Chemical Engineering Department

NIT SRINAGAR

➢ **SUBJECT :** **CHEMICAL TECHNOLOGY - II**   Course No – CHE-703

Credit 4

UNIT I - CHEMICAL TECHNOLOGY TOPICS

I) COAL

➢ Defination of Coal and its types   (Softcopy)

➢ Coal as an energy resource   (Book - Dryden Outlines Of Chemical Tech, Pg- 370)

➢ Nature , occurrence ,mining and uses of coal   (Book - Dryden)

➢ coking of coal (process description with flowsheet)   (Book – Dryden Pg -372)

➢ gasification of coal (process description with flowsheet)) (Book Dryden Pg -374)

➢ chemicals derived from coal   (Softcopy)

➢ Carbonization of coal   (Softcopy)

   i)   High temperature carbonization

   ii)   Low temperature carbonization

➢ Hydrogenation of coal (Process description with flowsheet)   (Dryden pg 376)

II) COAL TAR

   ➢ Definition of coal tar   (Softcopy)

   ➢ Distillation of coal tar   (Dryden Pg 374)

   ➢ Chemicals from coal tar   (Softcopy)

III) SUGAR

   ➢   Manufacture of raw sugar crystals from sugarcane   (Dryden pg 316)

   ➢   Refining operations

IV) STARCH

   ➢ Manufacture of starch from various materials   (Dryden pg 321)

   ➢ Properties of starch   (Dryden pg 319)

   ➢ Starch derivatives   (Dryden pg 321)

   ➢ Manufacture of glucose

V) PENICILLIN   (Dryden pg 561)

- Types
- Properties
- Manufacturing process
- Consumption pattern

COAL AND ITS TYPES

Coal is a flammable black hard rock used as a solid fossil fuel. It is mainly made up of 65-95% carbon and also contains hydrogen, sulphur, oxygen and nitrogen. It is a sedimentary rock formed from peat, by the pressure of rocks laid down later on top. The harder forms of coal, such as anthracite, are metamorphic rocks because they were changed by higher temperature and pressure.

Peat, and therefore coal, is formed from the remains of plants which lived millions of years ago in tropical wetlands, such as those of the late Carboniferous period (the Pennsylvanian). A similar substance made from wood by heating it in an airless space is called charcoal.

Coal can be burned for energy or heat. About two-thirds of the coal mined today is burned in power stations to make electricity. Coal is becoming less popular in new power plants as less expensive and less polluting technologies such as natural gas and hydroelectricity take over.

Coal can be dry-distilled (heated in high temperature in a place where there is no oxygen) to produce coke. Coke is even better fuel than coal, and can be used in smelting to reduce metals from their ores.**Coal** is a variety of solid, combustible, sedimentary, organic rocks, formed from vegetation that has been consolidated between other rock strata and altered by the combined effects of pressure and heat over millions of years. Carbon is the main component of coal, which also contains varying amounts of other components, like hydrogen, oxygen, sulphur and other impurities. Main parameters used to define coal are calorific value, ash, moisture and sulphur.

Types

1. Peat, which has industrial importance as a fuel in some regions, for example, Ireland and Finland. In its dehydrated form, peat is a highly effective absorbent for fuel and oil spills on land and water

2. Lignite (brown coal) is the lowest rank of coal and is used as fuel for electric power generation. Jet is a compact form of lignite that is sometimes polished and has long been used as an ornamental stone.

3. Sub-bituminous coal is used as fuel for steam-electric power generation. Also, it is a source of light aromatic hydrocarbons for the chemical synthesis industry.

4. Bituminous coal is a dense rock, black but sometimes dark brown. It is a relatively soft coal that breaks and burns readily and quickly. It used as fuel in steam-electric power generation, and for heat and power applications in manufacturing; also and to make coke

5. Steam coal was once widely used as a fuel for steam locomotives

6. Anthracite is the highest quality: a harder, glossy, black coal. It is longer burning, and used mainly for residential and commercial space heating.

7. Graphite is difficult to ignite and is not so commonly used as fuel: it was mostly used in pencils and, when powdered, as a lubricant.

Diamond is commonly believed to be the highest grade, but this is not true. Diamond is carbon but is not formed from coal.Coal contains impurities. The particular impurities determine the use. Coking coal has little ash or sulfur or phosphorus. Those would spoil the iron made by the blast furnace.

Chemicals Derived From Coal

Coal is an important feedstock in production of a wide range of chemical fertilizers and other chemical products. The main route to these products is coal gasification to produce syngas. Primary chemicals that are produced directly from the syngas include methanol, hydrogen and carbon monoxide, which are the chemical building blocks from which a whole spectrum of derivative chemicals are manufactured, including olefins, acetic acid, formaldehyde, ammonia, urea and others. The versatility of syngas as a precursor to primary chemicals and high-value derivative products provides the option of using relatively inexpensive coal to produce a wide range of valuable commodities.

Coal chemicals are obtained during the processing of metallurgical coke from coal. The aromatic compounds that are obtained as by-products during such processing are used as intermediates during the process of synthesis of some solvents, dyes, drugs, and antiseptics. Most of the by-products of coal chemicals are used as fuel.

