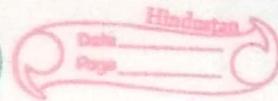
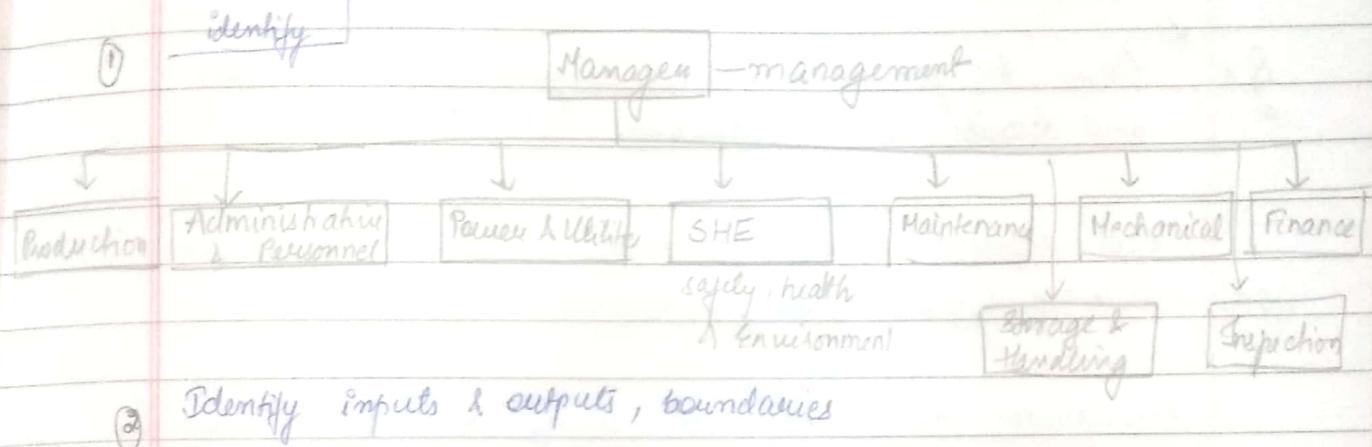


07.01.19

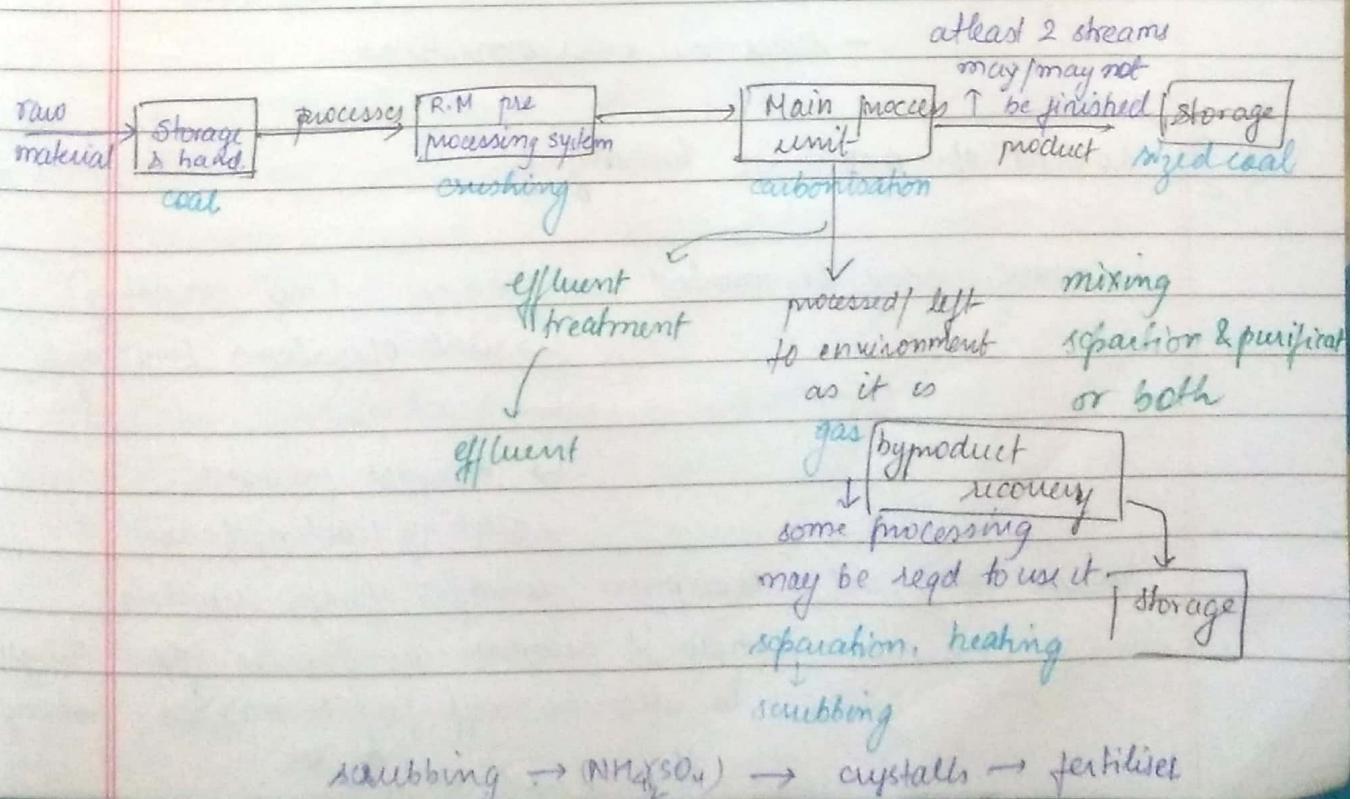
Chemical Processes Plant



→ Structure of any operating industry



③ Units, processes, intermediate processes,
↓
detailed functionalities



We generate effluent in every unit, must be handled
Power & utilities in each unit.

Q. Draw the generalised block diagram of an industry.
and describe its functionalities.

- allot different processes to blocks
- OR - start identifying blocks / processes

Descriptions can be conveyed using engineering drawings

- plan
- elevations
- side, front view
- dimensions
- * - isometric view

makes representation simple

* Block diagram:

- processes (overview), subprocesses
- sequence, interconnections

Q Content of B.D in industry?

- capacity may be marked on processes (not necessary)

↳ unit operations (mixing)

↳ reactions

↳ transport processes

↳ heating / cooling / etc

- process component description using specific symbols

→ now it becomes a Process flow diagram
to describe diff functionalities using

* sub processes *

A CO
Controllers Param

(b) P

→ Plant

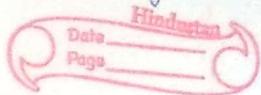
• Plot

(a)

(PFD)

• 3D

→ 3D



Q) List these symbols ?

8. Unit operations & unit processes -

dry processes has 3 components -

i) vessel

ii) piping

iii) pumps & compressors / conveyors, scoops in solid handling industries

→ we've to know about these three

Parameters :

i) T ii) P iii) Level iv) Flow v) Composition

v.v.Imp

very frequent

→ indicators for these parameters

→ we should ^{also} know these to be maintained

→ only indicators

with ~~and~~ controllers "closed loop"

↓
maintain level using inflow or outflow

(CV)

(MV)

A CONTROLLER IS A CLOSED LOOP

Controllers parameters not associated with parameters - OPEN LOOP

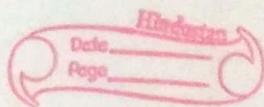
(b) P& ID : Piping & Instrumentation diagram

→ Plant layout for location of equipment

• Plot plan is a plan
elevations unknown

(P&I) • Isometric - 3D

-



Tools reqd to understand a plant :

BD

PFD

P&ID

Plot plan

Isometric

08.01.19

Toluene + solvent (A.A.)

140°C

5 kg/cm² gauge

high P reqd because of liq. phase of reactants

- high O₂ in this

Batch process - 40 min (residence time)

conversion = 90%

side reactions (no)

- Reactor

- Batch or continuous reactor? - economics?
- how to recover solvent? - throw or reuse?
- how will the temp' be maintained
- will it be a closed loop process? any recycle?
- separation techniques?
- source of O₂? - sparging of air (at bottom)

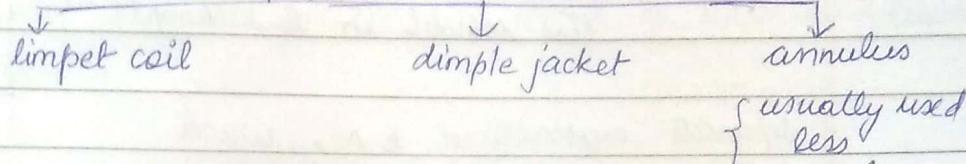
→ high t_b , volume inflow
inflow rate } use batch
go for economic analysis ideally. } reactor because

$\frac{V_{final}}{V_{initial}} = 10 \text{ min}$ sparging will increase volume
due to hold up of air

airspace - 30% of volume of liquid [$V = 400 \text{ ft}^3 \text{ at } 30\% \text{ more}$]

how will it be heated?

— heating jackets



- latent heat of steam at critical temp & pressure is '0'
no distinction

- 15 kg/cm^2 40°C superheat → closer to ~~T_c~~ T_c , less Δ
- ✓ $5''$ 5°C superheat more Δ

- How far we are ~~more~~ from saturation?
sensible + latent

cooling steam - heat transfer from ^{gas} film
condensing H.T.C. \gg gas heat T.C.
so, closer to saturation is preferred

- As vapour comes out of reactor, throttle it to make pressure 5 kg/cm^2
- Excess air has to be throttled
- Air coming out will contain vapours of AA & toluene cannot let it escape else we lose solvent & toluene

we will have a HE on top that condenses these & refluxes to reactor

- we cannot depressurise it, it will vapourise everything
- we will cool using C.W. in the same jacket.

We will draw the reactants
Benzoic acid, toluene

crystals of benzoic acid in ice water
↓
insoluble in low temp'

separate crystallised B.A., wash
with to water to remove remaining
AA

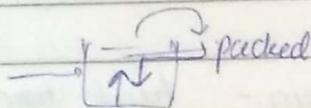
dry - compartmental drying - hot air circulation

Distill and separate water with AA.
(higher B.P.)

