CO and H₂
associated with non-combustible gas
like N₂ and CO₂. It is produced by
passing air or mix. of air with
little heat steam at 0.35 kg per
kg of coal over a bed hot coal or coke
bed maintained at about
1100°C in a special furnace called
gas producer.

The avg. composition of producer gas is -

CO₂ — 4 to 6%

CO — 20 to 30%

H₂ — 11 to 20%

CH₄ — 0 to 0.3%

N₂ — 46 to 55%

CV — 1250 to 1550 kcal/Nm³

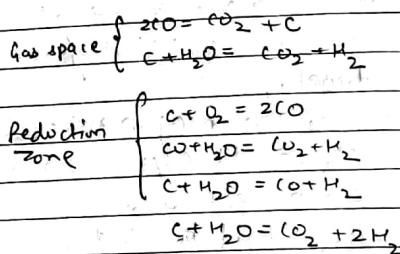
Sp. gravity — 0.85 to 0.9

Requirement of combustion air — 1 to 1.3 Nm³/Nm³ of producer gas

Steam consumption — 0.35 kg / kg of coal

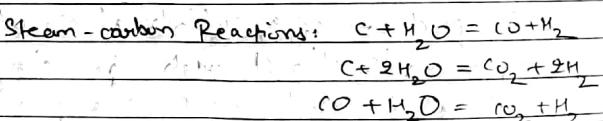
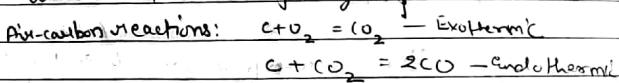
Gas producer is a cylindrical vessel inside
of which is lined with fire-clay bricks.
It is provided with a cup and lance

arrangement for coal feeding at the top & it has a side opening for the exit of producer gas. At the base, it has an inlet for passing air & steam & also the bottom base will be provided with an opening for removal of ash & clinker.



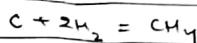
The principle

Principle Chemical Reactions - PCR in producer gas plant using coal & coke as fuel and moist blast for gasification are -



Methanation

Methane Reactions



producer gas process is favoured by high temp. of fuel bed - ensures enough time of contact b/w blast & fuel. The fuel bed should be thick & it should ~~not~~ be reactive.

Factors affecting composition of producer gas -

- (1) Nature of fuel - High volatile bituminous coal gives a richer gas containing a small proportion of CH_4 & gas free of tar.
- (2) Operating Temp. - Low temp. favours production of CO_2 . High temp. favours high production of CO .
- (3) Effect of Steam - Steam in air blast increases proportion of CO & H_2 in gas.
 \therefore CV will be higher but if steam addition is in excess, temp. of gasification will be reduced & more CO_2 will be formed & CO will be less. If steam addition

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If not there, then clinker formation will take place.

Producer gas can be made from ~~any~~ any solid fuel

Utilisation -

- (1) It is cheap, clean and easily can be produced.
- (2) Use for heating open-hearth furnace for production of glass & steel.
- (3) Use for heating of muffle furnace & other gasifiers.
- (4) It can be used as reductant in metallurgical process.

- (5) Can be used for heating of coke ovens.

Water gas

Water gas is essentially a mixture of CO and H₂ with a little fraction of non-combustible gases like CO₂, N₂. It is made by blowing steam ~~alternatively~~ air through bed of red hot coke

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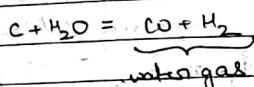
or coal maintained at about 1000°C in a ~~reactor~~ furnace or a vessel or a gas producer inside of which is lined with fire-clay bricks. The ~~reactor~~ has a feeding arrangement at the top & opening at the bottom for discharge of ash. The period of steam blow is usually 4 minutes while the period of air blow is very short i.e. 1-2 minutes. The duration of these periods are adjusted in such a way that the max. yield of water gas is obtained.

Water gas generator is a cylindrical vessel made of steel. It is about 4-5 metres in height & 2-3 metres in diameter. At the top, it is provided with a hopper for feeding coal or coke. Water gas outlet is provided at the top. It has 2 separate inlets for blowing steam & air. At the bottom, it is provided with an arrangement to take out ash.

Operation: During steam blow, water gas is produced & it is allowed to be taken out through water gas outlet. During air blow, N₂ & CO₂ are removed.

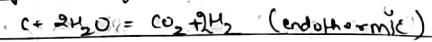
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Some CO may be formed which are allowed to be escaped in the atmosphere & the manufacture of water gas is an intermittent process.