Coal chemicals are typically mixtures of -

- Methane
- Carbon monoxide
- Hydrogen
- Small amounts of higher hydrocarbons, ammonia, and hydrogen sulfide

**Coal Chemicals** by-products are -

- Gas
- Light oil
- Tar

Coal chemicals by-products like benzene, naphthalene, anthracene, phenanthrene pyridines, and quinolines are not obtained from petroleum refineries. Furthermore, a substantial quantity of phenol, cresols, and xylenols are still obtained as by-products of coal chemicals.

The demand forIndian coal chemicals product is high mainly because of its quality and competitive pricing.India's low cost and high end coal chemicals product manufacturing expertise coupled with developing world class infrastructure is the main leveraging factor for the rise of this industry. Further, with the consolidation of the infrastructure development, this industry will be a big success in years to come.India offers **coal chemicals** products at a substantial discount compared to its western counterparts.

The processes for production of specific chemicals from coal are typically proprietary systems using specialized process systems. Formaldehyde ,olefins and methanol can be derived from coal also. Methanol (MeOH) is important primary chemical made from coal syngas; however, it is also a liquid fuel in its own right particularly in certain markets (China).

.I) Using Carbon Monoxide as feedstock

Syntheses of certain chemicals require high purity carbon monoxide (CO) as a feedstock. This is obtained by separation from syngas, which can be accomplished by several commercial processes: cryogenic purification, pressure swing adsorption, membrane separation, and salt solution absorption. Cryogenic purification is normally the preferred process except when the syngas feed contains large amount of nitrogen (N_2), due to the close proximity between CO and N_2 boiling points (approximately 8°F). Under this situation, copper salt-solution absorption can be used instead. The Eastman coal-to-chemicals plant at Kingsport uses cryogenic purification for CO/hydrogen (H_2) separation.
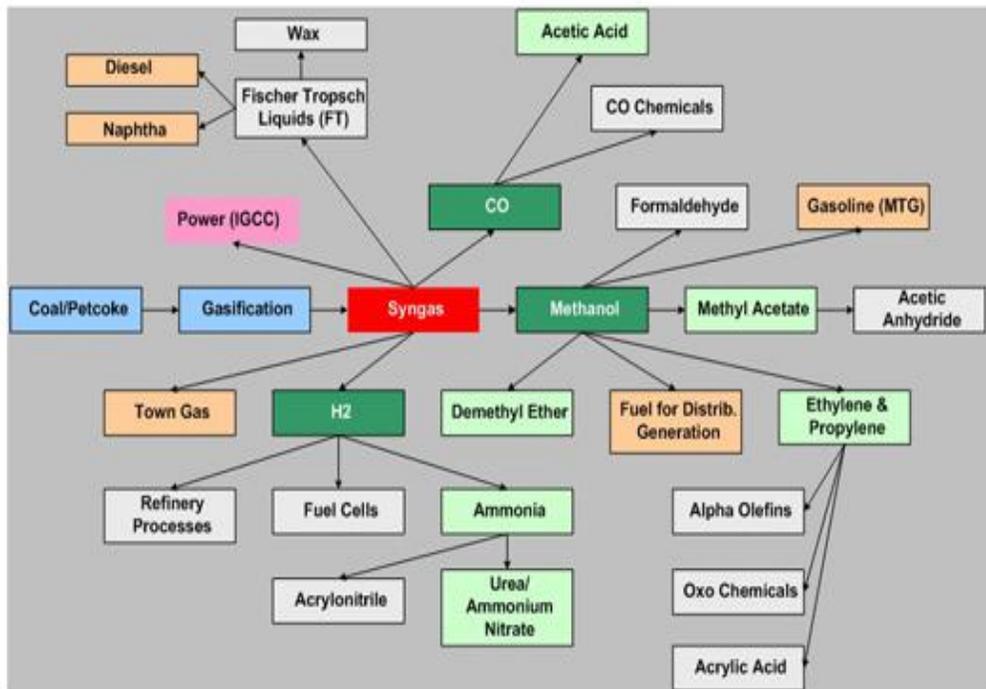
Figure 1: Coal to Chemical Routes

Figure 2 shows a simplified cryogenic partial condensation CO/H_2 purification scheme. Syngas feed is first pre-treated with molecular sieves to remove carbon dioxide (CO_2) and water before being chilled to approximately -300°F in the cold box by heat exchange against exit gases. Refrigeration is supplied by the cold product streams and by flashing the final CO liquid product stream exiting the stripping tower. Separation of CO/H_2 and purge gas is accomplished by a series of condensation/depressurization steps, of which, depending on the operating pressure cycle, the overall heat exchange/recovery and refrigeration streams may vary and can become very complex. Figure 2 shows a simple configuration of a condensation process. It includes a molecular sieve adsorber station, a cold box containing the plate fin heat exchangers to pre-cool the feed syngas against the product streams.
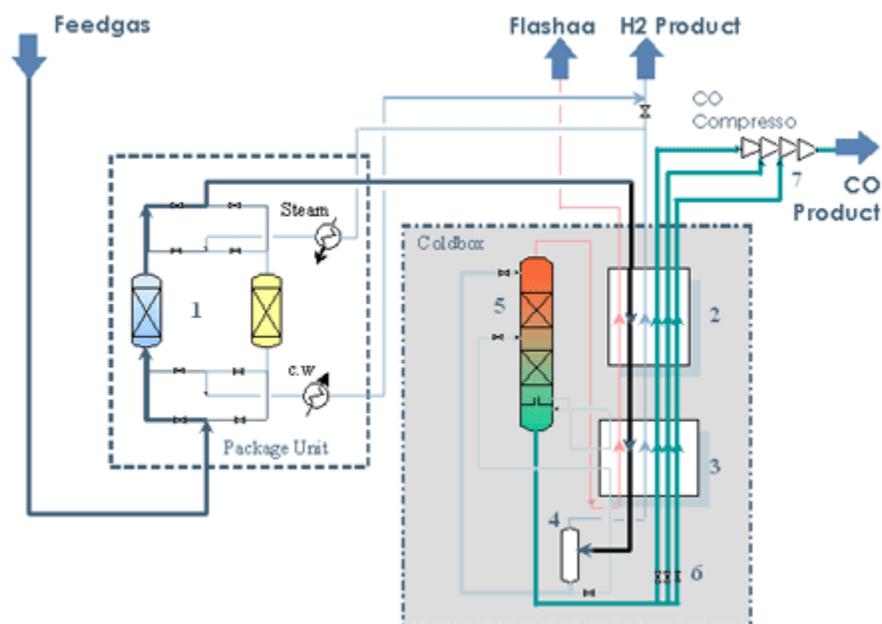
**Figure 2: A Simplified Cryogenic CO/H₂ Purification Scheme**

