

7th Aug → CPT, Prof. SS

① Basis of Coal

1) Run of Mine Coal (R.O.M) :- that is coal which is extracted out of mine.

2) As Received Coal :- After extraction the coal is loaded on trucks and to take it at processing point. During this point of conveying the properties of coal gets changed. This is known as.

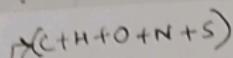
3) Air dried :- During transportation, coal may get dried (moisture content may get changed).

4) Dry Coal :- subtract moisture content and make the rest to 100%.

5) Dry and ash free (d.a.f.) :- remove moisture content, ash from the and take % of the rest contents. That is ...

6) Dry and mineral matter free (d.m.m.f.):

7) moist-mineral matter free / mineral matter free:



Coal Combustion

- doesn't depend on characteristics property of coal.
- depends on conc. of fuel compound.
- Oxygen content of coal decreases with the rank of coal.
- Volatile matter content - - - - -
- Fixed carbon content increases - - - - -
- Bituminous coal has highest calorific value.

Action of heat on coal:-

- devolatilisation:
 - active devolatilisation: oil come along with vapours.
 - It involves emission of volatile gaseous matter
- for peat and lignite start decomposing at around 100°C .
- Bituminous coal $200-300^{\circ}\text{C}$.
- Active devolatilisation of bituminous coal starts at $300-375^{\circ}\text{C}$.
- For bituminous coal, Primary devolatilisation starts at $350-550^{\circ}\text{C}$.
Products obtained \rightarrow Pyrolytic water, Primary tar and gases (hydrocarbon gases)
secondary devolatilisation starts at 700°C .
Products \rightarrow H_2 , secondary tar, lower hydrocarbon gases like CH_4 .
Pitch
- # Peat and lignite only shows primary de-volatilisation.

14th Aug

Prof. SS

Coal Preparation

→ size Reduce Simplest Operation → Separation of fines from the lumps.
(smaller industry)

For larger plants → various operations includes —

- i) size Reduction
- ii) size separation [use screen]
- iii) Cleaning
- iv) drying
- v) Mixing

Revolving Screen
Vibrating Screen
Shaking Screen

very large capacity to handle large amount of coal.

After these methods, hand Picking method is used to remove the visible darts.

Coal is consist of two parts —

- ⇒ dull Coal: - Preferred for furnace and boilers
- ⇒ Bright Coal: - Domestic use and coke preparation.

Coal Petrolium: - Petrography: Study of differentiating coal components by visual method, with or without the help of microscope.

Macroscopic Characteristic of Coal

Vitrain: Bright and Glowing Part of coal

Clarain: Semi Bright Part

Durain: Dull Part

Fusain: Patches of coal.

Float and Sink Test

(washability method measurement)

- i) Total Float-ash curve → Yield of clean coal (float) v/s. its ash content
- ii) n sink-ash → n n refuge (sink) v/s its ash content
- iii) washability characteristics Curve. → How far it is possible to separate the dust from the clean coal by washing.

→ Solvents used for washing: Mixtures of various organic liquids

Benzene (sp. gr. 0.88), Toluene (sp. gravity 0.87)

CCl_4 (S.P. Gravity 1.6), Bromoform (2.1)

Solvent sp. gravity range \rightarrow 1.2 to 1.6 by increment of 0.05.
Float and Sink Test: - CH_4 (sp. Gravity 1.6), Bromoform (2.1)

Weighted Portion of Coal Treated with SP gravity 1.2

float on top surface } air dried, weighed
 Sink at bottom } ash and moisture
 Treated with solvent | content all determined
 | separately at each step.

Float and Sink Method

→ Applied to any particle size of coal, usually 1-2 inch screen size.

→ Air dried coal not very coal
should be used.

Treated with solvent
of ~~starch~~ SP GP 1.25

air dried, weighed,
ash and moisture
content are determined
separately at each step.

Treated with solvent
of ~~starch~~ SP GP 1-25

float } .

sink.

Treat with solvent
of next sp. sp.