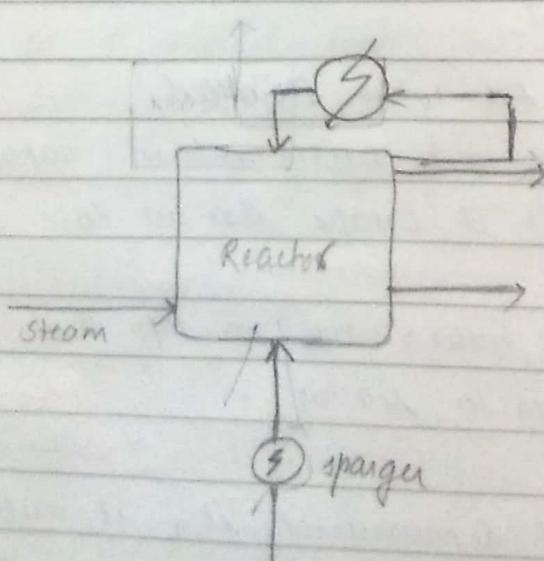
vapour - water

Batch distillat^n

Rayleigh - only 1



We can use variable / constant reflux ratio & in batch distillation



steam trap

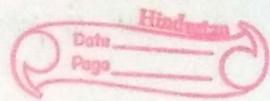
mechanisms

leam at least 2 types

Fres mody name
inverted bucket type

steam trap

Perry's Handbook

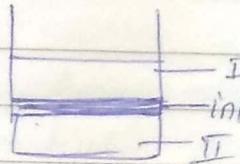


List - Requirements of steam, power

List - pollutants, effluents

- storages of raw material & products

We will not be able to recover 100% of water & toluene using decanter.



interface — what we do with it?

recycle to the

place where
reactor drains it.

(chilled mixture) instead of

(chilled water)

(i) Process

(ii) Material of construction

- most plants are made of ferrous materials,

* suitable metallurgy for different equipment in plant?

Study petroleum refinery?

i) What is the source of petroleum

Brice

Volume of consumption in India — 246 million metric tonnes

Where do we have them?

Why do we " " where they're located

How do we define quality of crude

- related to quality of pet we need

- flash point

- smoke point

- ~~sulphur~~

BS6, BS4

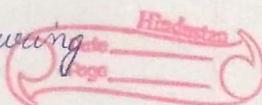
- list of products for

end uses — transport, fuel (cooking)

specifications

demand pattern

What is petroleum crude oil? naturally occurring hydrocarbons found under crust



how crude & pet are transported

Processes which will convert crude to pet

In refining section

— basic processes which will convert crude to pet.

—

Answers:

1. Bombay High, east

2.

Product has to be something sellable.

Quality:

— less impurities

— lower the s, better the quality

— dirt, water, silt, dissolved salts in aq. phase

BS&W — Basic sludge & water

< 0.7% by volume — acceptable pet. for.

p'

usually

— heavy metals : metals with density above 8.

few present as organometallics.

concⁿ of heavy metals will be higher in higher molecules

— ash content will tell which sample has heavy metals
oxides of metals present in residue

0.84 g/cm³

0.846 g/cm³ at 15°C

— density is a fⁿ of temp

earlier 60°F

now 15°C is the standard temp for defining density

Products

density (bitumen) at 15°C - slightly $> 1 \text{ g/cm}^3$
 diesel < 1

All oils will be floating on water.

- lightest products - LPG ^{clean} (0.55 g/cm^3 at 15°C) - houses, cars, glass
- next heavier pdt - naphtha (light)
- gasoline / petrol ~ heavy naphtha ($0.73, 0.74, 0.745$)
- kerosene / aviation turbine fuel \rightarrow jet planes ($0.77 - 0.78 - 0.784$)
diesel oil

glass industry has direct contact with flame. A very clean fuel is reqd for this - LPG

- diesel
- high speed diesel (HSD) (0.81) - 100% distillate fuel
- light diesel oil (LDO) ($0.88, 0.87$) - blend of " with linear alkane] a small proportion of residual fuel

furnace oil - initial light up done with LDO, then use fuel oil put furnace oil burners
fuel for compression ignition engines run at low speed, irrigation

brands of fuel
summer winter

- bitumen (\approx slightly above oil) - roads, roof coating, corrosion protection of UG pipes, water proofing

Petroleum coke - petcoke

- making of electrodes in metallurgical industries like Cu, ~~Si~~, Al, Ag
- Electrode - only from low S crude in India \rightarrow Guwahati

- impured

Distillate yield
low 33-35% ↑
High organic
acidity

Sources of crude - Digboi, Bombay High,
Nahal Karia, Gujarat, ?

Kalol crude

Location
Quality

Price per tonne - LPG > bitumen

28° API, S - 0.1%
Pour point +27°C

- lighter the petl, higher is the price

- heavy naphtha can be converted to motor spirit : gasoline
- Petrochemicals buy naphtha

- Naphtha based petrochemical

or other type - natural gas based

- fertiliser industry

urea

ammonia → C

N₂, H₂

naphtha

air hydrocarbon

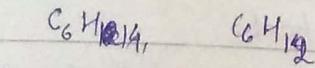
water splitting

1st hydroelectric project - Mangal

- higher % of H valued
- It is more difficult to crack lighter molecules less refractory
- chance of cracking a heavy molecule is more - more no. of cracking points

cracking T (LPG) > cracking (naphtha)

- lighter naphtha will have higher wt. of H



more H

light

aromatic
petrochen

precursors
~~add~~

aromatic

LPG

should

- Cu

1

- odo

- de

- H₂

- v

- m

- g

aromatic

petrochemical feed stock uses
3 basics

heavy naphtha
(higher ~~SO~~ for aromatics
than paraffins)

precursors to benzene, toluene, xylene etc (paraffins) will
~~also~~ (BTX)

BTX

aromatic

LPG specifications

- should not contain free H_2S (corrosive, explosive)
- Cu corrosion test - limits presence of any S compound
 - ↳ result will be worse if S present (~~R~~) (mercaptans)
 - ↳ so we cannot add mercaptans too much

- odour level? - specification?

- dose ethyl mercaptan added ~ 2 ppm

- H_2S (poisonous - nasties will get numb if exposed for long time)

- vapour pressure limit (8 kPa/cm^2 gauge at 65°C)
max temp[↓] attainable by iron

in hot summers ~ 60°C .

65 is maximum attained when left in very hot conditions.

- no composition specification for any of the pools

($\text{C}_3, \text{C}_4, (\text{C}_5 - \text{small})$)

- 95% evaporation - weathering test
when

-2 to 2°C

so that it does not contain lighter HCs

↳ if reaches above this, ~~SO~~
benzenes are present

Branch paraffins also have high O.N.

acc to BE's

Findings

Date _____
Page _____

Gasoline / Motor spirit (Technical name in India)

- used as a fuel in engines (spark ignition)

i) Octane number

- if O.N is X, it has same ^{of combustion} performance as a mixture of $X\%$ iso-octane by volume
 $100-X\%$ n-heptane

pure iso-octane \Rightarrow O.N = 100

while used in same engine.

(a) Cet
Oc

ex

Fuel

Kerosene

A

ATF

- smoke point $\sim 21\text{ mm}$
(min)
- technical name
- superior kerosene
- (lower limit)

- ✓ slightly lighter
- freezing point
cannot be above -55°C
- flash point (lower limit)
- aromatic content %

Diesel : - used in compression ignition engine

(i) Cetane number -

X - cetane % by volume

$100-X$ - alphamethyl naphthalene

specifications of octane number for gasoline & diesel in
difference in
lead content the petrol pumps?

(ii) tri

Hydrocarbons

P	O	M	A
Y.H	Olefins	naphthalene	a

(iii)

burner - pilot burner (contains ZPG)
light ↑
before other burners in the pit

(i) Octane no: highest for paraffins (for same C-no.)
Octane no: " " aromatics

as increasing octane no.?

Fuel oil:

- viscous (cannot drop quickly)
 - use sprayer (- spray nozzle where we have pressure atomiser)
 - most common in industries - stream breaking liquid into droplets
 - supply pressure ~ above 80
 - easily atomised depends on most importantly kinematic viscosity
- most ind. burners — 10-15 centistokes at the burner tip designed for

how to ensure:

- preheat (viscosity decreases)
- stored in that way.

(ii) ~~kinematic viscosity~~ (upper limit)

- strong fⁿ of temp^r
- specificatⁿ at 50 °C

summer

(higher)

170

winter

120 check

in summer, we can afford to have higher v.

(iii) ~~freezing point~~

diesel congeals at lower temp

- specificatⁿ - pour point

- diff in different states - why?

Bitumen:

- softness (should not be sticky in summer)

(i) Penetration number checks this →

Block of bitumen — standard needle over which a cut is put.

Remove needle, weight allowed to fall for 5 sec, mm it has penetrated

$$P.N = \text{mm} \times 10$$

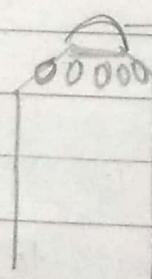
More the P.N, softer is the bitumen.

most common — 80/100 90 — P.N b/w 80 & ~~90~~ 90
8 & 9 mm

30/40 — hotter areas (desert)

60/70

Bitumen emulsion — when we cannot pour in colder areas or cannot melt it solvent is added that evaporates

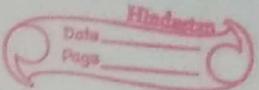


— small bushy flame

engine — [measure vibration]

wear devices to measure them

Operadic combustion — causes



Spark ignition

- mixture of fuel & air compressed, then combusted
 - almost adiabatic ($T \uparrow$ to 60)
 - if sporadic ignition occurs during compression knocking occurs. — poor power consumptⁿ

Compression — only air is compressed ($T \uparrow$ to 600°C)

fuel sprayed from top
unregulated air on piston, poor power consumptⁿ

Aromatic g. good for spark ignition engine

Petroleum coke :

- All of these have properties defined based on quality of end use.

Gas separation :

- i) distillatⁿ — diff in volatilities

The proportion of pett demand & pet crude compositⁿ not same.

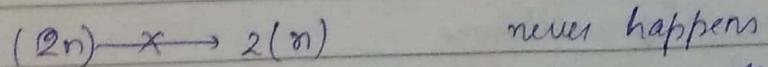
India - demand of kerosene is max^m

How do you meet demand?