Acetic Acid and Derivatives

Acetic acid (CH_3COOH), an important industrial chemical, can be produced from coal-derived MeOH indirectly through carbonylation of MeOH over rhodium or iridium catalysts (with various iodide or other additives) according to the following reaction:

$$CH_3OH \ + \ CO \rightarrow CH_3COOH$$
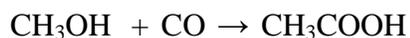
The rhodium catalyzed process is highly selective (>98% acetic acid) and operates under mild reaction pressure (~ 500 psia) in a liquid phase reactor. Technology licensors include Monsanto/BP, Celanese, BP, and Chiyoda, the latter three vendors represent an improved version of the original Monsanto/BP technology.

Figure 3 shows a simplified block flow diagram (BFD) of the Eastman Chemicals' coal-to-chemicals facility producing MeOH from coal derived syngas, followed by converting MeOH into acetic acid and its derivatives of methyl acetate and acetic anhydride.
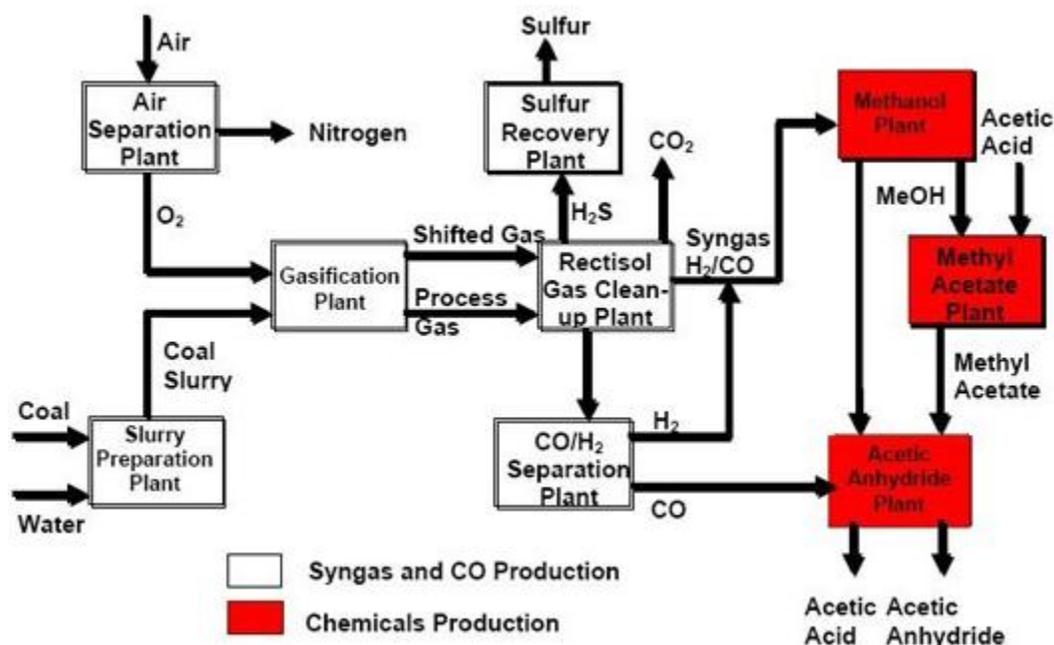
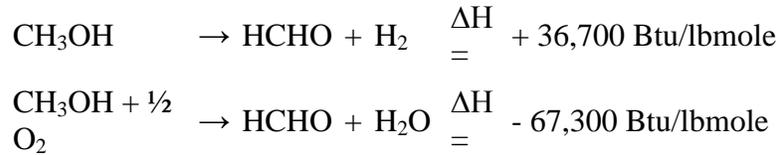**Figure 3: Eastman Coal to Acetic Acid & Derivative Chemical BFD[3]**