Continued

Washing with solvent with sp. gr. 1.6

Mineral Matter of Coal

ii) Inherent Matter: moisture content,

Extraneous matter: Mudstone, siltstone

→ Coal wash is effective for these as they can be removed easily.

Washability characterisation of coal

> SP. gr. of solvents (γ axis) vs. ash content of floats (X axis.) or. sinks

2) Yield of float/sink (y axis) vs. ash content of float/sink (x axis)

If we use bromoform, we need to wash the float and sink with methyl alcohol to remove bromoform so as to make it easier to air dry the content.

It is not easy to evaporate bromoform.

21st Aug, Prof. SS

Recovery of Clean Coal

$$\% \text{ recovery} = \frac{\% \text{ ash in refuse} - \% \text{ ash in feed}}{\% \text{ ash in refuse} - \% \text{ ash in clean coal}} \times 100$$

Expert of carbonisation: % of volatile matter present.
 Ash and P → Concentrated in coke
 S → remaining unchanged

Coal Carbonisation: heating coal at high temp (absence of air) to form coker coal which has higher calorific value than the parent coal.

i) low temp. carbonisation (LTC) at around 600°C

ii) Med. - (MTC) - - - 800°C

iii) High - (HTC) - - - 1000 - 1100°C

Process occurs at lower temp and product formed is soft coke / semi coke / briquette / char. → smokeless domestic fuel.

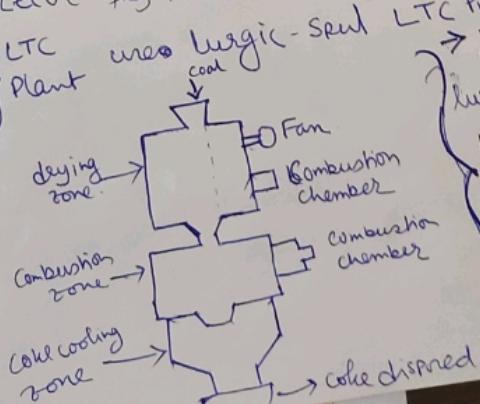
Major Product → coke + coal gas.

NOT Practised commercially. Mostly LTC ad HTC is operated commercially.

In revicoke, coal comp. are more conc., so calorific value is high. That is purpose of carbonisation. [moisture are evaporated + solidified]

LCO (name of revicoke)
they prepare.

Nayveli { LTC
Nasrur } Plant



LTC → While taking through vertical shaft, coal is successively dried and carbonised
 bulge - spout → Coal size 25-125 mm
 LTC → Hot gas remain in drying zone
 Diagla - by the help of big fan. It is removed by chimney after getting cool.
 → at high temp, coal evolves lot of volatile matter, these produce high valuable products (by). Carbonisation gas shouldn't go to drying zone.

avoid

To over-carbonisation —

^{Coal}
 > Direct heating of the charge by hot gases.

 > Movement of ^{Coal} charge by vertical fall.

 > Rotating the carboniser

 > Using fluidised bed,

→ coke is cooled by injecting water or cold gas, which is obtained from drying zone.

→ Combustion gas is taken out and key products are formed.

→ Products are —

i) Semi Coke

ii) low temp. tar

iii) crude low temp. spirit

iv) Ammoniacal Liquor

v) Gas.

Quantity / quality of prod depends upon that of coal.

Primary tar

[complex mix. of —

higher phenols,

Substituted aromatic

hydrocarbon, various N- and O-

Compounds of Carbon, hydrogen]

Crude low temp. Spirit :- Crude benzol (LT) with Paraffins, naphthenes and olefins, Benzol [mix. of benzene, toluene, Xylene, Solvent napthene etc.]

Gas: [mix of CO_2 , N_2 , H_2 (33%), hydrocarbon 50%]

22nd Aug

► **Coke Oven** (used for Production of coke from coal)

i) Beehive Coke Oven: Heat transfer is by radiation and by conduction from layer to layer.

ii) By-Product slot type

(not only produce coke but also capture various by-products)

By Products are burned in i) to supply heat of carbonisation, whereas by products are removed in ii).

Coke from coke oven → used in metallurgical purpose

Coal gas → Principle use as town gas.
↳ (Coke oven gas)

Retort coke → unsuitable for metallurgical use, but is a good domestic use.