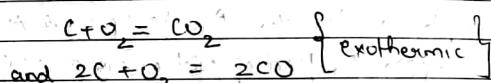
This Rx is endothermic & heat absorbing.

Coal or coke cools down after a few minutes and px proceeds in a different way to form CO & H₂ instead of water gas.



In order to avoid the above Rx —

the current of steam is intermittently replaced by hot air blow & then the px will be



Due to above exo. Rx, temp. rises again. When temp. reaches up to 1000°C, water gas Rx starts and after sometime, hot air blow is stopped and steam blow starts.

composition of water gas

H₂ - 48 to 51%

CO - 40 to 42%

CH₄ - 0.1 to 0.5%

CO₂ - 3 to 5%

N₂ - 3 to 6%

consumption of air - 2 to 2.5 Nm³/Nm³ of water gas

CN - 2500 to 2800 kcal/Nm³

sp. gravity - 0.51 to 0.55

steam consumption - 0.35

This water gas is also called blue gas

Vapour ratio is 1.5 - 1.6

(1) As a fuel gas in furnace

(2) As a source of H₂ for NH₃ synthesis for fertilizer plants.

(3) As an illuminating gas in towns when enriched by adding H/C, it is called carbonated water gas and its CN is very high

Flame Characteristics

A flame is a burning mixture or product of combustion of a combustible gas or vapour and air or flame is also a visible gaseous part of a fire.

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It is caused by highly exo- R^{\ddagger} taking place in the flame zone.

Types of flame -

- (1) Luminous Flame like candle flame/Torch flame/Coal gas flame.
- (2) Non-luminous flame like CO flame, H₂ flame, BF gas flame.
- (3) Long Flame / (Lazy) Flame - is produced when gases are burnt in less quantity of primary gas and flow is non-turbulent - .
It is produced when
- (4) Short flame / Intense flame - This type of flame is strongly cavitated. It is produced when gas is burned in high amount of air - as in case of blow-pipe

Flame structure -

The flame shape & size depends upon its types i.e. premixed & different diffusion laminar or turbulent & also on the burner dimension.

Flame stability - A free burning flame is said to be stable if there is no flashback or blow off. The normal velocity of flame propagation depends on (1) ^{natural} nature of fuel, (2) composition &

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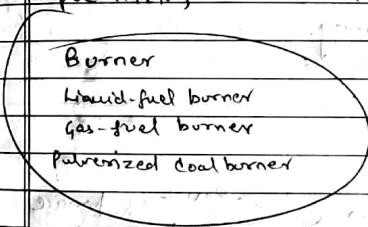


temp. of fuel-air mixture, (3) burner hole diameter.

The temp. of fuel-air mixture at the burner tip depends on the heat transfer from the PF zone, heat lost to the surrounding & size, shape and material of construction of burner wall. Heat loss to the surroundings depends on the flame length.

Colour & temp. of flame are dependent on the type of fuel involved in combustion.

Flame colour - depends on several factors, the most important being black-body radiation. The most common type of flame hydrocarbon flame. The most important factor determining the colour of flame is oxygen supply & the extent of fuel-oxygen pre-mixing which determine the rate of combustion.



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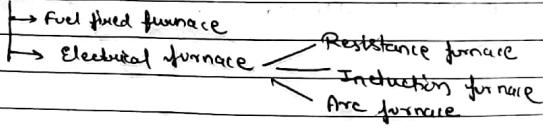


Character, shape & size of the flame -

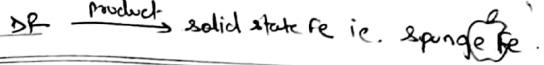
Fuel gases burnt at very high combustion velocity will produce very little luminosity regardless of the kind of the gas. CO and H_2 are burnt with an invisible to a clear flame while H/C gases develop highly luminous flame due to thermal cracking of H/C into carbon and hydrogen. Deficiency of air increases the luminosity and length of the flame and excess air decreases luminosity and flame length.

Pretreatment of combustion air reduces luminosity. Use of steam for atomization also reduces luminosity. A luminous flame has greater ability to transfer heat by radiation from a fixed temp. level. The transfer of heat by radiation varies inversely with square of the distance b/w the transmitter & recipient of the radiant energy.