With the Eastman facility, acetic acid is reacted with MeOH to form methyl acetate (CH_3COOCH_3), which is further reacted with CO to produce acetic anhydride ($[CH_3CO]_2O$). The catalytic reactions for these additional derivatives are shown in **Figure 4**.
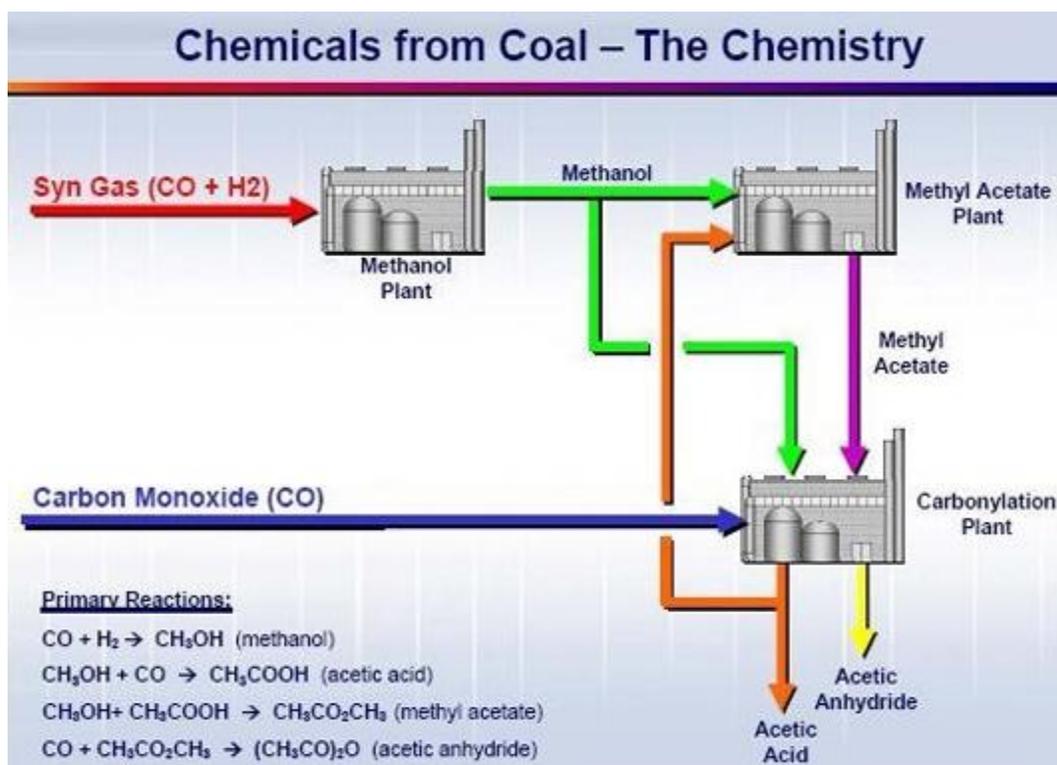
**Figure 4: Eastman Coal to Acetic Acid & Derivative Chemistry**

Formaldehyde

Formaldehyde can be produced from coal indirectly through dehydrogenation and partial oxidation of MeOH using a silver catalyst, based on the following reactions:

$$CH_3OH \rightarrow HCHO + H_2 \quad \Delta H = +36,700 \text{ Btu/lbmole}$$

$$CH_3OH + \tfrac{1}{2} O_2 \rightarrow HCHO + H_2O \quad \Delta H = -67,300 \text{ Btu/lbmole}$$

Equilibrium conversion and potential side reactions are highly temperature dependent. The overall reaction temperature is controlled by the quantity of air (oxygen) used, and the addition of inerts, such as water and/or nitrogen.

Figure 5 shows a typical flow scheme of a MeOH oxidative dehydrogenation process producing commercial grade formaldehyde. A mixture of methanol and water is mixed with air and recycled gas, and the total feed mixture is vaporized by heat exchange against hot reactor effluent. The vaporized feed mixture is fed into the catalytic reactor to form formaldehyde. Excess reaction heat is removed by generating steam. The reactor effluent, after cooled by heat exchanging with incoming feed, is scrubbed with water in the absorber to remove the formaldehyde product as a 55% solution. Water can be added to produce commercial grade formaldehyde at 37% concentration. A portion of the product gas leaving the top of the absorber is recycled, and the remainder is incinerated. Typical overall formaldehyde yield is in the range of 92 to 95%.
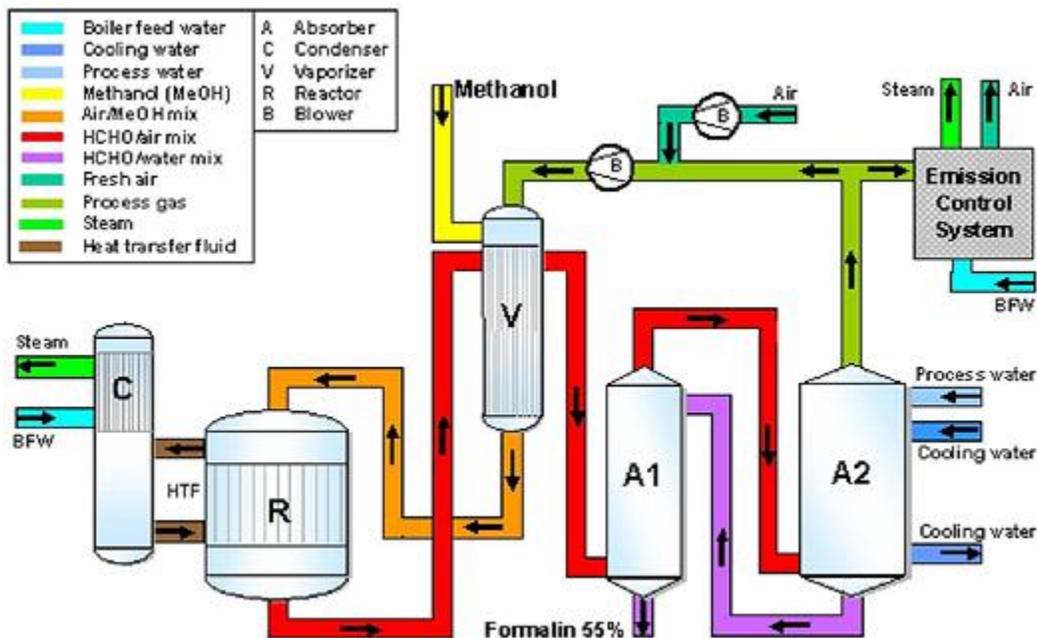
## Figure 5: A Typical Methanol Oxidative Dehydrogenation Process of Producing Commercial Grade Formaldehyde