→ specialised vessels or chambers used in production of gas from carbonaceous solids.

Gas Retorts → horizontal Retort → used for wood gas production

↳ Intermediate-retort

continuous-retort

② demerits of beehive Coal Oven:-

i) no recovery of by products

ii) lower quality coke due to partial combustion.

iii) lack of flexibility of operation

iv) Production of quality coke only by using good coking coal.

Merits:-
coke of reg. reactivity
good coking quality

extremely good quality, strong and blocking

low capital and running cost

v) Coke production is not connected with the availability of a market for the byproducts.

Coke: Hard, Porous, Carbonaceous material.

source of reactive carbon in blast furnace, gasifiers, boilers.

→ source of coke to steel works

metallurgical industries

- ① Test for Coke Strength or brittleness:—
- ↳ Shatter test
 - ↳ Micum Test

Three imp. Properties of Coal:—

Purity	Strength	Reactivity
↓ Moisture, ash, sulphur, Phosphorous	↓ hardness/brittleness measured by Shatter, Micum test	→ no standard reaction tests, but Porosity may give an indirect measure of reactivity.

② Shatter Test: 4 times coke is dropped from a height of 6ft over a metal plate. After that it is sieved in 4 types of different sieves. And the hardness is reported as the % of oversize and undersize after impact. Eg. if 80% coke remains intact after specific sieves, the result is recorded as 80% shatter. Higher shatter values indicates stronger and less brittle coke, which is desirable.

③ Micum Test: The impact, the result is recorded as 80% shatter. Higher shatter values indicates stronger and less brittle coke, which is desirable.

④ Micum Test

Purpose: to measure the resistance of coke to abrasion and measuring its structural integrity when subjected to mechanical wear. This is particularly important for coke used in transportation and handling systems.

Process: Coke samples are rotated in a metal drum at a definite rate for a set specific period and reported as % oversize, undersize of a specific screen.

Coke with lower Micum index is preferred for applications where it needs to endure mechanical wear and abrasion without significant detonation.

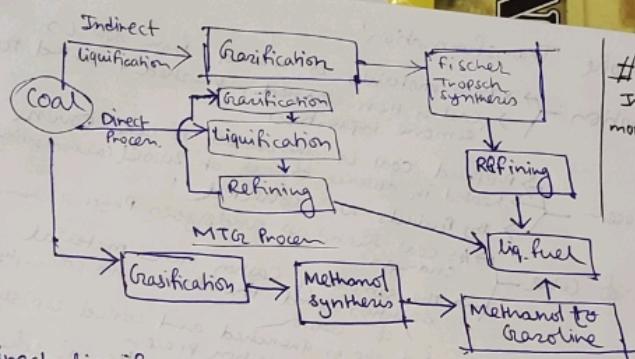
Coal to Coke Transformation:—

- a) Coal Preparation:
 - Raw materials is mined from sources
 - Coal is then cleaned, crushed, sorted to remove impurities
- b) Cooking Process:
 - Prepared coal is introduced to coke oven
 - Heated in absence of air at 2000°C [Carbonisation]
 - By products are collected
- c) Formation of coke:
 - As coal heated up undergoes physical, chemical changes
 - The remaining carbon rich material solidifies and transforms into coke, high % of carbon
- d) Quenching and Cooling:
 - Hot coke is quenched and cooled rapidly to stop carbonisation process.
 - Often done by spraying the hot coke with water or another cooling medium.
 - This rapid cooling helps coke from further softening.
- e) Coke sorting and handing
- f) By Product Recovery

g) Quality Control

- h) Coal liquification: Adding off or increasing hydrogen content of a coal is called coal liquification. Carbon is called 'carbonisation'.
 - Single stage
 - Direct
 - Double stage
- These are three options for Coal Liquification plants
- (Hydrogen content)
in liq. coal > (Hydrogen content)
of solid fuel coal

- H-C type liq. fuel obtains by—
- i) Hydrogenation of coal [Bargius Process]
 - ii) Solvent extraction of coal and hydrogenation of coal extract
 - iii) Refining of tar and oil obtained by carbonisation of various solid fuels
 - iv) Gasification of solid fuels into synthesis gas and conversion of latter into liq. fuels and chemicals.
Exmp. Fischer Tropsch Process, MTG (methanol to gasoline) Process.