Furnace



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A furnace is essentially an equipment used to melt metals for casting or to heat materials to change their shape i.e. rolling, forging or change of properties like heat treatment or process raw materials at high temp. like blast furnace, DR plant (Direct reduction plant). Several industries like iron & steel making, non-ferrous metals production, glass making, manufacturing, ceramic processing, calcination in cement production → all these imply furnace.

Different components of a furnace -

- (1) Refractory chamber constructed by insulating materials to retain heat at high operating temperature.
- (2) Hearth to support or carry the steel which consists of refractory material supported by a steel structure part of which is water cooled.
- (3) Burners that use liquid or gaseous fuels with air to raise & maintain the temp. in the chamber.

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④ Electrical Energy through resistance heating or induction heating or arc heating is also used to raise & maintain temp.

⑤ Coal in the form of pulverized coal can also be used in some furnace.

⑥ Chimney to remove combustion exhaust gases from the furnace chamber.

⑦ Charging & Discharging arrangements or doors through which the furnace chamber is loaded & unloaded.

⑧ Instrumentation & control - Proper I&C should be provided.

⑨ Heat exchanger for utilisation of waste heat.

Classification

Classification of Furnace -

Based on the methods of generating heat, furnaces are broadly classified into 2 types mainly combustion type using fossil fuels and electrical type using electricity.

Combustion type furnaces can be further classified based on the following types - categories -

- 1) Types of fuel used
- 2) Mode of charging of material
- 3) Mode of heat transfer
- 4) Mode of waste heat recovery

and Electrical type furnace classification -

- 1) Induction heating
- 2) Arc heating
- 3) Resistance heating

Combustion furnace -

Classification Methods

- ① Types of fuel used

Types of furnace

Oil fired furnace, Gas fired furnace, coal fired furnace

- ② Mode of charging of material

Intermittent charging / Batch type (Periodical furnace)

→ Forging furnace → Retracting furnace

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	Continuous type
	→ Pusher type furnace
	→ Walking beam furnace
	→ Walking hearth furnace
	→ Continuous re-circulating bogie type furnace
	→ Rotary hearth furnace

(3) Mode of heat transfer	Radiation type (open fire plane) Convection type (heating through media)
(2) Mode of heat recovery	Re-cuperative Re-generative

Classification of furnace based on process needs —

Physical processing furnace → based on metallurgical operation based

Chemical processing furnace

Unit Process	Purpose	Type of furnace	Energy source
(1) Carbonization	Conversion of coal to coke.	Lake oven furnace	Heating by burning fuel
(2) Calcination	→ Cement production → Production of anhydrous lime	Rotary kiln furnace	Fossil fuels
(3) Roasting	Conversion of sulphide to oxide	Multiple Hearth Furnace	Fossil fuels

Unit process	DATE	Purpose	Type of furnace	Energy source
(1) Heating		To perform hot rolling to perform heat treatment	Batch-type furnace or Continuous-type furnace	Oil fired, coal fired
(2) Sintering		To produce sinter or to produce compactness of particle	Sintering furnace	Gas / coal

Chemical processing furnace

Unit Process	Purpose	Type of furnace	Energy source
(1) Electrolysis of Molten salt	To produce Al or Mg by electrolysis	Hall-Heroult's furnace	Electricity
(2) Refining	To produce Steel	LD Inverter, electric arc furnace, open hearth furnace	Electricity or Chemical RX
(3) Melting	To produce casting furnace (either ferrous or non-ferrous or steel)	Electric Induction furnace, reverberatory furnace, Peverberatory furnace	Electricity or Chemical RX
(4) Smelting Reduction	To produce matte	Flash smelter, reverberatory smelter	Electricity or Chemical RX
(5) Converting	To produce hot metal zinc, Pb, Fe	Blast furnace	fossil fuel or Chemical RX
	To produce Cu from copper matte	Zn " " Pb " " slide blown converters	Chemical RX

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Fuel-fired Principle of Combustion furnace -

In fuel-fired furnace, heat is supplied by combustion of fuels & is transmitted by a combination of heating process. Fuels can be solid fuels like pulverized coal, oil or gas. Common method of and the selection of fuel to be used should be based upon a study of the comparison prepared based on cost, cleanliness of operation, adaptability to temp. control, labour required & the effect of each fuel on the material to be heated and on the furnace lining.

Attention must be paid to the quantity of fuel to be burnt in each burner. The atmosphere desired in the furnace & the uniformity of temp. distribution required which determines the number & location of burners.