Olefins

Olefins, such as ethylene and propylene, can be produced from coal gasification indirectly by catalytic cracking of MeOH, commonly called the methanol-to-olefins (MTO) process.

Figure 6 shows a simplified flow diagram of UOP/HYDRO's MTO process. Other technology licensers include ExxonMobil and Lurgi, using different types of catalyst systems and process know-how. Per **Figure 6**, fresh MeOH feed is combined with recycled water and fed to a fluidized-bed catalytic reactor, equipped with a catalyst regeneration and recycle reactor as shown. The reactor operates at typically 350°C and at 30 psig. With UOP/HYDRO's proprietary catalyst system, claimed methanol conversion is quite high, and the process is 80% selective for ethylene and propylene. The produced ethylene/propylene ratio can be altered from 1.5 to 0.6, depending on operation conditions.

Reactor effluent leaving the reactor is cooled to condense most of the water and unreacted methanol for recycling. Spent catalysts from the reactor are routed to the regenerator where the coke deposits are burned off with air. Regenerated catalysts are recycled. The cooled reactor effluent is compressed to remove CO_2 and water, followed by further compression to high pressure to liquefy the hydrocarbon mixture for separation by distillation. The final product from distillation separation typically consists of polymer grade ethylene and propylene, a methane-rich fuel gas, plus small amount of ethane, propane, butane, pentane and higher molecular weight liquids.

Other MTO technology licensors include Exxon/Mobil and Lurgi, of which the ExxonMobil process is very similar to that of UOP/HYDRO except perhaps with the use of a different catalyst formulation. Lurgi's process is optimized for propylene production, and is being marketed as a methanol to propylene (MTP®) process.
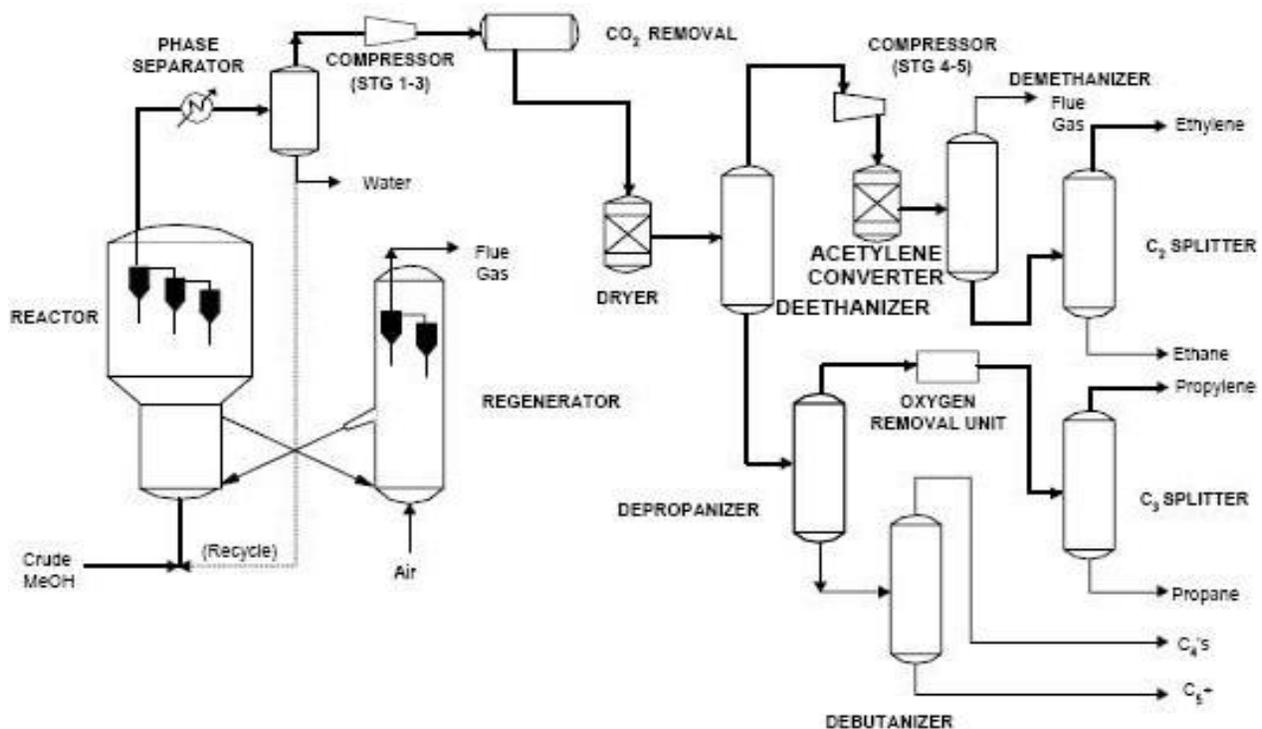
Figure 6: Simplified Process Flow Diagram for UOP/Hydro MTO Process[1]

