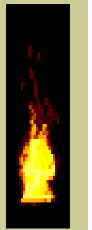
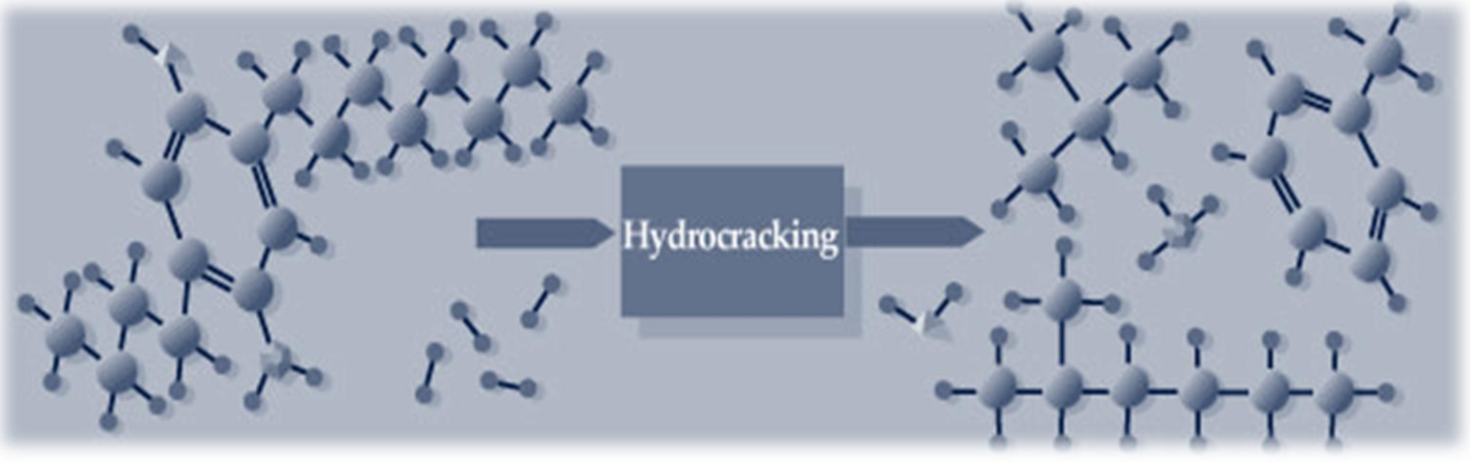
HYDROCRACKING TECHNOLOGY



Contents

Unit Function

Hydrocracker is a process that uses heat, pressure and a catalyst to break larger hydrocarbon molecules into smaller, lighter molecules and also converts heaviest and least desirable petroleum cuts , into marketable products.



Purpose Of HCK

- Converts high boiling points hydrocarbons of high molecular weight to lower molecular weights.
- Saturates olefins and aromatics
- Remove sulfur , nitrogen and Oxygen
- Producing a mixture of essentially pure paraffins, naphthenes, and aromatics.

Feed and Products

HCK feed stocks

The unicracking unit can be fed from different sources as blend from:-

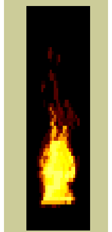
- Atmospheric & Vacuum gas oil
- Coker gas oil
- FCC Cycle oil
- Blends of the above

In addition to

Hydrogen Makeup.