Common methods of burning furnace fuels are -

- ① Solid fuels - Solid fuel coal was once a common fuel for industrial furnaces

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either hand-fired or stoker-fired or through pulverized coal burners. With the increasing necessity of increase control of temp. & atmosphere, coal has been replaced by liquid & gaseous fuel.

- ② Liquid fuels - To burn liquid fuels effectively it is necessary to atomize the oil into tiny droplets which then vaporise & burn. Atomisation can be performed mechanically or with the help of steam & air.

With heavy oil & tar, it is important to maintain proper viscosity of oil or the atomiser by pre-heating of it. Combustion air is supplied by combustion fans of appropriate capacity & pressure.

- ③ Gaseous fuels - Different types of burners have been developed for diff. types of gases like burners for Natural Gas, ~~etc~~ coal gas, coke oven gas, etc.
crude gas - BF gas
CO gas

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All burners take care of required amount of air by burning the fuel. Some of the important fuel-fired furnaces are -

(1) Oven furnace - In this furnace heat is transferred from the product of combustion of the fuel in direct contact with heated materials by convection & direct radiation of hot gases or by radiation from hot walls of the furnace.

Oven furnace is classified into 3 categories based on methods of firing -

→ Direct fired furnace

→ Over fire

→ Under radiant tube

(2) Muffle furnace - In this furnace heat is conducted through the metal or refractory muffle which protects the heated material from contact with gases & is then

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transformed from the interior of the muffle by radiation to the material which is sometimes surrounded by inert gases to exclude air.

(3) Liquid Bath furnace - This is metal pot which is heated ~~for~~ the outside or by immersion. The pot contains a liquid heating or processing medium which transfers heat to the material contained in it. This type of furnace include low temp. tempering furnace, hardening furnace, using a bath of lead, cyaniding furnace.

The ~~key~~ direct fired methods finds increase utilisation from constant improvements in the design and control of gas and oil burners especially for temp. above 650°C.

In ~~over~~ fired furnace, radiant burners fire through the roof and are arranged in patterns to obtain the best temp. distillation

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The under-fired furnace is excellent for temp. b/w $400 - 1000^{\circ}\text{C}$ because the heat product is protected from burning fuel.

The temp. & atmosphere can be closely controlled but the temp. is limited by the type of refractory to about 1000°C .

Many furnaces are now designed for the use of special protective atmosphere. This involves use of radiant tubes to avoid any contact with the combustion gases.

These fuel-fired tubes of heat-resistant alloy may be horizontal across the furnace above the & below the treated material or may be vertical on the side wall of the furnace.

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Heat transfer in the furnace -

The main ways in which the heat is transferred to the steel is convection & re-heating surfaces are -

- (1) Radiation from the flame hot combustion products & furnace wall roof.
- (2) Convection due to the movement of hot gases over the steel stock surfaces. At high temp. implied in reheating furnace the dominant mode of heat transfer is wall radiation. the heat by gas radiation is dependent on the gas combustion, the temp. & the geometry of the furnace.

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Energy conservation measures in furnace -
The different measures are -

- (1) Complete combustion with min. excess air
- (2) Proper heat distribution/distribution.
- (3) Operation at the optimum furnace temp.
- (4) Reduction in heat losses from furnace openings.
- (5) Maintaining correct amt. of furnace draft.
- (6) Optimum capacity utilization.
- (7) Waste heat recovery from flue gases
- (8) Min. refractory class.
- (9) Use of ceramic coatings.
- (10) Selecting the right refractory

(1) Complete combustion with min. excess air -
The amt. of heat lost in flue gas depends
on the amt. of excess air. To obtain
complete combustion of fuel with the min.
amt. of air, it is necessary to
control air in + filtration, maintaining
proper combustion air, fuel quantity
& quality & monitor the amt.
of excess air.

Too much excess air will reduce flame
temp., furnace temp. & heating

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gaste. Too little excess air will result
in an increase in unburnt components
in the flue gas. Therefore, optimizing
combustion air with the most attractive
& economical measure for energy
conservation in the furnace.

(2) Proper heat distribution

A furnace should be designed to
ensure that within the given time
the material is heated uniformly
to a desired temp. with min. amt. of
fuel. Where burners are used to
fire the furnace, the following points
should be ensured -

- (1) The flame should not touch or
obstructed by any solid objects in
the furnace.
- (2) The flame of diff. burners should
not collide.
- (3) Burners ~~excess~~ air should be
such that it should not heat the roof.

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large burners produce larger flames which may be difficult to contain within the furnace. we should always have smaller burners with more numbers.