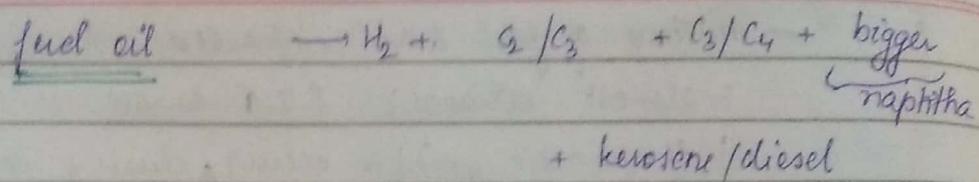
- convert some unwanted to that wanted

Usually, more C, less demand

so, we crack large & heavier hydrocarbons into smaller ones.



Usually, some small molecules are also generated.



Crude oil Dist. col. / atmospheric dist. col.

\downarrow kg/cm²
 typically operates at 1.2, 1.3 @ gauge

Characteristics of C.D. cl.

1st component - very small amt of C_1
 C_2 - non condensable - fuel gas
 C_3/C_4 - LPG
 C_5 - naphtha B.P. $\sim 140^\circ\text{C}$, indicative value

$\boxed{\text{C}_5 \text{ 140 cut}}$ \uparrow
 ATF $140-240^\circ\text{C}$

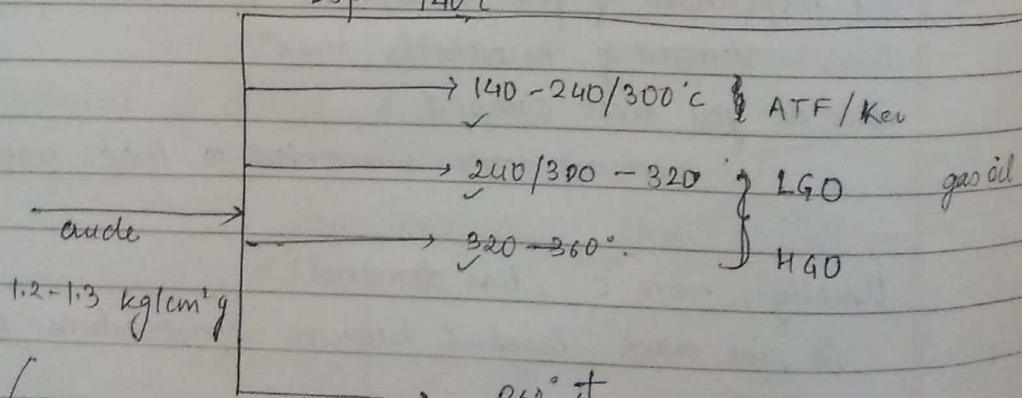
I can separate a cut of $\frac{140-240}{\text{ATF}}$ or $140-300$ \downarrow Kero

diesel upto 360°C

Reduced crude oil — $360 + ^\circ\text{C}$

C.D.C.L.

ibp - 140°C



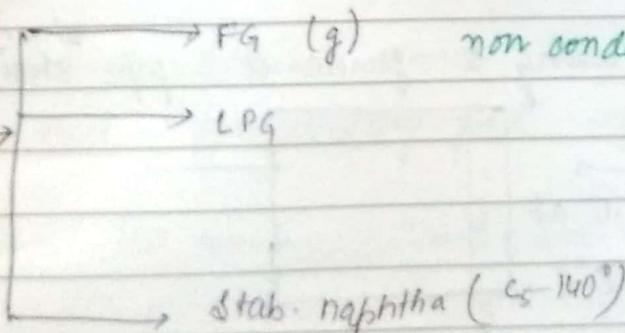
has min^m of 2 columns

working in pairs

Continuous fractionator with side stream draws

- operates at $1.2/1.3 \text{ kg/cm}^2$ gauge
- no reboiler
- side stream draws

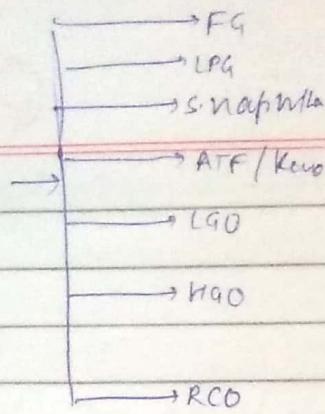
naphtha stabiliser col.



What decides dist. col. O.P.?

- boiling point of top pdt.
- top pdt to be refluxed should be in liq phase
- condensed using cooling water
- $T_{in} = 30-33^\circ\text{C}$ (India)
- LPG should be liq at $50-55^\circ\text{C}$ for effective heat transfer to occur
- It will be at bubble pressure ($\sim 10-12 \text{ kg/cm}^2$)

unstable naphtha has vp. much less than $10-12 \text{ kg/cm}^2 \approx 1.2-1.3$



such high capacity with such p_h high pressure will be expensive

Hindustan
Date _____
Page _____

— we do not draw S. naphtha from 1st column

Crude DCL does not have a reboiler

to maintain the bottom pdt. compn's

without OR add preheated feed

- will reduce load of reboiler - not proper sol'n

OR we can put

inert live steam at bottom

will reduce v.p., lighter components will vapourise fast.

Pressure at bottom - $i + 1.2/1.3$

36°C at 1 atm

Heating surface should be $\approx 400^\circ\text{C}$

Cracking at 400°C

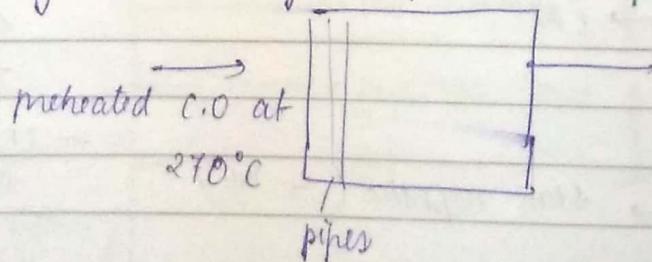
- coking of reboiler

- use bottom stripping stream

anything boiling at $< 360^\circ\text{C}$ stored at $\approx 40^\circ\text{C}$

This heat is used to preheat the crude feed.

Final heating done using a furnace - pipe ^{steam} steel heater



Crude contains large amt. of brine - water with dissolved salts

- salt deposition

- removed in a unit called Electric dissolving unit.

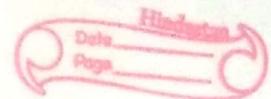
② Cracking

③ Hydro. -

high potential

○ polar H₂O

low pot.



will start oscillating
collide with other,
become bigger,
settling velocity is
more.

Impurities :

(Sulphur)

- dissolved H₂S — in LPG,
FG

small) ATF / Kero

- thiophenes

more S in RCO than LPG
 \downarrow 3-4% \downarrow ppm \Rightarrow heavier the H-C, more
is the sulphur

Kerosene — 0.45% S — removed using Hydrotreatment
as organosulphur compounds
 \downarrow
form H₂S

has high vp

X/ Hydodesulphurization:

there is saturation of bonds
during hydrotreatment

easy to separate
we can strip it out

○ Streams which we cannot sell outside can be used as ~~to~~ to
meet supplementary fuel requirements.

100 tons

— 0.4 tones loss

— 99.6 → part as fuel

fuel gas
fuel oil

column
Cracking
(0.2-0.4%)

Captive P.P. — power generation using own ~~not~~ components

pcft = total - lost - ~~not~~ fuel

crude oil - olefin content is very less

Hindustan

Date _____

Page _____

Chemical process — cracking

— convert paraffins to aromatics

$(C)_n > C$

has high O.N.

— more C_6^+ in heavier cut

④ Refining — catalytic reforming of naphtha
usually 'Pt' — cat.

Plat former

fastest

$C_6H_{12} \rightarrow C_6H_6$ ① catalytic dehydrogenation

adds max^m O.N.

inc in O.N due to this

from of naphthenes to aromatics

$C_6H_{14} \rightarrow C_6H_{12}$

② dehydrogenation of paraffins to naphthenes

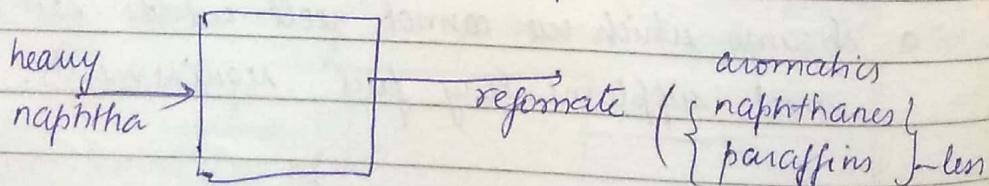
These 2 ~~not~~ will generate H_2 also.

this H_2 will be

some amt. of cracking is inevitable
 H_2 will immediately hydrogenate the cracked ones

→ ext
→ C
→ P
→ LPG
— hydrocracking ③

petrol can be sent to LPG

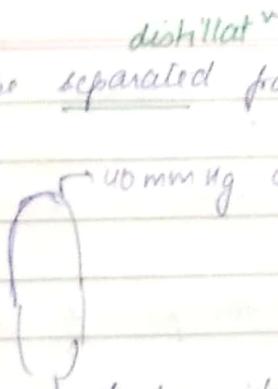


higher O.N for motor spirit

T_{BPT} - true boiling point cut temp

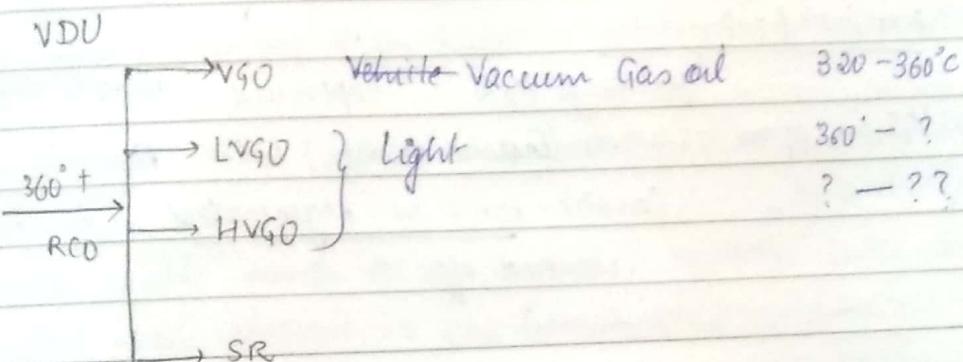


Bitumen can be separated from RCO by in no VDU by reducing N.P.