Efficiency of Indirect Process is more than direct one.

- Direct Liquification → i) Single Stage → Produces distillates via Primary reaction
- ii) Two Stage → Produces distillates via two reactions in series

Two main key stages —

- i) Hydrogenation: At this 1st stage Coal is liquified. The crushed coal is mixed with hydrogen-rich solvent and mixture is subjected to high pressure and temp. conditions. During this —
 - a) Coal molecules breakdown into smaller fragments, ~~soot~~ releasing volatile compounds
 - b) leads to saturation of carbon-carbon and carbon-hydrogen bonds, converting coal's complex str. into simpler one.
 - c) Sulphur, Nitrogen present in coal may also undergo hydrogenation to make the product cleaner and simpler.

- ii) Depolymerization and Hydrocracking: After hydrogenation, resulting mixture still contain complex hydrocarbons. So additional hydrogen is introduced, mix. is further heated and pressurised.

a) The complex hydrocarbon from first stage break down into smaller, more uniform hydrocarbon.

b) High pressure favours cracking of larger molecules into smaller one.

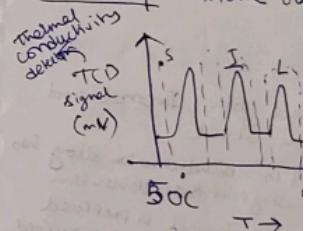
c) The goal is to produce liquid hydrocarbons with properties similar to retro petroleum-based crude oil.

29th Aug, B.B.

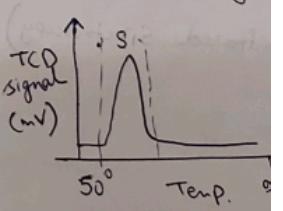
Surface acidity / basicity

- Feed / Producer gas (NH_3)
- o low T → strong
- o Intermediate T →
- o High T → low