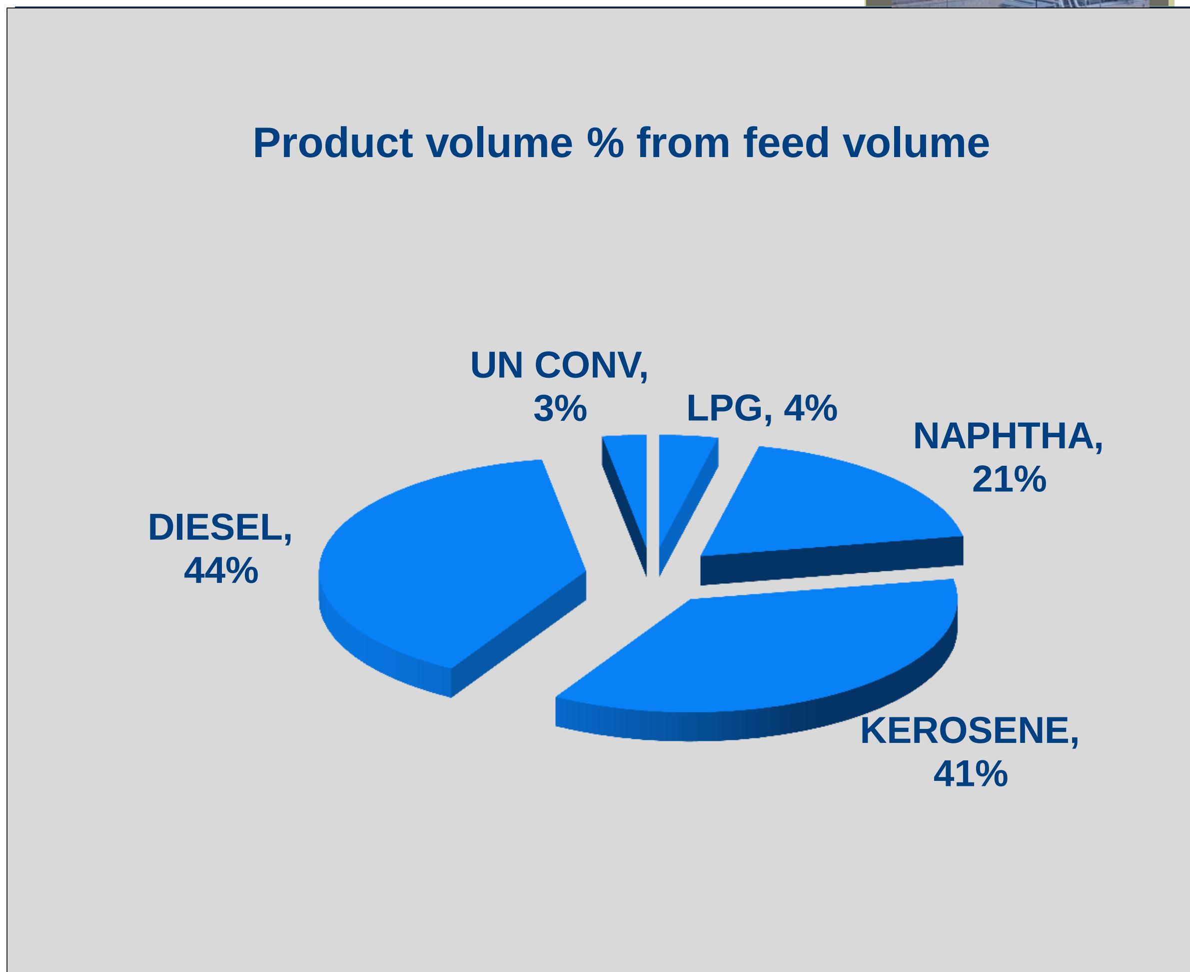
Unit products

- **Sour gases** are routed to refinery fuel gas system.
- **LPG** are routed to caustic wash system for further H_2S removal.
- **Naphtha** is sent to naphtha hydrotreater unit
- **Kerosene** (JET FUEL) is sent to storage tanks
- **Diesel** is sent to storage tanks
- **Unconverted oil** is sent to storage tanks.



Volume Expansion

LPG	4%
Naphtha	21%
Kerosene	41%
Diesel	44%
UCO	3%



Hydrocracking Chemistry

Reactions

Desired Reactions

- Treating to remove contaminants
- Cracking to obtain desired boiling range products.

Undesired Reactions

- Coking
- Condensation of PNA

Why pretreat feed stock ?