- col. top pressure is reported as col. pressure
 $(\text{press.})_{\text{bottom}} > (\text{press.})_{\text{top}}$

→ short residue (SR)



Heavy pdts
— Bitumen

— Coke
— Fuel oil (2) (170 at 50°C)

RCO has 2 of ~~~400-300~~ 300-600 centistokes at 50°C

excess coke → RCO cannot be sold as fuel oil

→ coke formation will cause choking

do a mild thermal cracking process with an aim to reduce viscosity of oil

visc breaking

not catalytic

What decides severity of cracking → low P & high P T

do not heat it much to prevent sintering

→ temp ↑

— no. of pdt molecules ↑

anything which is heavy

operated at ~ 500°C

liq. phase cracking

— heater is the main component

— separator — fractionating column

visc breaking fractionator

of catalyst

bending of pipes

28.01.19

- heat recovery HEs.

largest op. cost contrib is heat energy cost

- heat in the form of steam, heater, ...

- Naphtha / Kero has small amt. of H_2S - removed by amine treatment, wash with amine & was regenerate for large H_2S expensive monodiethylamine when H_2S in ppm - wash (Caustic wash) with caustic soda. Caustic can't be regenerated - has to be washed off.
 - economic
 - simple to handle

Caustic wash followed with demineralised water

- some fine drops of Caustic so is bound to remain in tank.

In all tanks with , there can be some water always at bottom - from atmosphere.

Two types of roofs used in refinery

- fixed - kerosene
- floating - when vp of solvent is less, vapours also present in ~~fixed tanks~~ above it, if the floats, vap(solvent) lost to atm. crude stored in here, naphtha, motor spirit

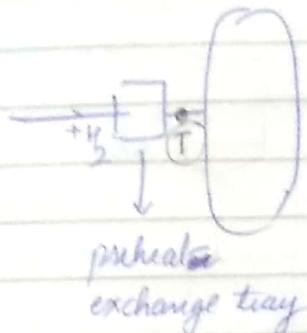
Importance - price of crude

- energy consumption

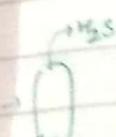
Hindustan

Date _____
Page _____

22-01-19



preheating to a specific temp^r
- regulated heating

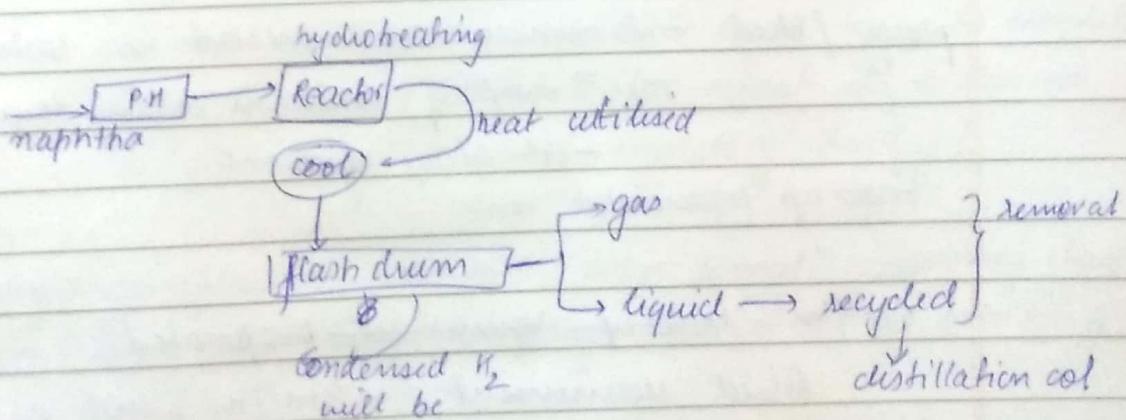


► vap phase reaction - a particular temp^r at a particular press

mix with H₂ before - reduces partial pressure - easily vaporize.
hydrodesulphurised

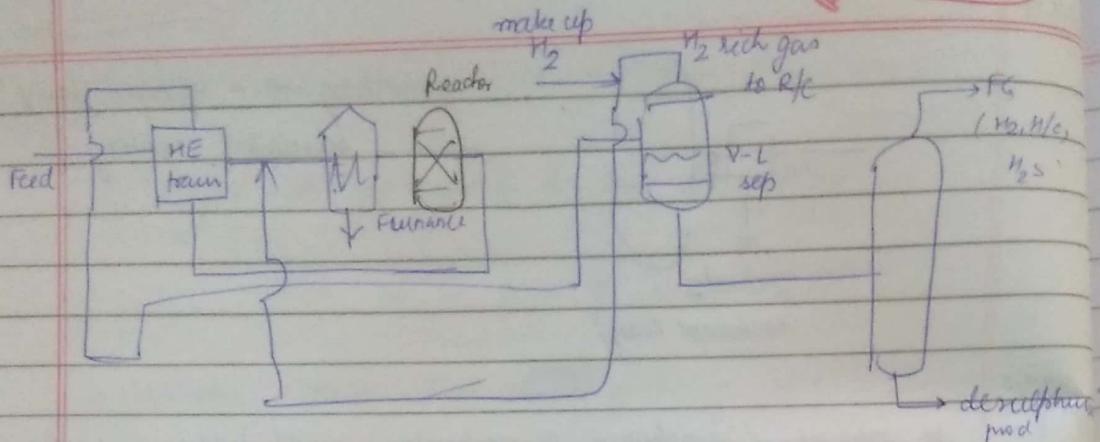
→ heated crude needs to be cooled, naphtha will condense.
LPG will remain in gas (small amt).

Equiv. naphtha stabiliser : Top product - gas (good amt. of H₂S)
all cracking will produce some amt. of H₂S. ↓
washed with amine



This gas phase is stripped with amine soln.

Compressor - reciprocating
larger units use centrifugal compression



93% H₂ purity

$$0.27 \text{ W/s}^3 \quad 20 \text{ fph}$$

IS requires 1 mole H₂

$$\frac{0.2 \times 20}{100} = 2.2 \text{ fph}$$

$$\frac{0.2 \times 20}{0.93} = 5 \times 10^{-6}$$

We will supply more H₂ - unused has to be released through FG

If give a perfect catalyst, amt. of

purge / bleed - to remove solids present in water
min^m temp of water in cooling tower:
-4° above ambient
make up requirement more

6 m³/h - make up requirement evaporated

Bleed requirement - 8 m³/h based on max^w concⁿ
 \Rightarrow for make up = 14 m³/h

Sanghera index:

Most react's in which H₂ & O₂ are involved
as reactants are exothermic

faster reach

Reformer :
Precursor for
- feed sh

This unit
cannot accept

Vapour ph
increase as

\rightarrow we use a

$\rightarrow T_f < T_i$

\Rightarrow u

If dehydrat
We need a

mo. of reo
compressor

Refineries
for pro

$$\text{Exo : } T_f > T_i$$

Date _____
Page _____

faster reacting \rightarrow aromatics from naphtha — strongly endothermic (490°C)
cracking — endothermic

Reformer :

Precursor for forming aromatics

- feed should contain C_6, C_7, C_8

depending on what we want?

- BTX

- Octane no

This unit has to precede the reformer feed as catalyst cannot accept S

Vapour phase reaction, no. of moles of compounds will increase as H_2 is produced.

\rightarrow we use a packed bed reactor.

$\rightarrow T_f < T_i$, gradually rate of reactⁿ \downarrow ($k \downarrow$ exponentially)

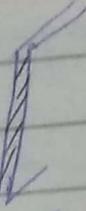
\Rightarrow we ~~no~~ need more residence time for rx to complete long reactor, we have to heat it to desired temp' using furnace (regulatory heating)

If dehydrogenation is very fast, coke formation may start.
We need to continuously supply H_2 (obtained from top of PBR)

no. of reactors = no. of hydrocarbons
compressors,

Refineries do not produce lub oil but lube base that is used for producing " "

property - kinematic viscosity
 lubricate must be of adequate viscosity
 grade, it will be always
 pressed from both sides - should not come out.



Viscosity
index

T rises due to energy lost \Rightarrow viscosity \downarrow
 should prefer big which whose $\nu \neq f(T)$
 sensitivity of ν with T variation minimum

- low pour point

K.V

VI

higher the VI, lower the
Pour point variation
high

(small qty) P

(small amt) N

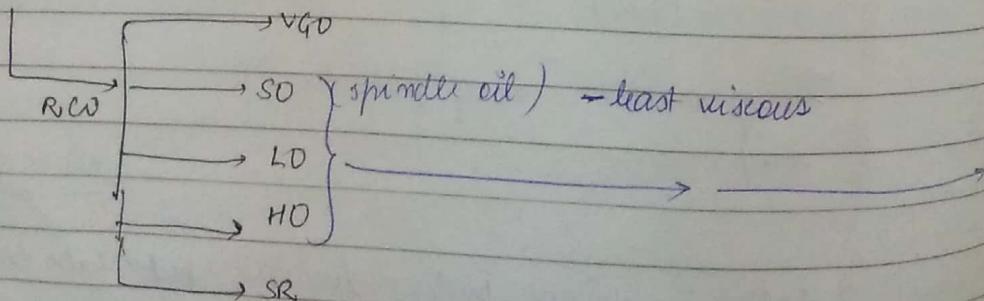
A highest
lowest.
(highest sensitive)

Specif. weight
 K_J with
temp

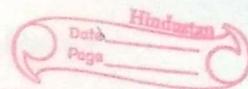
grease is a mixture of lub. oil + soap

when we want lubricant to stick to the surface

start with RCO \rightarrow diff. sections based on different viscosity
 ↓ split using vacuum distillation
 (fractionation possible at low T)



fields which studies lubrication



To improve pour pt, remove wax

To " K.V., remove Aromatics
aromatics

Dearomatization → Dewaxing → wax

↓
Dearomatised oil

(Solvent extraction)
Phenol/Furfural /NMP

Dewaxed oil

Lube oil base stock,
cooling crystallisatn & filtration

hydrofinishing
(lube oil base
stock)
(SO, LO, HO)

Crude oil contains small N_2 & O_2 — combine with
to generate coloured compounds.

should not bother about colours.