CARBONIZATION OF COAL

Carbonization of coal is the thermal decomposition of coal in the absence of air, represents one of the largest utilizations of coal, and is an essential process for production of a carbonaceous residue (coke), gas , and tar.

It is the term for the conversion of an organic substance into carbon or a carbon-containing residue through pyrolysis or destructive distillation. The term carbonization is also applied to the pyrolysis of coal to produce coke. It is the only method of producing hard coke from coking coal with better size consistency, hardness and richer in fixed carbon content to cater the needs of the blast furnace, foundry, and chemical industry.

Coal carbonization is used for processing of coal to produce coke using metallurgical grade coal. Coke making process is multistep complex process and variety of solid liquids and gaseous products are produced which contain many valuable products. Various products

from coal carbonization in addition to coke are coke oven gases. coal tar, light oil, and aqueous solution of ammonia and ammonia salt. Coke oven gases are about 310-340 cum per tone of dry coal which contains gaseous products, coal tar vapours, light oil etc,

Carbonization of Coal for Metallurgical Coke Production

Carbonization of coal is also known as coking of coal. The process consists of thermal decomposition of coals either in the absence of air or in controlled atmosphere to produce a carbonaceous residue known as coke.

Carbonization of coal can be carried out at the following three temperature ranges.

- Low temperature carbonization is normally carried out in the temperature range of 500 deg C to 700 deg C. In this type of carbonization, the yields of liquid products are higher and there is lower gaseous product yield. The coke produced is having higher volatile matter and is free burning.
- Medium temperature carbonization is done at temperature range of around 800 deg C. This carbonization produces smokeless soft coke. By products produced are similar in characteristics to high temperature carbonization. Medium temperature carbonization is rarely practiced these days.
- High temperature carbonization is carried out at a temperature which is above 900 deg C. This carbonization gives higher yield of gaseous products and lower yield of liquid products. This carbonization produces hard coke and is normally employed for the production of metallurgical coke from coking coals.

Process of carbonization of coal

The coal to coke transformation takes place as the coal is heated. When the state of fusing is reached, the layer of heated coal softens and fuses. From about 375 deg C to 475 deg C, the coal decomposes to form plastic layer. Destructive distillation reactions proceed rapidly in the plastic layer with evolution of volatile products. At about 475 deg C to 600 deg C, there is a marked evolution of tar, and aromatic hydrocarbon compounds. The gas and condensable vapour are entrapped in the plastic mass and, as they expand tend to swell it. As the reactions proceed and as the temperature of the fused zone increases, the plasticity of the coal decreases. With continued heating and evolution of the gas the fused layer gradually resolidifies into semi coke having typical, cellular coke structure. The coke at this stage still contains substantial volatile matter. As the temperature increases further beyond 600 deg C, the

destructive distillation reaction continues with the evolution of gas and a little tar. The coke stabilization takes place as the temperature increases from 600 deg C to 1100 deg C. This is characterized by contraction of coke mass, structural development of coke and final hydrogen evolution. At this stage the final reactions take place. These reactions split off hydrogen from extremely complex, high molecular weight hydro- carbons. With increasing temperature, the coke mass shrinks with the development of shrinkage cracks**.**

The caking mechanism

When the coking coals are carbonized then first the plastic mass of optical isotropic is formed, and thereafter gradually lamellar nematic liquid crystals are formed. This polymeric phase is called mesophase. This is the intermediate phase between the isotropic fluid coal and the solid anisotropic semi coke ultimately formed from the mesophase, and has properties which are intermediate between solids and liquids. If the fluidity of the intermediate phase is quite high then mesophase coalesce immediately into a single larger unit. Over a range of increasing temperature, mesophase is formed continuously, grows in size and ultimately touches each other. Thus the mesophase can solidify and convert from coking coal into optical anisotropic texture of coke.

History of coking coals

Coke was produced in ancient China as per historical sources dating to the fourth century. The Chinese people first used coke for heating and cooking no later than the ninth century. In 1709 a coke-fired blast furnace to produce cast iron was established in Great Britain. , During early 18th century the coke was manufactured by burning coal in heaps on the ground in such a way that only the outer layer burned, leaving the interior of the pile in a carbonized state.

The 'Hearth' process of coke making, using lump coal, was continued to be used in many areas during the first half of the 19th century. This process was similar to that of charcoal burning but using a heap of coals covered with coke dust instead of a heap of prepared wood, covered with twigs, leaves and earth.

These led subsequently to the development of beehive ovens of different shapes and sizes to meet the increasing demands of hard coke for iron smelting.