- Reduce temperature rise in cracking beds
- Extend cracking catalyst life time by removing feed metal.
- Protect cracking catalyst from plugging due to particulate
- Improve cracking catalyst effectiveness

Desired Reactions

Hydro treating Chemistry

1. Sulfur Removal
2. Nitrogen Removal
3. Oxygen Removal
4. Olefin Saturation
5. Metals Removal
6. Halides Removal

Sulfur Removal

- Mercaptan

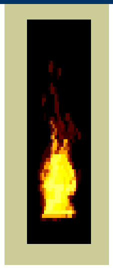
$$C\text{-}C\text{-}C\text{-}C\text{-}SH + H_2 \longrightarrow C\text{-}C\text{-}C\text{-}C + H_2S$$

- Sulfide

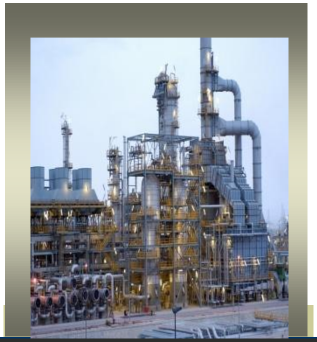
$$C\text{-}C\text{-}S\text{-}C\text{-}C + 2\,H_2 \longrightarrow 2C\text{-}C + H_2S$$

- Disulfide

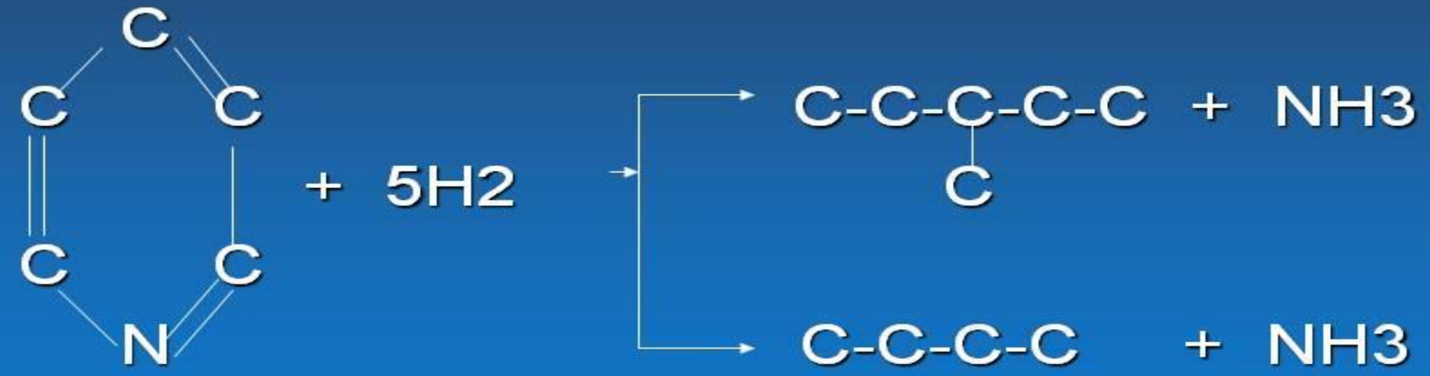
$$C\text{-}C\text{-}S\text{-}S\text{-}C\text{-}C + 3H_2 \longrightarrow 2C\text{-}C + 2H_2S$$



Nitrogen Removal



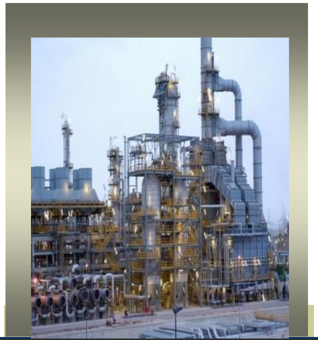
- A.(pyridine)



Oxygen Removal

- A – PHENOLS

Olefin Saturation



- A- LINEAR OLEFIN

$$C-C=C-C-C-C + H_2 \rightarrow C-C-C-C-C-C$$

- B- CYCLIC OLEFIN

Metals Removal

Almost all the metals removal occurs at the top bed of the first reactor.

Metals are retained on the catalyst by a combination of adsorption and chemical reaction.

The catalyst has a certain maximum tolerance for retaining metals.