Product should have to be stable — free from N_2 , O_2

hydrotreatment

→ NH_3 , H_2S

Solvent extraction of aromatics -

earlier phenol was used, now furfural
dissolving

phenol/furfural /NMP (n-methyl pyro)

• dewaxing — cooling cyst

Crystals of wax should be monodispersed — not too small
clog filter media

too large (solvent trapped in b/w)

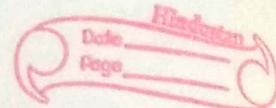
double pipe chillers are used for controlled cooling

• ammonia vapour refrigeration used for this

NH_3 vapours

Reduce diffusional resistance so that crystals come together
— add a solvent of low viscosity then shake it
hom

Methyl ethyl ketone / Benzene / Toluene



solvent added to feed → heated to 90° (homogenise)

{ NH₃ refrigeration cool (chilled)
 ↓
 filtered

ideal composition

make up will have diff composition

due to difference in volatility

we lose more volatile component

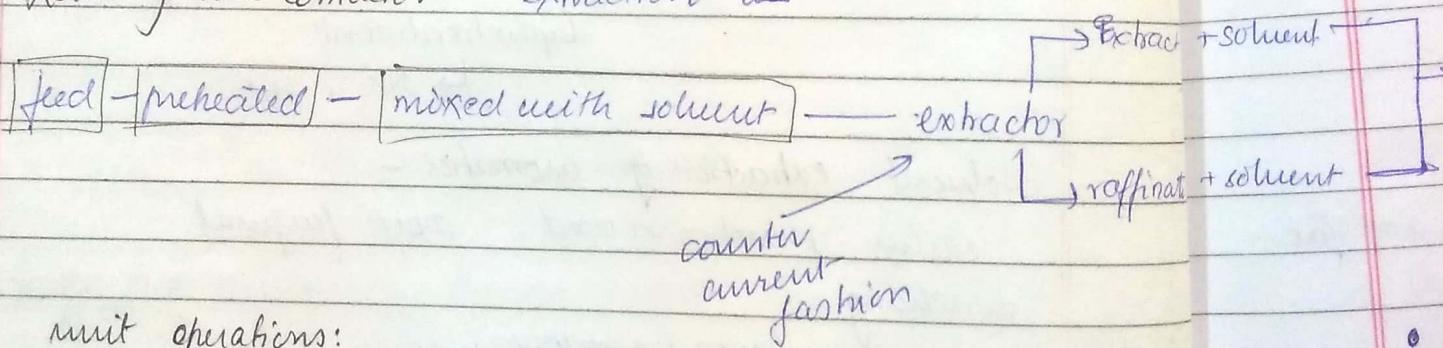
↓ in maxⁿ
toluene will be ~~minⁿ~~ amt.

which

Gross

solid

Rotating disc contactor - used for extraction ~~etc~~



unit operations:

- i) separation
- ii) mixing
- iii) adsorption -

dehumidification - adsorption
of water by alumina
(large scale)

Industrial Gases:

Which is better? liquid or gaseous fuel?

↓
fuel oil (~ 9600 kcal)

Gross C.V & Net C.V — relevant is for HCs.

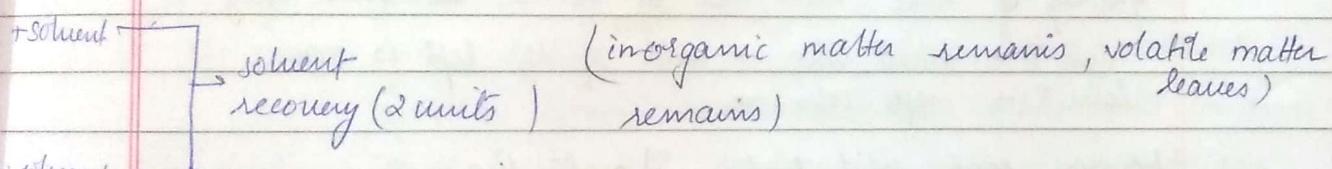
solid fuel - coal

peat
 anthracite
 →
 →

due to extent of changes they've gone

- coke (derived from coal)

↓ heat in absence of air
coke



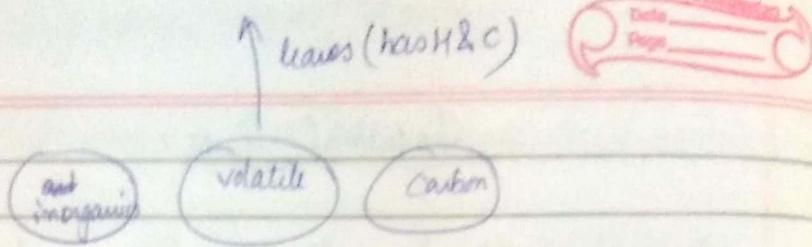
Ash - metal oxides, silica (inorganics)

- During coke formation, volatile matter leaves,
1 g coal < 1 g coke
 y g inorganic $\frac{y}{< 1}$ g → increase in ash content

- There is some incomplete removal of volatiles

- H_2 has much higher kcal/kg than C

- Volatile matter is some hydrocarbon



by wt
Q. H, where is more?
— volatile matter X
— averaged over coal
higher

\Rightarrow Coke has, Q. carbon, \Rightarrow Calorific value will come down
↓ + mineral matter
↓ + r

coal to coke is a carbonisation process

↓ can be low T or high T

↓ when coal heated
to higher T

Quality of coke will not be same for both ways:

high T \rightarrow hard coke \rightarrow amt. of H₂ left is more

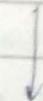
low T \rightarrow soft coke \rightarrow

how is coal solid fuel — i) grate fire

— ii) pulverise the solid fuel and fire it for

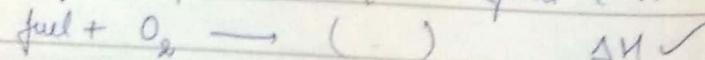
fuel firing \rightarrow grate

\rightarrow pulverised



C.V. imp.

heat of formation of compounds reqd to find C.V.



(pure) CH_4

for non-pure, experimentally.

\downarrow elemental
estimate of
medium given Q. composition of coal, C.V.?

- \rightarrow Coke used in a) steel industries
- \rightarrow as a reducing agent in a blast furnace

Yes!

burns with
 $\hookrightarrow \text{CO}$

Properties de-

- i) coke white not break
- ii) high C
- ↳ hard coke

b) metall

- soft coke
- production

smoky gas

N₂, H₂,

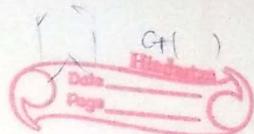
whatever

By product
distillate

BF gas also

We have
 \rightarrow heating

C.V. of gas



burns with O_2

→ CO reduces iron ore

Properties desired -

- { i) coke which can be easily compressed if less hard, should not break but remain in chunks
- { ii) high C
- ↳ hard coke

b) metallurgical industries

- soft coke used in ~~sign~~ ovens.
- production of coal gas

smoky gas produced by volatile matter.

N_2 , H_2 , $\downarrow N_2$, lighter $HC_s^{(C_2-C_3)}$, naphthalenes, tarry material
washed off (because we do not want them) which will condense
whatever that will not condense is called coke oven gas.

By product recovery plant in steel industries handles dry distillate

used as fuel

BF gas also produced - what burns (internal use)
is CO (contributes to C.V.)

We have pipelines to handle BF, CO gas

→ heating of ingots (combination of both) → due to huge diff
more C.V. of CO gas in C.V.s of both
due to presence of H_2

C.V. of gas in m^3

for Gas as a fuel - higher fuel/gas box
more concentration of HC_s in

low vol. C.V.

liquid fuel

but high mass C.V.

intense heat generation - liquid fuel

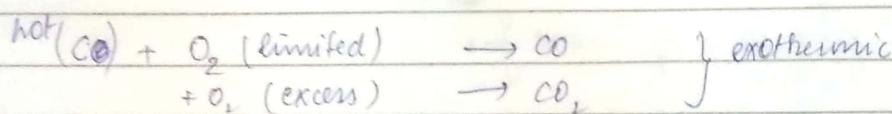
cheap - solid fuel
indirect heating

clean fuel - glass industries

- coal can't be used

↓ low C.V., not clean

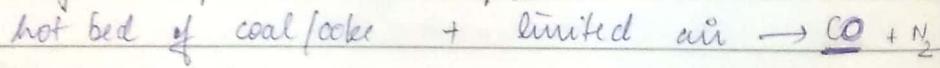
- gaseous is the cleanest one
(present source is LPG ↓
earlier - coal (cheapest))



N₂ will remain unaltered

(very small/some N₂O will also be produced)

Producer gas is produced in a producer



Requirements:

i) vessel - porous material shell

ii) refractory brick lining

a material used in the form of bricks which does not undergo thermal change when heated

iii) bed should not be small (else will compact) & not lumps
depth ≈ 0.8 m

iv) bed supported on grate

coal added from top to

through a bell & hopper arrangement

or ball & "

coal

bed

grate

air

- how feeding arrangement is done via working
& sketch engineering problems?

how to run

find method
as

S/T >

Shell &
Rotating
hearth

4 - water g

Product n

C + H₂O

upflow
air/water

Engineering

for in
if you
comp

e.v. comp

how to remove ash?

→ has MOs which can melt
Find melting point of ash?
Ash softening temp?

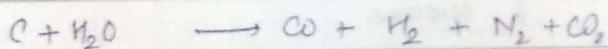
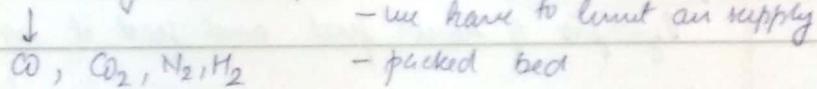
If $T >$ melting point, ash melts - molten ash
dumped in cold, solidifies

Shell 9

Rotating grate? - so that bed does not get clogged
heap formation - short circuiting

4- water gas

Product of producer gas is simplest:



water gas much higher C.V than producer gas

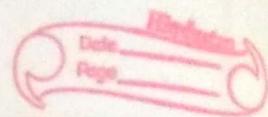
→ upflow of air,
we've to remove ash easily

Engineering problems - feeding from top

- prevent heap formation
- rotating shell / rotating grate for removal of ash

For 100 m^3 of Coke/coal,

C.V. if you know heat of reactions, can you estimate best possible composition of producer gas?