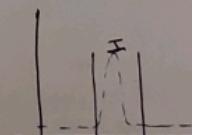
Cae - I Existence of

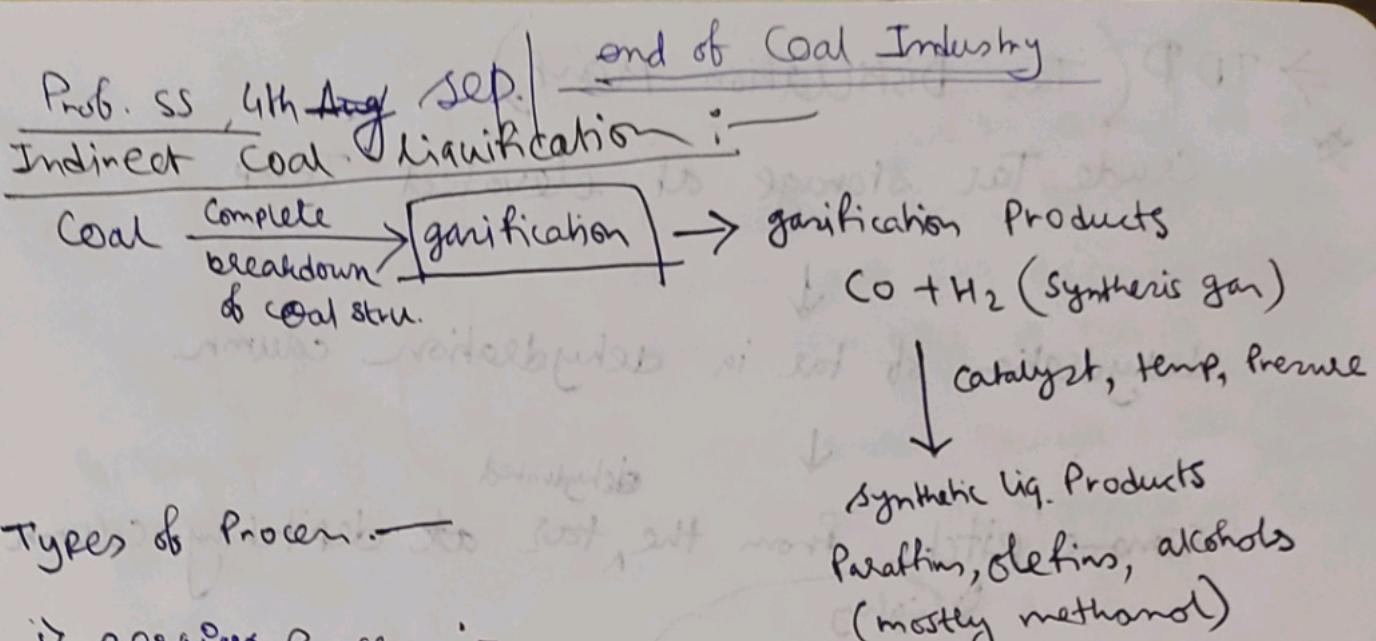


Cae - II Existence of Strong C



Cae III → Instinctence





i) Bergius Process :-

ii) Fischer Tropsch Process: Coal → Gasification → Syn gas → Fischer Tropsch Catalyst [Co, Ni, Ru, NiCr] → light hydrocarbons (gasoline, diesel)

iii) Low temp carbonisation: Coal to tar production.

Tar acid is mix. of various kind of phenols, group of cresols, xylenols along with the aliphatic group.

Tar acids → Group of phenol: crude phenol

Tar acids → Crude cresol

Tar acids → Crude xyleneol

HBTAs (High Boiling Tar Acids): unsaturated, big molecule

Crude phenol,

Tar acids are valuable and can be converted to other

chemical after refining

→ Tar distillation plants to recover core chemicals from Taracid.

→ Produce tar acid from crude tar
recovery of ammoniacal liquor
from coal carbonisation plant.

→ TDP (Tar Distillation Plant)

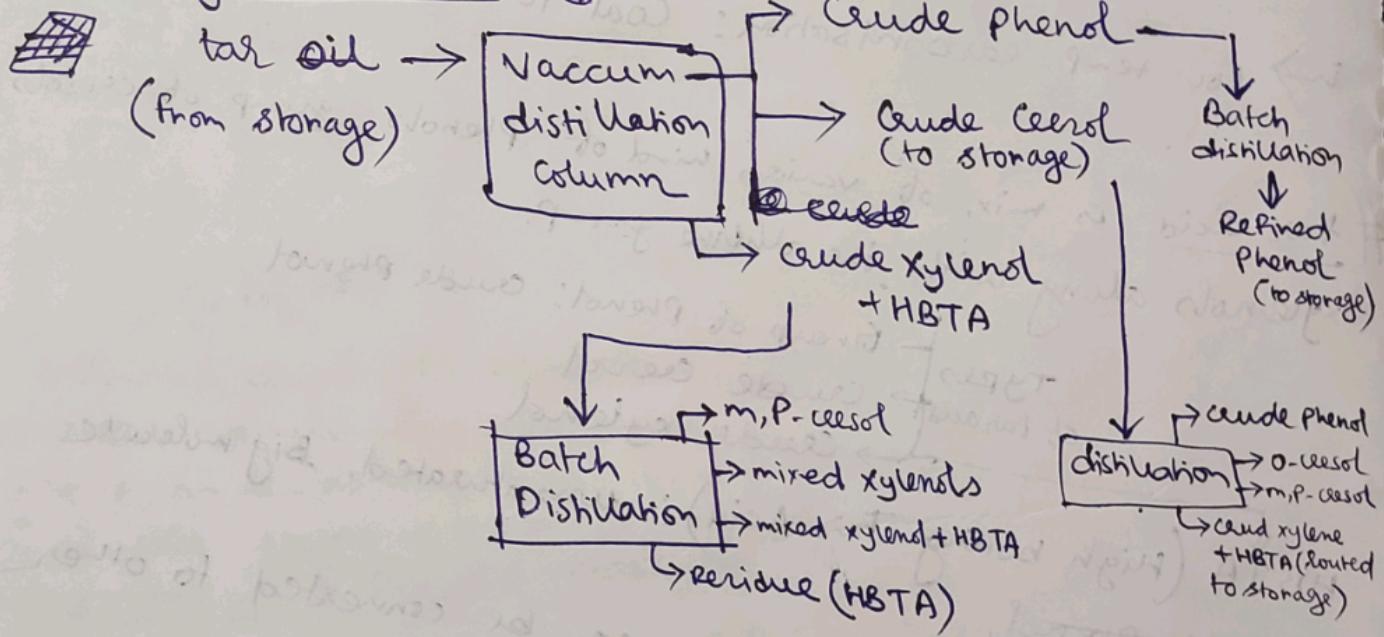
Cunde Tar storage at elevated Temp.