(3) Operation at the optimum furnace temp. It is imp. to operate the furnace at its optimum temp. Operating at too high temp. causes heat loss, excessive oxidation, decarbonisation & stress on refractory. Therefore, optimatic control of temp. is important.

(4) Prevent heat loss through openings Heat can be lost by direct radiation through openings in the furnace such as charging inlets, discharged outlets & the plenum holes in the walls or ceiling. Heat is also lost due to press. differences b/w the inside of the

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furnace & outside environment causing combustible gases to leave through opening.

(5) Control of furnace draft Proper management of press. difference b/w the inside & outside of furnace is imp. to minimize heat losses & impact on the quality of the product.

If the negative press exists inside furnace, air can infiltrate through cracks & openings & it will affect air fuel ratio control this will cause non-uniform temp. & metal may not reach the required temp. & fuel consumption & product rejection rate also may go high. if it is advisable to operate the furnace at slightly +ve press. & press. diff. should not be too large

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- (6) optimum capacity utilization -
 One of the most vital factors affecting furnace energy efficiency is the load. This includes the amount of material placed inside the furnace, the arrangement of loading inside the furnace, residence time of load inside the furnace. If the furnace is underloaded, the proportion of total heat available that will be taken by load is smaller, resulting in a lower efficiency.

~~Overloading can lead to improper heating of material within a given time period.~~

- (7) waste heat recovery from furnace flue gas

In any industrial furnace combustion products leave the furnace at a temp. higher than

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the stack temp. flue gas carry 35-55% of heat input to the furnace with them through flue chimney. As higher the amount of excess air & flue gas temp., the higher the amount of waste heat. But primary objective for a furnace designer should be to minimize the amount of waste heat generated through various energy conservation measures discussed here - waste heat recovery should only be considered after waste recovery.

Waste heat in flue gas can be recovered by -

- (1) charge pre-heating
- (2) pre-heating of combustion air
- (3) Utilizing waste heat as a heat source to generate steam

- (8) Minimizing furnace skin loss -

About 30-40% of fuel used in intermittent or continuous furnace is used to make up heat loss through furnace

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skin or furnace walls. The extent of skin loss depends on -

- ① emissivity of wall, ② thermal conductivity of refractory, ③ wall thickness
 - ④ whether furnace is operated continuously or intermittently.
- There are several ways to minimize skin loss -
- ① choosing appropriate refractory material
 - ② increasing wall thickness.
 - ③ installing insulation blocks.
 - ④ planning proper operating time of furnace.

There are 2 types of arc furnace commonly used -

- ① 3-phase furnace
- ② 5-phase furnace

In general the 3-phase furnace is melting & refining of carbon alloy steel & 5-phase furnace is used to melt non-

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ferrous alloys. Capacity of electric arc furnace are varying to meet the requirement of refining of iron & steel. The electric arc furnace are a firebrick lined "U" shape vertical vessel in which scrap steel is melted by an electric arc instead of the usual fossil fuel. Electric arc furnace consists of following components -

- ① furnace probe
- ② transformer
- ③ Tilting mechanism
- ④ Roof retraction & electrode removal mechanism
- ⑤ Laddles
- ⑥ Fume extraction system

Principle & working operation of EAF

EAF works on the principle of the electrode forming an arc b/w itself & the top layer of the metal to be melted. The operation begins with a delivery of steel scrap to the furnace by baskets of scrap. Basket is loaded with scrap in such way that topmost layer is light scrap then heavy scrap then

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Baskets have bottom opening doors. Some pig iron is also added. sponge iron is also added separately.

Before delivery to the furnace, basket may pass through a pre-heat system say exhaust gases from EAF. Furnace roof is retracted and basket is unloaded. Once the charge is in the furnace, the lid is replaced on the furnace & electrodes are lowered on the top layer of light scrap. An arc is struck and the electrodes start sinking into the scrap. The rate of sinking and voltage are controlled automatically. Oxygen burners are energized and melting starts.

The EAF temp. of the molten metal is around 2970°F but obviously the temp. of the arc is in the range of 11000°F . A normal melt of 100 tons will take just an hour to complete melting, using about 400 kWh power. The formation of slag is an imp. component of

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EAF operation due to the following
1. slag forms on the top of the molten steel & act as a sponge to gather the impurity in the metal.

2. slag acts as an insulation layer on top of the metal, preventing excessive heat loss.