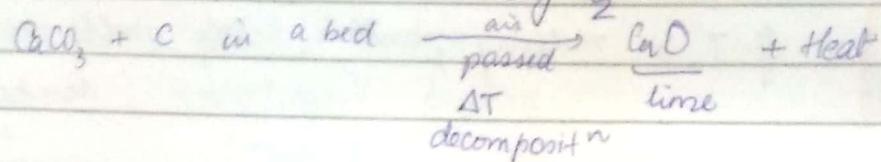


Standard heat at 25°C , 1 atm

H_2 will not affect C.V.

- will affect Kcal/m^3

Lime kilns - not interested in collecting CO_2



In practice, CO_2 product reduces C.V.

- i) Best possible amt. of C.V we can get?
- ii) C.V when $\approx 9\% \text{ CO}_2$ is formed?

Pyrolysis of liquid fuel and feed it as vapour.

b) kerosene

b) cracks into gas

Diff in these types of plants? and why?

For making \approx normal m^3 of producer gas, coke requirement?
How will you estimate?

— composition (H_2) of coal/coke

— moisture content of water

Verify if figures quoted are correct?

State Requirement of raw material will depend on scale of process.

We require approx $25-30 \text{ kg}$ of coal $\Rightarrow 20-25 \text{ kg}$ coke / $60-80 \text{ normal m}^3$ of air
Why \Rightarrow coal consumption is higher?
q. C in coke is more

- applicable for a range of capacity of producer.

25 - 250 m³ gas capacity production

Why scale of product^n. important?

- efficiency of scale of product^n

small - η more but more heat loss \Rightarrow more air supplied \Rightarrow more CO₂ formed

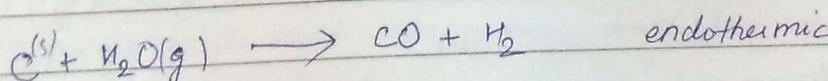
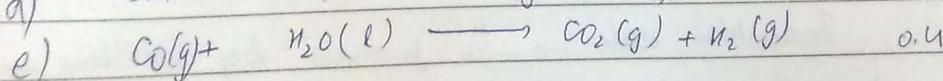
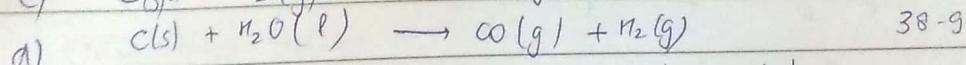
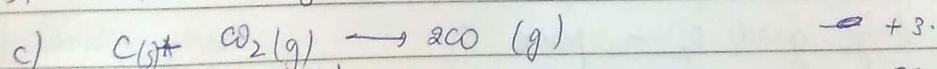
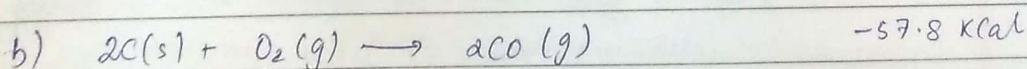
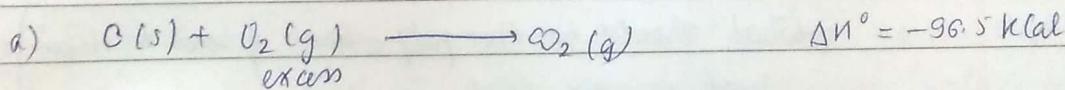
Carbonated producer gas.

Arrangement where pyrolysis of some gases

- to increase C.V.

spend additional amt. of energy to increase C.V.

Water gas :



hot bed, pass steam

T \downarrow after react^n

rate of react^n \downarrow

if rate falls more, reaction will stop
increase temp by heating it up

by burning C
it will form CO_2 .

At high tempⁿ of bed, CO will form (ΔH of $\text{CO} + \text{CO}_2$)
- Le Chatelier's principle
T again decreases

Is it possible to run process in 1st or cycles?

2 types of water gas units -

i) regenerative type

- cycles of blow

- cycles of productⁿ

ii) continuous type

just low grade O_2 is passed,

having certain amt. of CO_2 ,

some CO & N_2 , net heat

of reactⁿ = 0

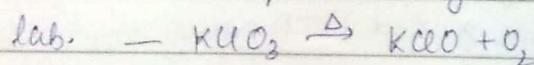
burning of coke - productⁿ of heat.

productⁿ of water gas - consumptⁿ of

What should be the proportion of air & steam so that net heat is zero.

high grade O_2 - pure O_2

Industrial scale - O_2 produced by distilling air



~~lynn~~

adv: % of O_2 in feed is more

& dilution of product with N_2 is min^m.

- C.V. will be less if N_2 present in prod

but some amt. of CO_2 present will reduce C.V.

Blow :

→ In cycles,
how can
they ..

Water gas

We can h

Synchroni

order s

order t

- use a

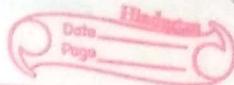
7

use can

- steam

over

Outline of ~~with~~ chemical technology



Blow : blowing in — blowing out

At the end of upflow run, we have non-uniform T.
We pass air from bottom to get more T at bottom.

→ ~~10~~

In cycles, we have both upflow & downflow
how can we change direction of flow?

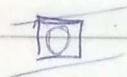
Perry

- rotary valve (3-way)

↓ multipost plug valve

Water gas regeneration process :

T values : fully on / fully off
not regulatory



plug value is a regulatory value
rotary

full value has 2 values parts

We can have series of valves operated using same shaft.
Synchronization reqd in water regenerative process because
many reqd to run parallelly
order shell

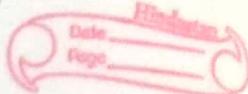
order these valves

- use a steel shell, material has to be contained
T so high that refractory brick lining should be
there,

still hot, heat can be used to preheat water
we can manage with low grade metallurgy

- steam pressure to be such that it should be able to
overcome AP of bed, else flow rate will fluidise bed.
not high, above moderate

raw material for producing 100 normal m³ of water gas?



Calculate C.V. of water gas?

engineering problem?

- * → i) maintain exact amt. of low grade heat O_2 with steam so that s.s. operatⁿ runs & net heat = 0 regulate based on temp^r

through how to measure?
thermocouple inserted, thermowell

→ how will you decide the depth of thermowell?

- based on Biot no.

to avoid temp^r gradient

transient response on thermometer would depend on this.

regenerative process has 2 plant reactors?

I can also do with a single reactor — have gas holdup

→ for continuous supply of steam

cycle time : 4 to 6 min (T of bed falls sharply)

(Blow) heatup - 35% time

down run 33%

uprun 30%

short purge 2%

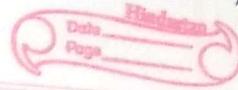
- significance? purge with steam or air?

• during down run, the temp^r at top decreases, T at bottom is high, we start to reverse the direction that

- uprun

* not a big problem because we measure T at atleast 3 points, we can control flow rate using Temp^r

all produce ~~or~~ produces water gas only when it is cheap to produce.



- iii) levelling of bed
- iv) taking out ash

Pumps:

- positive displacement (P.D)
- ~~also~~ rotatory

Examples of reciprocating pumps?

Basic diff b/w plunger pump & reciprocating pump.
movers inside
a cylinder

if any fluid from suction to feed will not come back.
(reciprocating pump is P.D pump)

McCabe & Smith — pumps.

gear pump is a rotary pump
one tooth wheel coupled with
another tooth wheel

means of transmitting rotary motion from one
shaft to another.

It is the displacement pump

Screw pump:

lobed pumps - teeth not present in gear type arrangement

rotary & the displacement

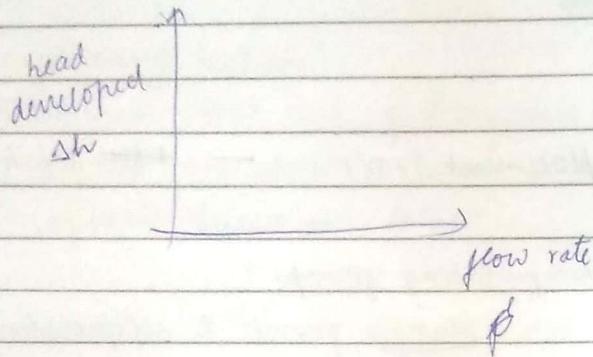
transported using helical screw.

Reciprocating pump requires valves - one open, one closed

such not reqd for screw & gear pump

high $\mu \rightarrow$ gear, screw

Characteristics of pump:



why not ΔP vs Q ?

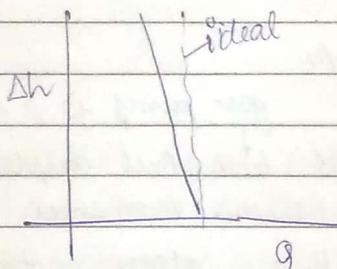
hard coke
continuous on

Physical an
for & desti

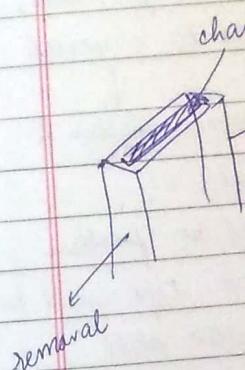
- rectangular

gear pump:

if rpm fixed, amt. delivered is same
whatever ΔP we have



leakage tilted towards left
- at high Δh , $Q \downarrow$
due to leakage



- o hard coke - used for reduction of iron
% ash higher in coke

Volatile matter - ~~good~~ ^{good} H_2 , some N_2 , H_2S (nowhere except in Assam)

{ some CH_4 ,
60% H_2 , 25% CH_4 , 5% CO , 2% CO_2 ,
some impurities of H_2S & HCl

lighter part & cracking part of volatile matter

some amt. of moisture

some amt. of N_2 combined with H_2 \rightarrow some NH_3

tiny matter that will condense

g. f. sh.