↓
dehydration of tar in dehydration column

↓
remove 'pitch' from the tar at depitching column
 (Canadian)
 highly
Carbonaceous Pdt.

↓
separate tar oil in fractionating column
 (contain tar acids)

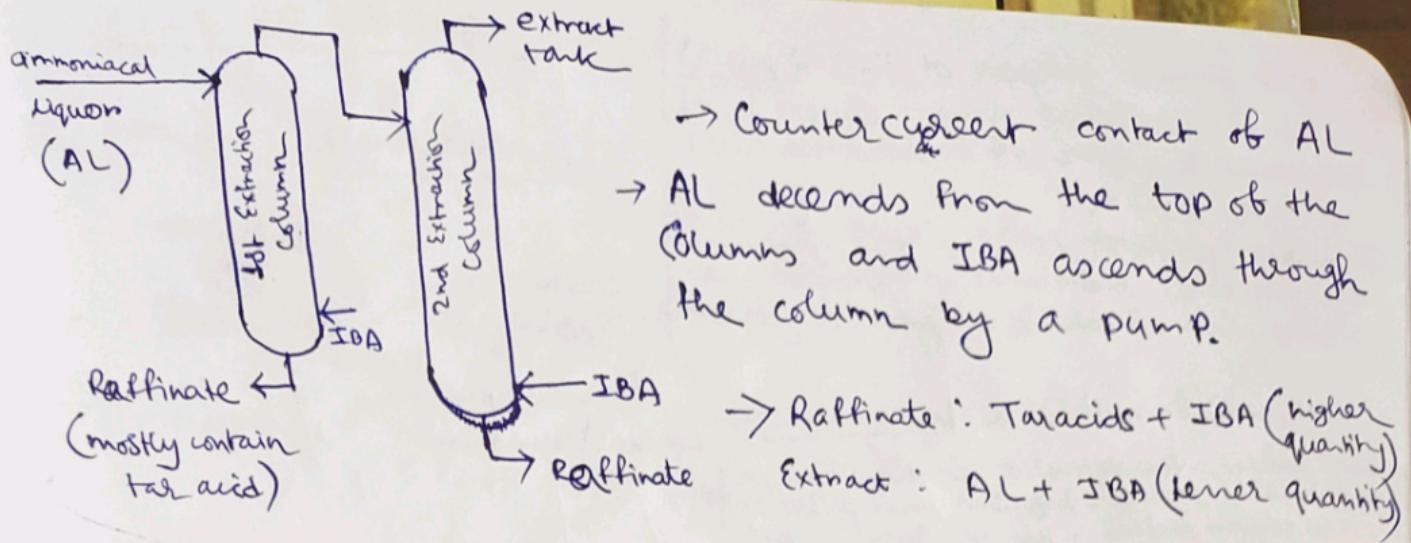
→ Recovery of Tar Acid



② Ammoniacal liqu. extraction Section

Purpose: to extract tar acids in the ammoniacal liquor
 Using the solvent isobutyl alcohol (IBA)

→ is done in two stage extraction column



② Extract and Raffinate Still Section

Objective:

- i) To separate solvent from tar acids
- ii) To recover entrained solvent from extract

Steam stripping is the process for recovery of pure AL after distillation.

\rightarrow Aq. NH_3 liq. of $\sim 35\%$.