3. slag helps reduce ~~weakening~~ away of refractory lining of vessel.

Slag formation is helped by injection of magnesite dolomite in the form of MgO & CaO . Now the melt has reached for tapping. Another basket of scrap can be added and once all metal is melted samples can be taken and composition of steel analysed for the correct composition and if required, composition can be adjusted by addition of some more slag forming products, injection of oxygen which will blow away impurities like Al, Mn, P, S. Once sample have conformed to the correct composition of steel, metal is tapped.

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Industrial furnace

There are 2 types of metal melting induction furnaces -

- (1) coil type
- (2) coreless type

Both types utilise the principle of a transformer.

The high voltage circuit is coupled with that of a low voltage circuit without directly connecting the 2 circuits. The elements responsible for this coupling is magnetic field.

The induction heating utilises properties of a magnetic field which enables the heat to be transferred without direct contact.

The induction furnace capacity ranges from less than 1kg to more than 100 tons & add are used to melt iron & steel, copper, Al, and other precious metals. The advantage of Induction furnace is clean, energy efficient

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A well-controllable melting process as compared with other means of metal melting. Most modern foundries use this type of furnace and even cupolas are being replaced by induction furnace for melting cast iron since no arc ~~or~~ or combustion is used, the temp. of the material is not ~~very~~ higher than required to melt. This can prevent loss of valuable alloying elements.

But, the ~~one~~ drawback in induction furnace is lack of refining capacity i.e. charge material must be very clean of oxidation & of known composition

Coreless type - This type of furnace consists of a crucible, copper coil & framework or supports arranged for tilting & pouring. The specially designed induction coil acts as the primary of the transformer.

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The crucible conforms to conventional refractory pricing. A ~~reinforced~~ ^{reinforced} crucible is used for furnace above 50 kW and preformed crucible are used on smaller furnaces as in the laboratory uses.

Operation of IF - The initial charge in the furnace is cold-scraped sponge iron. As the power is applied, the heat cycles progress so charge becomes molten. Additional cold-charge may be added to bring furnace to desired temp. & composition. Then furnace is tilted & tap firstly slag and then metal.

In b/w continuous ~~steaming~~ steaming of slag is done.

cold IF is useful in melting charges of known analysis as refining cannot be done.

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core type IF

The transformer is actually wound to conform to a typical transformer design having an iron core & layers of wire acting as a primary circuit. The melting channel acts as a short circuit around this transformer. Air-pulling is used as required to prevent undue heating of induction coil & magnetic core. This furnace is useful for melting of non-ferrous metals like Al, Cu-alloy and Zn. core type furnace is most efficient of all IFs because its iron core concentrates magnetic flux in the area of magnetic loop ensuring max. power transfer from primary to secondary. Efficiency in the use of power is high as 95-98%.

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Resistor furnace

In this furnace, heat is developed by the passage of current through distributed resistors mounted apart from the charge.

AC current of a standard power frequency is used. The furnace is used for heat application on solid material such as heat treatment of metals, annealing glasses etc., firing of vitrified enamel.

RF may be either batch or continuous type. Standard RF are designed to operate within temp range of 550 to 1200°C.

The heating chamber of a standard RF is an enclosure with a refractory lining. A surrounding layer of heat insulation & outer casing of steel plates. For larger furnace, outer casing may be of bricks. The mix. of air and gas evolved from the melting of charge constitute a

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natural atmosphere. Resistor of standard furnace is a sinusoidal mounted on the inner surface of the heating chamber.

Refractory

These are materials which can withstand high temp. and do not fuse even at very high temp.

Eg - fire clay refractory, silica, chromite, magnetite refractory, etc.

Classification of Refractory

Depending upon the chemical composition, refractories can be classified as

Type of Refractory material	Example	Remarks
① Acidic refractory (Silica-SiO ₂ is the main constituent with some bases)	Fire clay R, Silica R, Quartz R, Aluminosilicates R, semi-silica R, etc.	It should not be allowed to come in contact with basic products to avoid R ^x .
② Basic refractory (it consists of basic oxides without free silica)	Dolomite R, Magnesite R, Bauxite R, Zirconia R, Alumina R,	It should not be allowed to come in contact with acidic products to avoid R ^x .

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(3) Neutral Refractory
(which does not combine
with acids or bases)

Chromite R,

Graphite R (Carbon R),

Carbide R, Mullite R,

Kyanite R, Pure alumina R,

Al.

(can be used
in conjunction
with acids
or basic
properties.)

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