Cooled

Heating

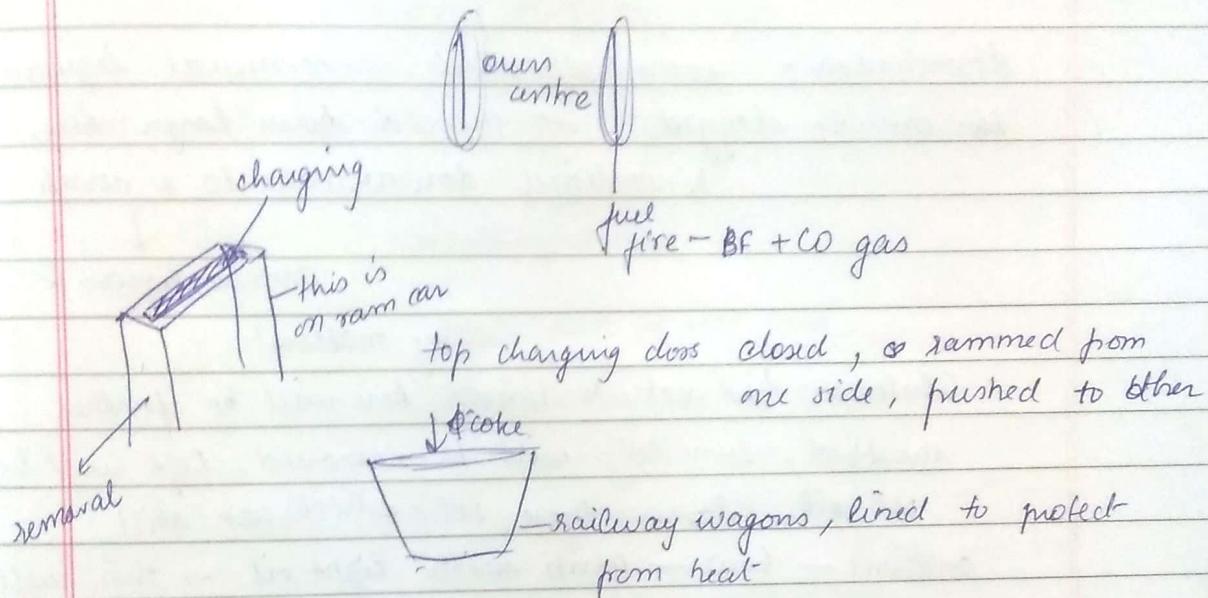
Thermal

Reuses
they sh

hard coke product has temp' around 1000°C .
continuous or batch will depend on economics

Physical arrangement so that powdered coal is heated for & destructively & heated for 10-12 hours?

- rectangular oven construction heated from 2 sides



It should be quickly cooled — quench — it
car that receives it is called
quench car.

go through a tower & having water jet.

cooled further

Heating space should be there at sides of oven
Thermal efficiency much higher when heated in slices.

extremes

Pores will \not be formed during the process of carbonisation
they should be removed from the ram car end — why?

set of ovens - battery

Date _____
Page _____

11/20/07

Volatile matter leaving at 970°C comes out from a main header

At a time, $\frac{1}{3}$ of ovens produce gas. All these gases should contain heavy HCs. If cools down, there can be flooding.

We can use flashing liquors to heat it

downstream - some separated ammoniacal liquor can be clogged. so should have large dia, & inclined downwards to a vessel
↓
contains liquor & tarry material.

Whatever had not condensed here will be further scrubbed. Some NH_3 will be removed. Left will be HC oil. Remove those HC which can still condense - how - scrub with light oil - this will absorb HCs (heavy ones) - light oil has to be regenerated.

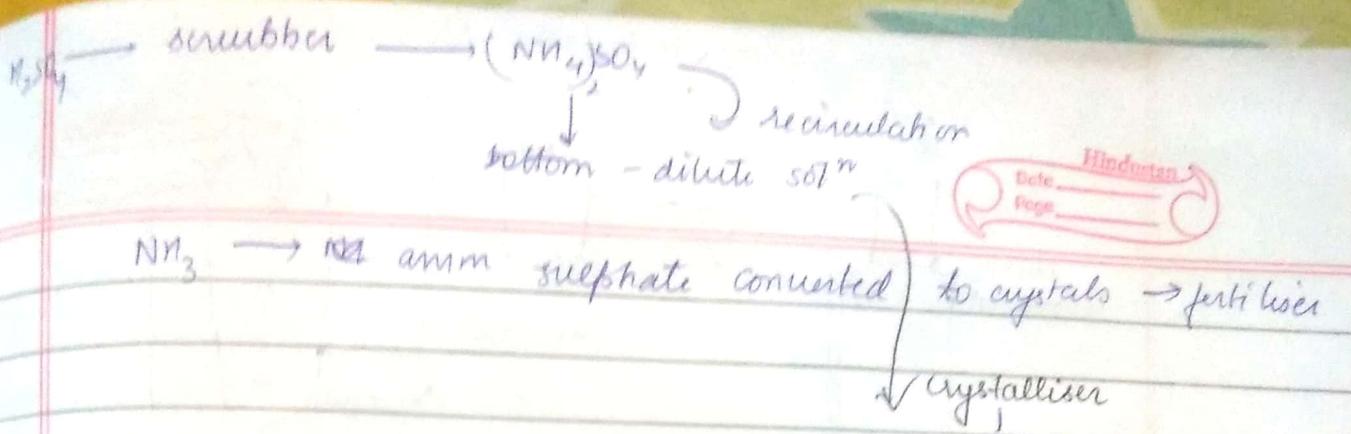
Tar will condense first

scrubber → regenerated

light oil - the ~~o~~ HC which is distilled off from

cyclone is used to separate particulates from gas. mostly ESP used.

Tar first, then light oil ~~o~~, then far \rightarrow which get carried away goes to ESP. left with gas containing some NH_3



solubility increases with temp' - so cool it

~~evaporation~~

cooling

used when solubility is high (NH₄)₂SO₄ - high

What is the construct of evaporative crystalliser?

discharged on a .

↓ liquid will be sent back

↓ crystals need to be dried

- continuous dryer

- rotary dryer - exit to silos

↓ into

bagging & packing → sacks

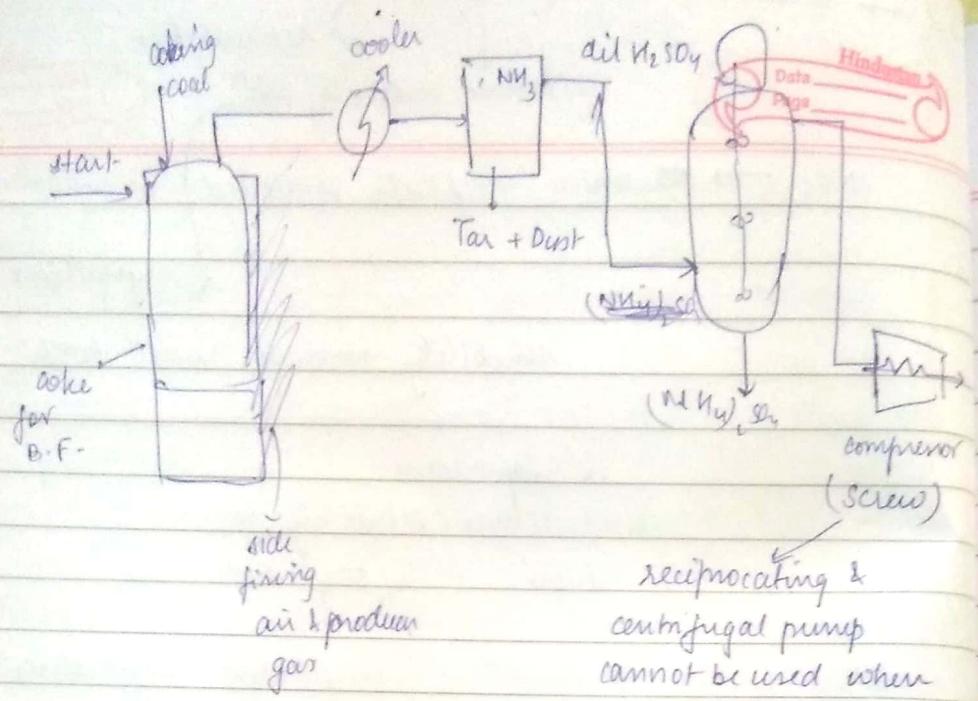
N₂ will not condense

as critical temp below Tambient

can be used to produce NH₃

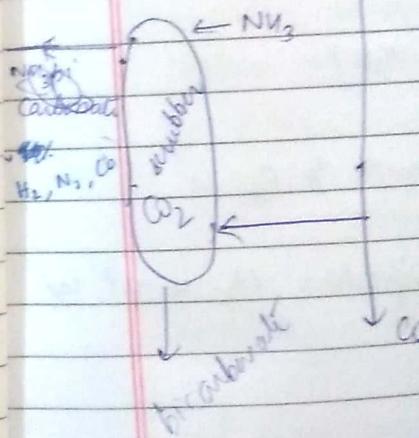
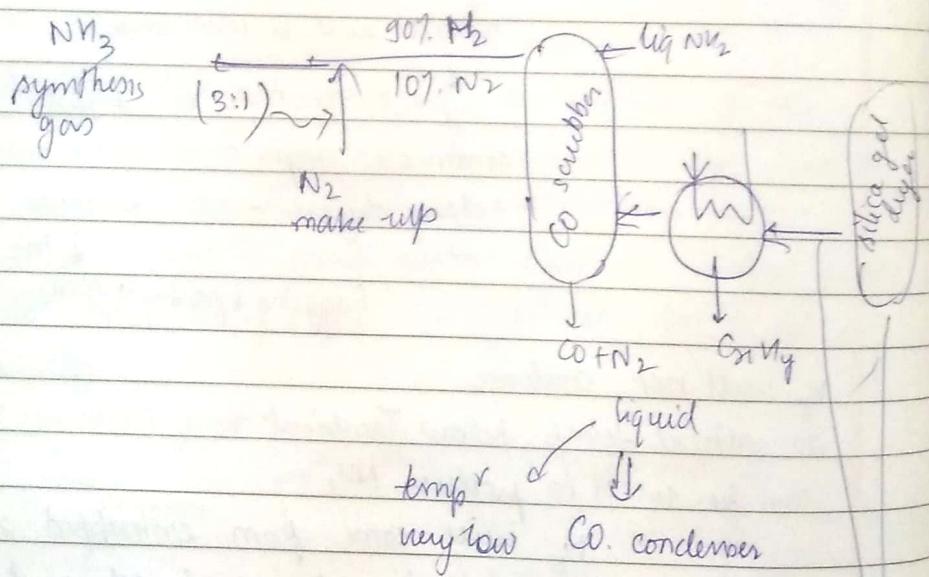
N₂ will come from entrapped air b/w
Interstices of powdered coal.