5th Sep, Prob. SS

Preparation of O₂, N₂ from Air

Air Separation Unit (A.S.U)

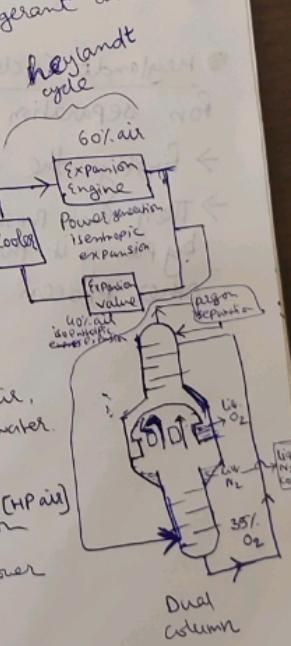
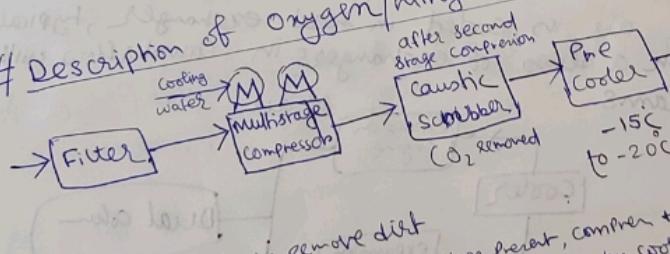
Uses of O₂

- i) Major use \rightarrow Production of steel in open-hearth furnace
- ii) Oxygen to remove scales by using oxyacetylene flame (steel industry)
- iii) In chemical industry \rightarrow e.g. acetylene and ethylene oxide Production (large consumer, ~~and~~ Partial oxidation or hydrocarbon to produce NH₃, CH₃OH etc.)
- iv) Metal working, underground gasification, fire fighting, medical purpose etc.

Uses of N₂

- i) Major usage of N₂ is in Gaseous blanket (excluding oxygen/moisture)
- ii) To achieve extremely low temperature (-210°C)
- iii) To produce ammonia (NH₃)
- iv) Use in food processing industry as refrigerant and transportation.

Description of Oxygen/nitrogen plant

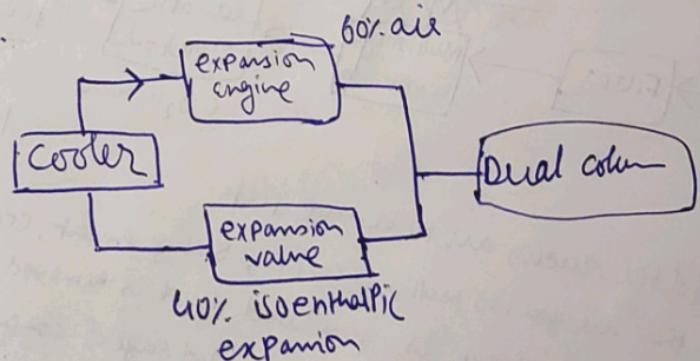


- \rightarrow Filter removes air to remove dirt
- \rightarrow Then air goes to multistage compressor, 5 stage heat exchanger, lot of heat is generated. Heat is removed by cooling water.
- \rightarrow Caustic Scrubber CO₂ is removed. (2nd stage of compression)
- \rightarrow 165 - 170 kg/cm² Pressure is attained after MS. compression (HP air)
- \rightarrow after final state of compression, air is taken to cooler to lower temp.

- After that, air successively goes through different stages -
 Vapourisation cooler $\xrightarrow{(\text{ie. } \text{N}_2 \text{ cooler})}$
 oil separator \rightarrow moisture separator \rightarrow oil filter to remove
 oil present \rightarrow alumina dryer (remove left out moisture) \rightarrow dust filter
 (remove minute dust particle)
- (60% air)
 Expansion engine, expansion is done, some air got liquified
 rest 40% air goes to isenthalpic expansion
- Expansion valve give higher efficiency than expansion engine.
 Because expansion engine is used to generate the power to run the entire system.
- After that, send it to lower end of dual column.
 at middle of dual column
 Heat exchanger, condenser both lower column and reboiler
 for upper column.
 O_2 is heavy so comes at reboiler side

■ Heylandt Cycle: is thermodynamic process used in A.S.U.s. for separation of air's primary component: N_2, O_2 .