Halides Removal

Organic halides such as chloride and bromide, are decomposed in the reactor. The inorganic ammonium halides salts which are produced when the reactants are cooled are then dissolved by injecting wash water into the reactor effluent

$$RCL + H_2 \longrightarrow RH + HCL$$

$$HCL + NH_3 \longrightarrow NH_4CL$$

Cracking chemistry

Extensive catalytic cracking followed by hydrogenation to form iso paraffins are the primary reactions. The rate of hydro cracking increases with the molecular weight of the parrafins.

$$C_{22}H_{46} + H_2 \longrightarrow C_{16}H_{34} + C_6H_{14}$$

Hydrocracker

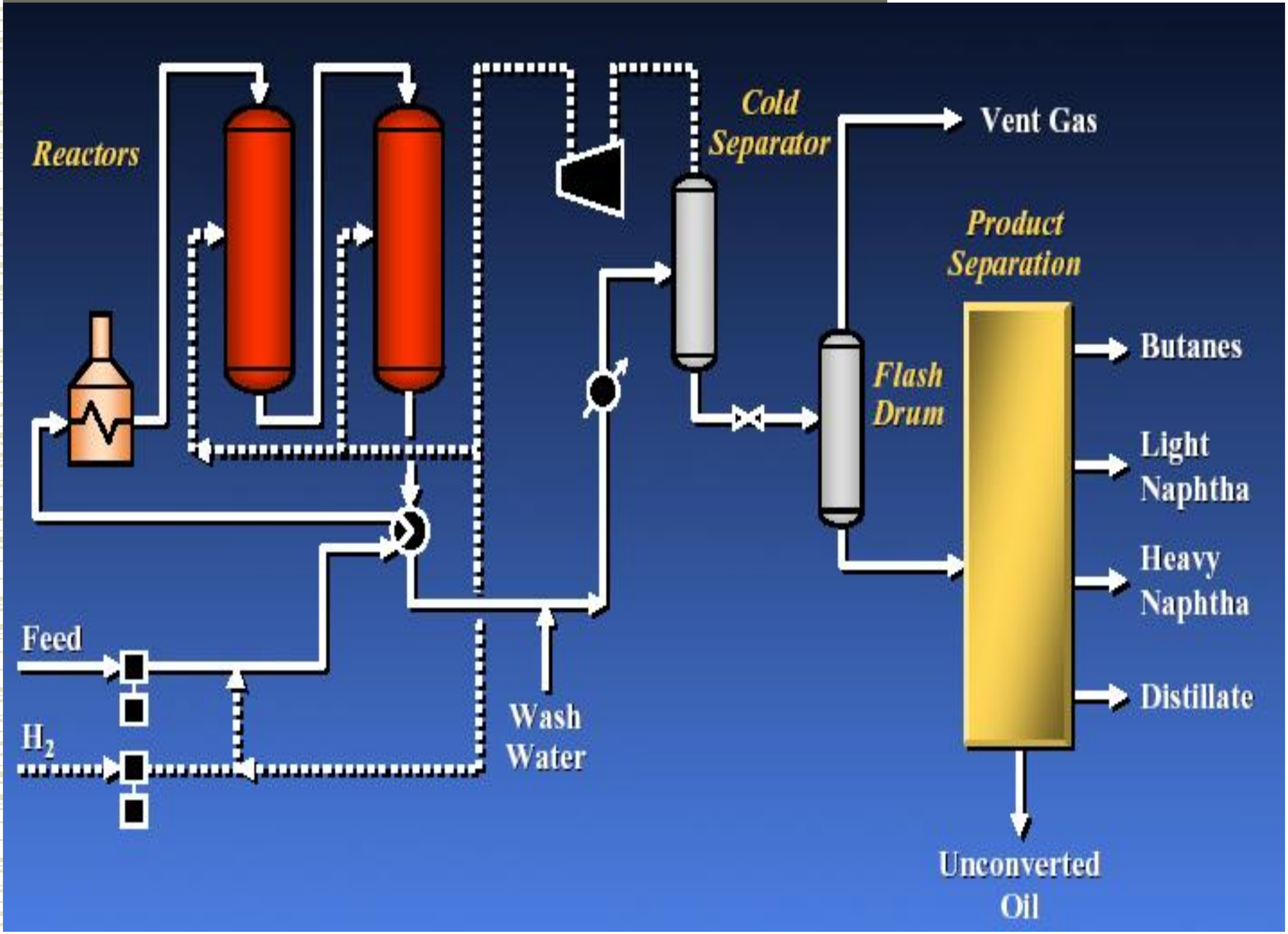
Flow Scheme

Flow Scheme

Hydrocracker could be classified according to its reactor section flow scheme as follows.