Beehive ovens

A beehive oven is a simple firebrick chamber built with an arched roof so that the shape inside is that of an old-fashioned beehive. Its dimensions are typically 4 m in width and 2.5 m in height. Beehive ovens are usually built in rows, one oven beside another with common walls between neighboring ovens. Such a row of ovens is termed a battery. A battery usually consists of many ovens, sometimes hundreds, in a row. Typical cross section of a beehive oven is shown in **Fig 1.**
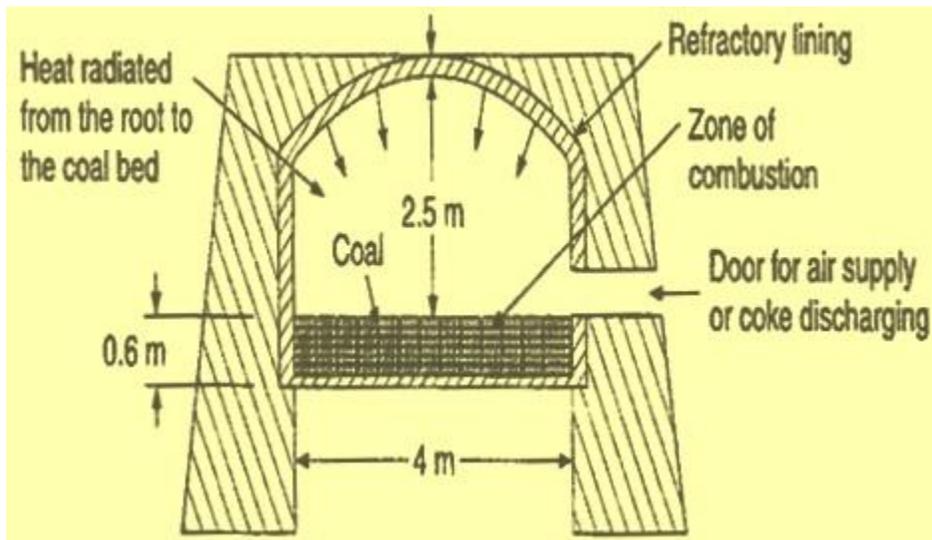
Fig 1 Typical cross section of a beehive oven

Rail tracks for handling the coal to the ovens ran along the tops; and other rail tracks for handling the coke cars ran beside the ovens. The roof has a hole for charging the coal or other kindling from the top. The discharging hole is provided in the circumference of the lower part of the wall.

Coal is charged into an empty oven through the hole at the apex of the dome. It forms a cone-shaped pile which is levelled to a uniform layer by means of a rake passed through the door to produce an even layer of about 600 mm to 900 mm deep.

The carbonization process is started by means of the heat retained in the walls of the oven from the previous charge of coal. Almost immediately after charging gas consisting of volatile matter is produced from the coal. The air for combustion is admitted through an opening at the top of the oven door or through side door. Start of carbonization produces volatile matter which is burnt inside the partially closed side door. Carbonization proceeds from top to bottom. Heat is supplied by the burning volatile matter so no by-products are recovered. The exhaust gases are allowed to escape to the atmosphere.

The time of coking which depends largely on the depth of the layer of coal, ranges from 48 to 72 hours. As coking proceeds, the volume of gas evolved decreases, and the size of the opening in the door is correspondingly decreased or by introducing bricks at the top opening. This regulates the quantity of air and prevents the entrance of an excessive volume of air, which otherwise would burn part of the coke and might be sufficient to cool the oven as well.

The hot coke is quenched with water and discharged, manually through the side door. When coking is complete, the door is opened and the white hot coke is quenched by stream of water directed through the opening. The quenched coke is then raked from the oven manually and loaded into train cars for transport. The walls and roof retain enough heat to initiate carbonization of the next charge.

When coal is burned in a coke oven, the impurities of the coal not already driven off as gases accumulated to form slag, which is effectively a conglomeration of the removed impurities. Since it is not the desired coke product, slag is either discarded or being used as an ingredient in brick-making, mixed cement, and even as a fertilizer.

New ovens are brought up to temperature by heating with coal or wood before charging.

Beehive coking is now an obsolete process because of the small quantity it manufactured and the very large amount of pollution it produced. However it is still being used.

Byproduct coke oven batteries

Maximum amount of global coke production comes from these batteries. Coal in these batteries is carbonized in absence of air and these batteries are operated with positive pressure in the ovens. The coke making process in these coke oven batteries is called byproduct coke making since the off gas is collected and sent to the byproduct plant where various byproducts are recovered. Most of the byproduct coke oven batteries are integrated in an iron and steel plant for the purpose of coke oven gas.

Non recovery coke oven batteries

 In non recovery coke oven batteries the coal is carbonized in large oven chambers. The carbonization process takes place from the top by radiant heat transfer and from the bottom by conduction of heat through the sole floor.

Carbonization can be carried out :

- **Low Temperature**

- **High Temperature**.