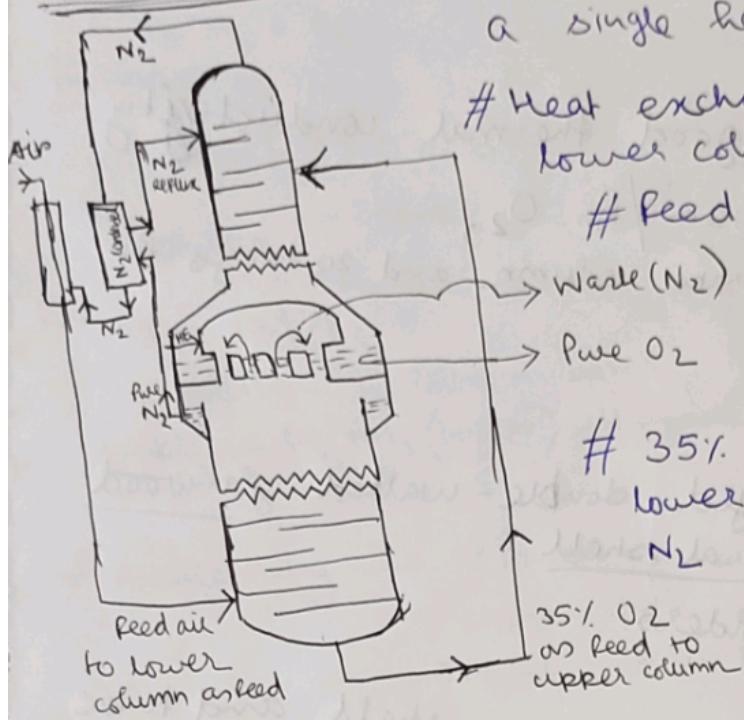
- firstly the air is compressed using a compressor.
- Then high pressure air is cooled in heat exchanger, typically by passing it through a series of exchangers in counterflow with other process streams.



11th sep, S.S.

Dual Column

Two tray type distillation column formed by
a single heat exchanger at the middle.



35%. Pure O₂ from the bottom of the lower tray, after exchanging heat in N₂ superheater as fed to the upper column as feed. It is subcooled 35% O₂ as feed to the column to avoid flashing in the column.

The upper column pressure is 0.5 kg/cm^2 ,
 whereas lower column pressure is 5 kg/cm^2 .

Pure O₂ is collected at the reboiler side of the upper column, the pure N₂ is obtained at the condenser side of the lower column. The O₂ is 12.8% more than that of N₂.

The boiling point of O_2 is 12.8°C more than that of N_2 , so O_2 descends through the column and N_2 ascends.

O₂ Product is obtained as saturated vapour from the bottom of the upper column.

All the streams, which are introduced into the upper column at low pressure are subcooled in the N_2 superheater to avoid throttling and flashing.

Throttling :- Process used to reduce pressure of a high pressure gas stream. It is ~~operated in the~~ employed to achieve the desired conditions in low-pressure column of a dual-column distillation system.

Flashing - is a phase separation process used to separate high pressure gas liquid mixture into vapour and liq. Phase. Commonly in low-pressure column of distillation.

MOC of dual column and trays:

Column → ~~Braz~~ Brass column or cast iron with brass lining.

Trays → Brass/Cu for good thermal conductivity
For the production of $400\text{m}^3/\text{hr}$. O_2 ,
no. of trays = 56 for upper column and 20 trays for lower column.

Storage:

liq O_2 → specially lagged double-walled glasswool insulated spherical shell.

gaseous O_2 → Cu-shell holders.

Heat exchanger and cooler are shell and tube type. Brass tube with mild steel shell.

Importance of ~~coke~~ coke in steel industry —

i) Coke as fuel: it is used to produce the heat needed to melt the iron ore and limestone.

ii) Coke is a Reducing Agent: It takes the oxygen out of iron ore, leaving only the pure iron.