- Once-through
- Single Stage
- Two Stage
- Separate Hydrotreater

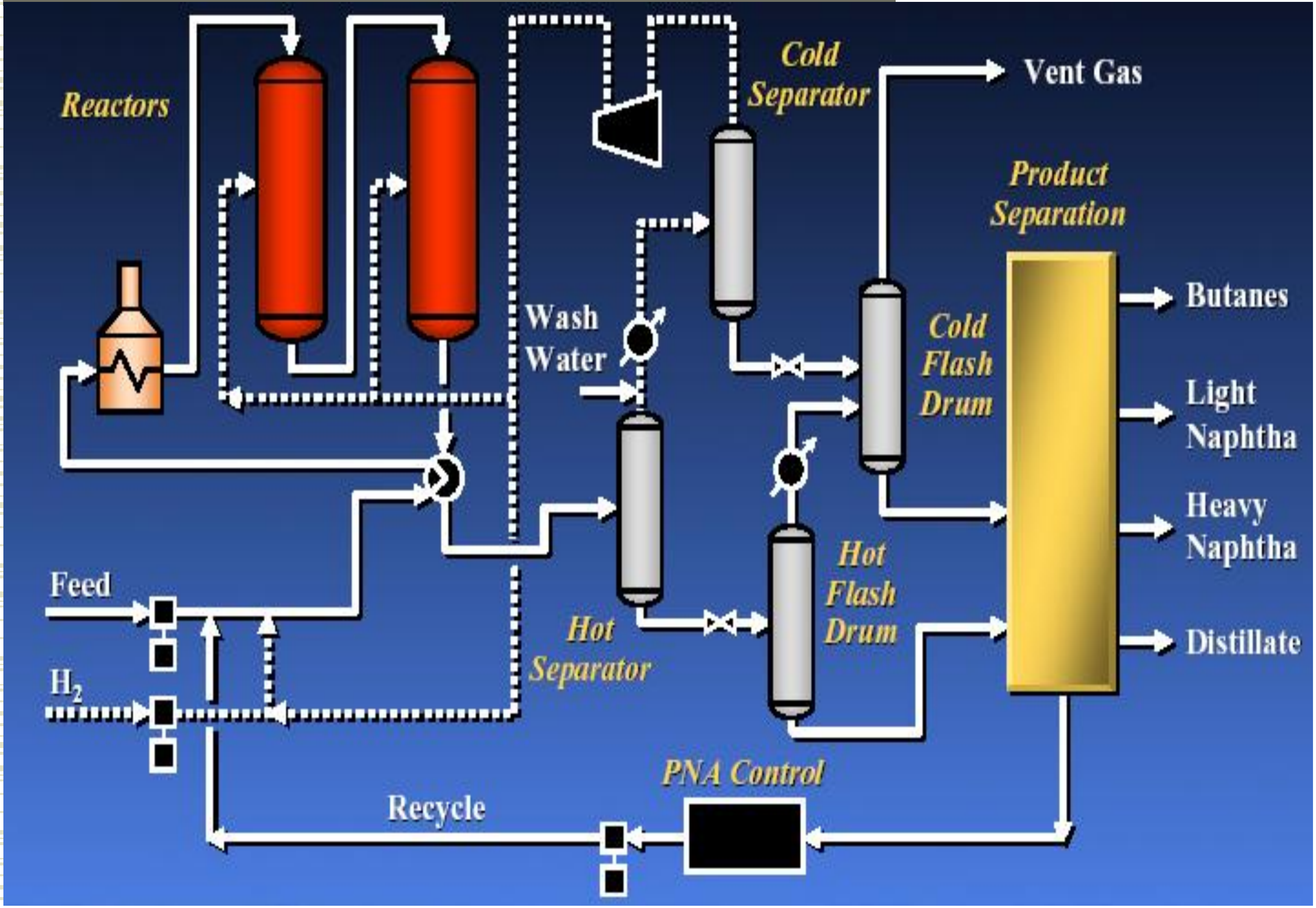
Once Through Flow Schemes



Once Through Flow Schemes Features

- Lowest cost.
- High feed rate.
- Process very high boiling feed stocks.
- Produces high value bottoms for FCC, and Lube oil.