CO gas has high amt. of C.V. due to high H₂.



high P ⇌ abs
15 atm
light oil
607
259
64
29
3m

right
P
light oil
scrubber
oil coal
chemicals
(where does it
go?)
are
what, the
chemicals
recovered?



✓
CO produced
by
reducing CO₂
CO + NH₃ → urea

15 atm

high P \Rightarrow absorption of HC will be more

light oil

high
P
light
HC
scrubber

oil coal
chemicals

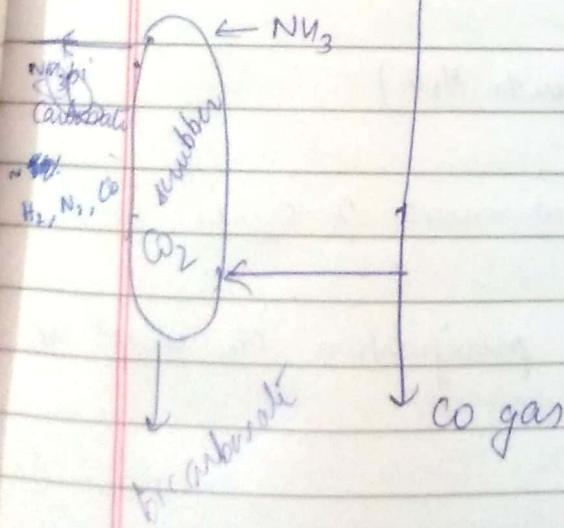
(where does it
go?)

are
what the
chemicals
recovered?

60% H_2
25% CH_4
6% CO
2% CO_2

Impurities

Organic
Olefins
Hydrocarbons



Inert gas uses:

- (i) reducing reactivity
- (ii)

Instability of lubricating oil - hydrotreatment

for nitrogenous & oxygenaceous compounds which colour the oil when reacted with O_2 .

Cannot store oil in any tank else it will react with O_2 in air. Cannot use floating head due to expenses

- N_2 - from air

- CO_2 (sometimes - it is soluble with H_2O)

It depends on the application how much % O_2 is tolerable.

For inert gas blanketing, high purification N_2 is not required

Other options?

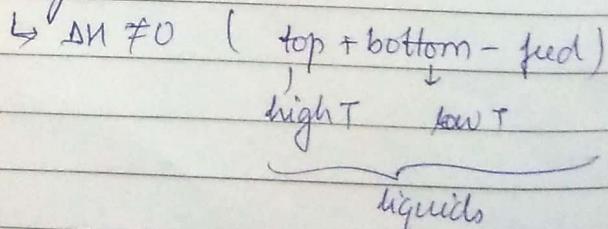
Air liquification X

distillation is expensive?

~~of air~~

- capital cost

- first law efficiency

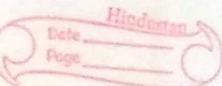


$$\text{Efficiency} = \frac{\Delta H}{\eta_{\text{feed}}}$$

Many reboiler heat duty

✓

Roof of tank is weakest.
- to protect from
pressure



Never beyond 2 digits in %. for distillation

Distillation - most used separation process

Combustion of HCs,

water easily removed, CO_2 .
clean N_2 obtained by light HCs.

Submerged combustion of LPG - product is inert gas
- what and how?

from pyrogallol - explosive
- weak chemical reaction

Alternating - adsorption

carbon molecular sieves used as adsorbents to separate O_2
and N_2

Haldia - adsorption based inert gas generator.

Inert gas blanketing - required only for fixed head tanks

oil fires removed using CO_2 fire fighters directed opp to the
tank so that base of the flame is tamper destroyed.

Vent arrangement should be there. Regulated -

Breathe out - Opens at +25 mm water gauge pressure inside
Breathe in also allows air to get in at -20 mm

Pressure vacuum value (~~20~~ PV ~~value~~ value)

Header at top to vent - will be at low pressure

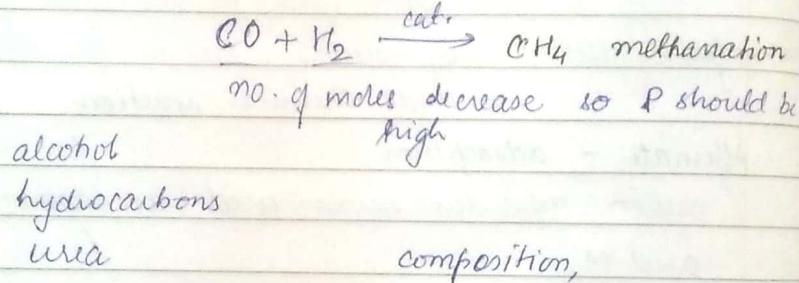
we require a control valve & arrangement else we'll lose inert gas continuously.

It will open when pressure is below 80 mm & vice versa.

Synthesis gas :

most chemical products require C & H.
source could be

- gas



based on T, P, appropriate cat. A separation method of methods economically

Basically, 2 types of gases

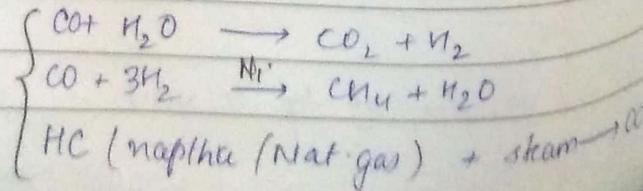
starting with NH_3 , we can produce dyes, urea,

Raw materials:

1. Producer gas

(steam + coke)

but proportion should be different
for different composition



Find AN for

syn gas for
by hydrocarbon

We should also
 H_2 is more so

CO_2 product"

Synthesis of C

Ni cat

at 252

high

Components -

- i) coal handling
- ii) gasifier

iii) reactor
large ha

used to

(iv) product

v) recycle

to an

in

we

Hindustan
Date _____
Page _____

Find ΔH for each of these class of reactions, T & P?

syn gas for NH_3 — 1:3
by diocarbon

We should also have a method to control the ratio.
 H_2 is more scarce.

source in industry - steam reforming of naphtha

CO_2 product not a problem.

Synthesis of CH_4

Ni cat

200-250-500 °C

high pressure

endothermic

Hydrocarbons - Fischer Tropsch process

$\text{CO} + \text{H}_2$ — 0.5 to 2.0

iron

180-300 °C, 1-30 atm

- producing light HC's.

- source is coal

now, where & why - based plant

Components -:

i) coal handling section

ii) gasifier — like a producer gas generator or

reactor - packed bed - heterogeneous

iii) large range of ratio — generates in the naphtha, gasoline range

used to produce ~~gas~~ fuel for engine.

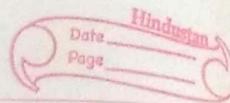
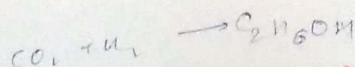
fuel-gas phase

iv) product separation

v) recycle

- we never recycle completely ~~recycle~~ recovered to avoid build up of impurities that are present in raw materials.

we have to have a purge to limit contaminants



Synol process -

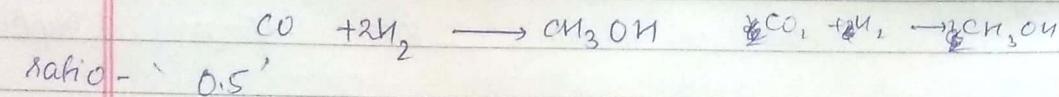
CO_2, H_2 ratio 0.2 to 0.5

Cat. - iron

185 - 225°C

150 - 30 atm

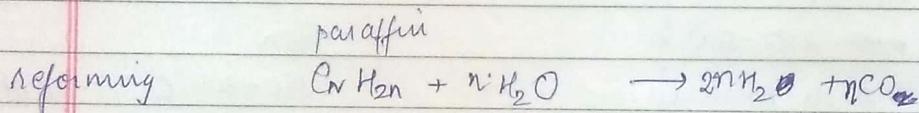
because reduction in no. of moles is larger



ratio - '0.5'

entire thing doesn't get converted ≈ 0.3

higher alcohol - higher pressure & higher T range



$\Delta H = +52$, $n=1$

$\Delta H = 238$, $n=6$

Mc McCabe Thiele

We decide

The reqd contactor take

B) CO by

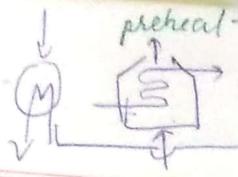
H_2 obtained from steam also - so reforming is the major source for large amt of H_2 .
and non-catalytic reforming of naphtha

large qty of H_2 required for hydrodesulphurisation of diesel for reducing S content in diesel (1% to ≤ 50 ppm)

Oxo, Methanation reaction :

df TIB-6 denitrification HC - acts as a poison in the process catalytic

absorber & stripper
 forms $KHCO_3$
 separate out CO_2
 regenerate K_2CO_3



Fertilizer industry flow sheet - N_2 for NH_3 synthesis

Instead of K_2CO_3 , amine system can also be used.
they have affinity for CO_2 .

Absorber - bubble column, spray column, packed column

how to decide type?

McTabe Thiele method is an eqm approach.
We deci are looking into kinetics.

The reqd residence time has to be provided, ~~it de~~
contactor MT rate determines how much time it will
take

B) CO produced present in the exit can be removed
by passing through methanator

disadv of K_2CO_3 → ~~adv~~: alkaline,
↓ typical to coal based fertiliser
more to deposits on cliff surfaces →

Amine based system: more toxic

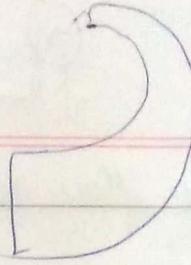
prepared by refineries

centrifugal pump:

casing, impeller inside

impeller turns, liquid is imparted KE by circular motion

liquid leaves from periphery
and edge of casing - volute



large pumps have
volume of diff. c.s \Rightarrow velocity comes down, pressure ↑
Liquid enters through eye of pump.

Outlet has got a flange, -