- **LOW TEMPERATURE & HIGH TEMPERATURE CARBONIZATION**

- **Low Temperature Carbonisation (LTC)**
-
- (a)It is carried at 700°C.
- (b)It produces semi-coke which is used as a smokeless domestic fuel. It can sometimes be used in boiler also to avoid smoke.
- (c)Yield of coke oven gas is less in LTC. It is about 150-160 Nm^3 gas/ton dry coal. Less gas yield is due to less devolatalisation of coal and less cracking of hydrocarbons at lower temperature of carbonisation. (d)Yield of tar is high in low temp carbonisation. It is about 10%
- of dry coal.
- (e)Ammonia yield is low.
- (f)Calorific value of coke oven gas produced in LTC is more due to higher percentage of
- methane and unsaturated hydrocarbons in it. C.V. Is about 6000-6500 kcal/Nm^3.
- (g)The tar produced is aliphatic in nature. It contains less quantity of aromatic ring compunds like benzene, toluene, naphthalene, phenol, anthracene etc. However, tar acid
- content is higher.
- (h)After carbonisation, discharging of coke is difficult as it swells a lot but does not shrink much finally at the end of coking due to lower temperature of carbonisation.
- (i)Free carbon in tar (which results from the cracking of hydrocarbons) is less. It is about 5-10% of tar. Since cracking (HC-H+C) is less severe at lower temperature.
- (j)Coke produced is weaker (due to less shrinkage) bigger in size and more reactive (due to higher porosity).
- (k)Volatile matter content in coke is more (5-7%) hence it is easier to ignite it because of lower ignition temperature of high volatile matter containing coke. Ignition temperature of LTC coke is about 425°C. (l)Hydrogen content in coke oven gas is less (35-40%) Hence, difference in gross and net calorific value is less.
- (m)Coke yield is more. It is about 77% of coal.
-
-
- **High Temperature Carbonisation (HTC)**
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- (a)It is carried at 1000°C.
- (b)IT produces metallurigical coke for use blast furnace and cupolas in foundry etc.
- (c)Yield of coke oven gas is more in HTC due to more cracking of hydrocarbons (maintain
- methane in coke oven gas) at higher temperature. Yield is about 270-300 Nm^3/to of dry coal.
- (d)Tar yield is less here. It is 3% of dry coal
- charged. (e)Ammonia yield is more (10-
- 15gm/N coke oven gas).
- (f)C.V. Of coke oven gas produced in H.T.C is less. It is about 4200-4400kcal/Nm only due
- to lesser percentage of hydrocarbons resulting from its cracking at higher temperature of
- carbonisation.
- (g)Tar produced has more of aromatic ring compounds (due to crystalisation reaction of straight chain compounds being favoured at higher temperature).
- (h)Discharging of coke is easier as it shrinke finally to a more extent comparatively due to higher temperature of carbonisation.

➢ (i)Free carbon in tar is more (due to more intense cracking of hydrocarbon at higher temperature. It is about 15-20% of tar. Higher carbon in tar chokes the hydraulic main and other tar flow pipelines). (j)Coke produce is stronger (i.e shalter index micum index, abrasion index are more) smaller in size and less reactive (due to low porosity) due to higher amount of shrinkage of coke at higher temperature.

- ➤ (k)V.M in coke is less (1-2%) hence the ignition temperature is more. Ignition temperature of high temp coke is about 605°C.
- ➤ (l)H_2 content in coke oven gas is more (55-60%). It is beneficial for an adjoining nitrogeneous fertiliser plast attached to steel plant (as in the case of Rourkela Steel Plant) which gets hydrogen (for ammonia making) from oven gas by its cryogenic cooling.
- ➤ (m)Coke yield is less (about 70% of dry coal).
- ➤
- ➤ **Physical Chemical Changes During Carbonisation. Progressive events during carbonisation of medium volatile coking coal is given in the table.**

temperature °C	Effect	Nature of products		
		Carbonaceous residue (solid)	Tar and Oil	Gas
300	Initial decompositon temperature	Coal	Nil	Some $CO+CO_2$, H_2O
320	Slight appearance of oil	Coal	Thin, light coloured oil	Above plus some CH_4 and unsaturated
360	Marked evolution of thick coal, oils and hydrocarbon gases, coal residue begins to soften	Partially Softened	Darker, red or brown oil	More CH_4 and higher parafins, some H_2.
430	Evolution of viscous oil and tar. Coal residue becomes softer and swells. Pronotned gas evolution causes bubble formation, rapid decomposition of coal.	Soft carbonaceous mass of maximum volume and hubble structure	Darker brown more viscous oil	Maximum evolution of paraffin and unsaturated hydrocarbons with some CO, H_2 and H_2O.
460	Oil and tar yield reduces, plastic expanded mass solidifies to semi coke	Solid semicoke with maximum bubble structure and weak cell walls.	Nearly viscous oil or tar	Diminishing yield of hydrocarbons water, une in CO and H_2O
600	Oil and tar cease, hard semi-coke starts to shrinks	Semi-coke is harder and shrunken, color is	Non evolved	Gasses namely CO, H_2 and CH_4.

		still black.		
900-1050	Continued shrinkage hardness the coke, structure changes with commencement of formation of graphite lattice.	Hard, silvery grey appearance.	Non evolved	

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- Hence mechanism of carbonisation may be summarised as occuring in three stages.
- Stage1I. Primary breakdown of coal at 700°C yields decomposition products like H_2O, CO, CO_2, H_2S aromatics paraffins, olefins, phenalics, nitrogen containing compounds etc.
- Stage -II. Secondary thermal reaction among these liberated primary products as they pass through hot coke, along hot oven walls and through highly heated free space in the oven involve both synthesis and degradation.