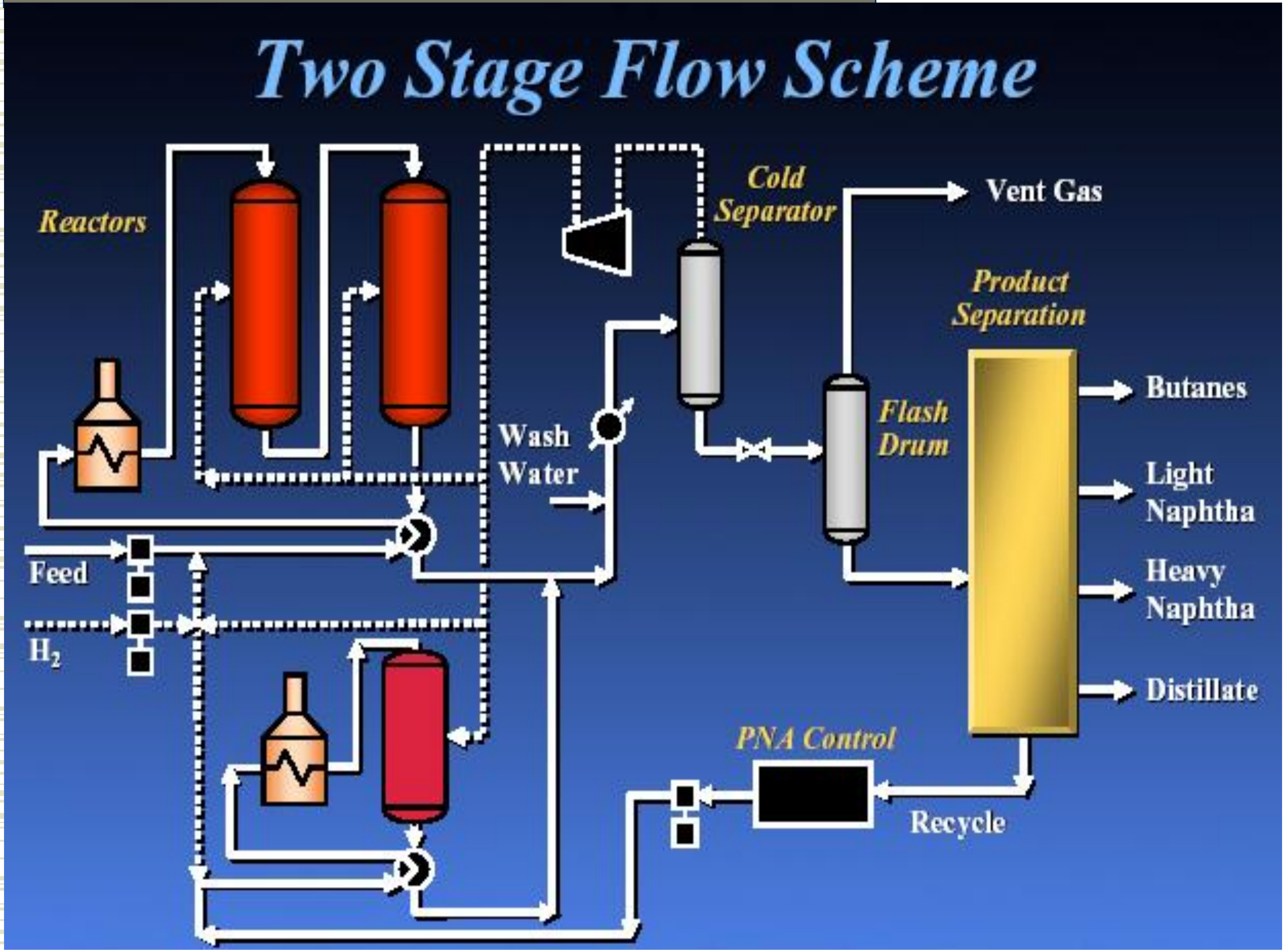
Single Stage Flow Schemes



Single Stage Flow Schemes Features

- Moderate product slate and quality flexibility.
- Full conversion possible.
- PNA problem manageable.

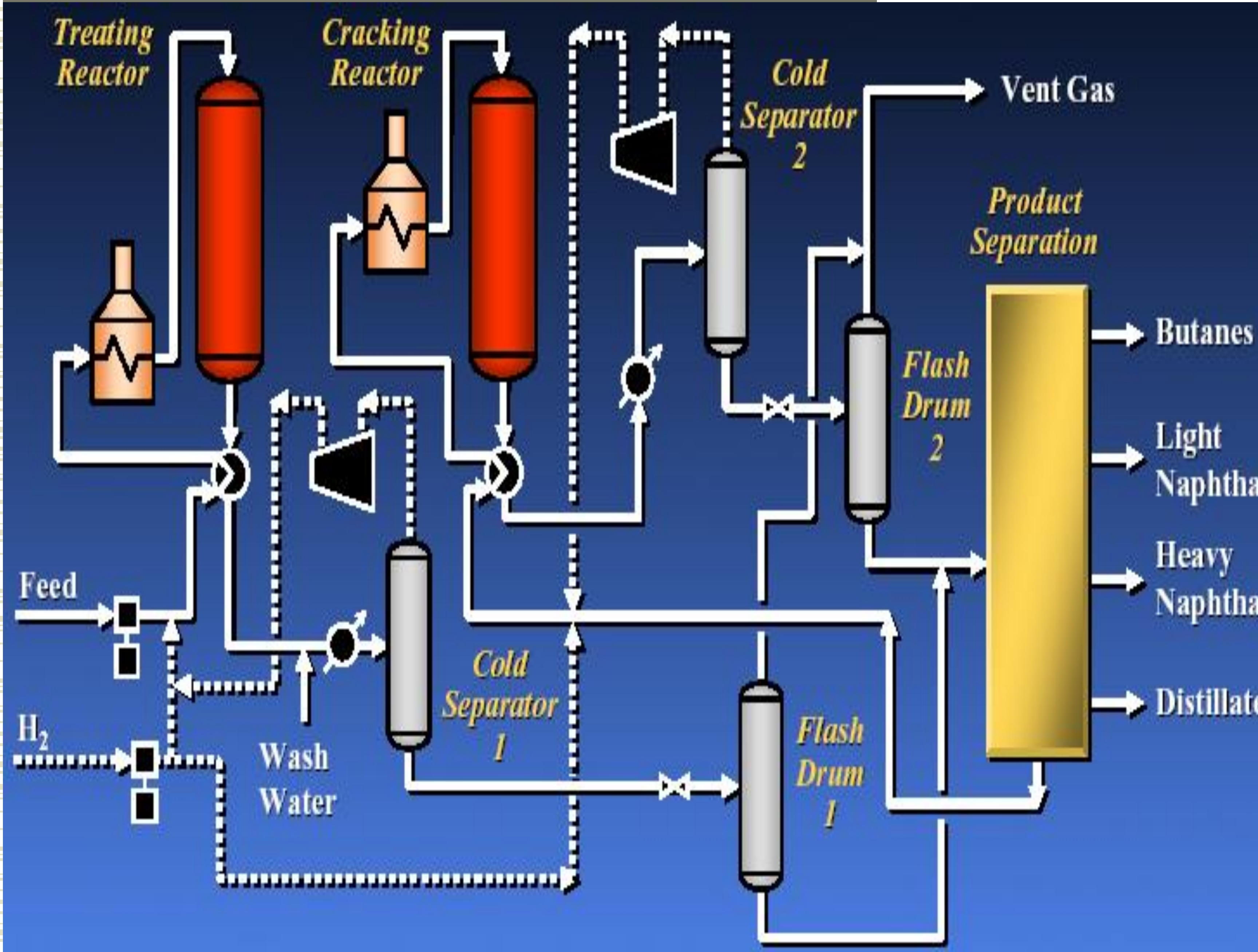
Two Stage Flow Schemes



Two Stage Flow Schemes Features

- Most cost effective for large capacity units.
- High conversion with high throughputs.
- First stage is hydrotreating with some cracking while the second stage is only cracking.
- Provides high product quality and product slate flexibility as single stage.

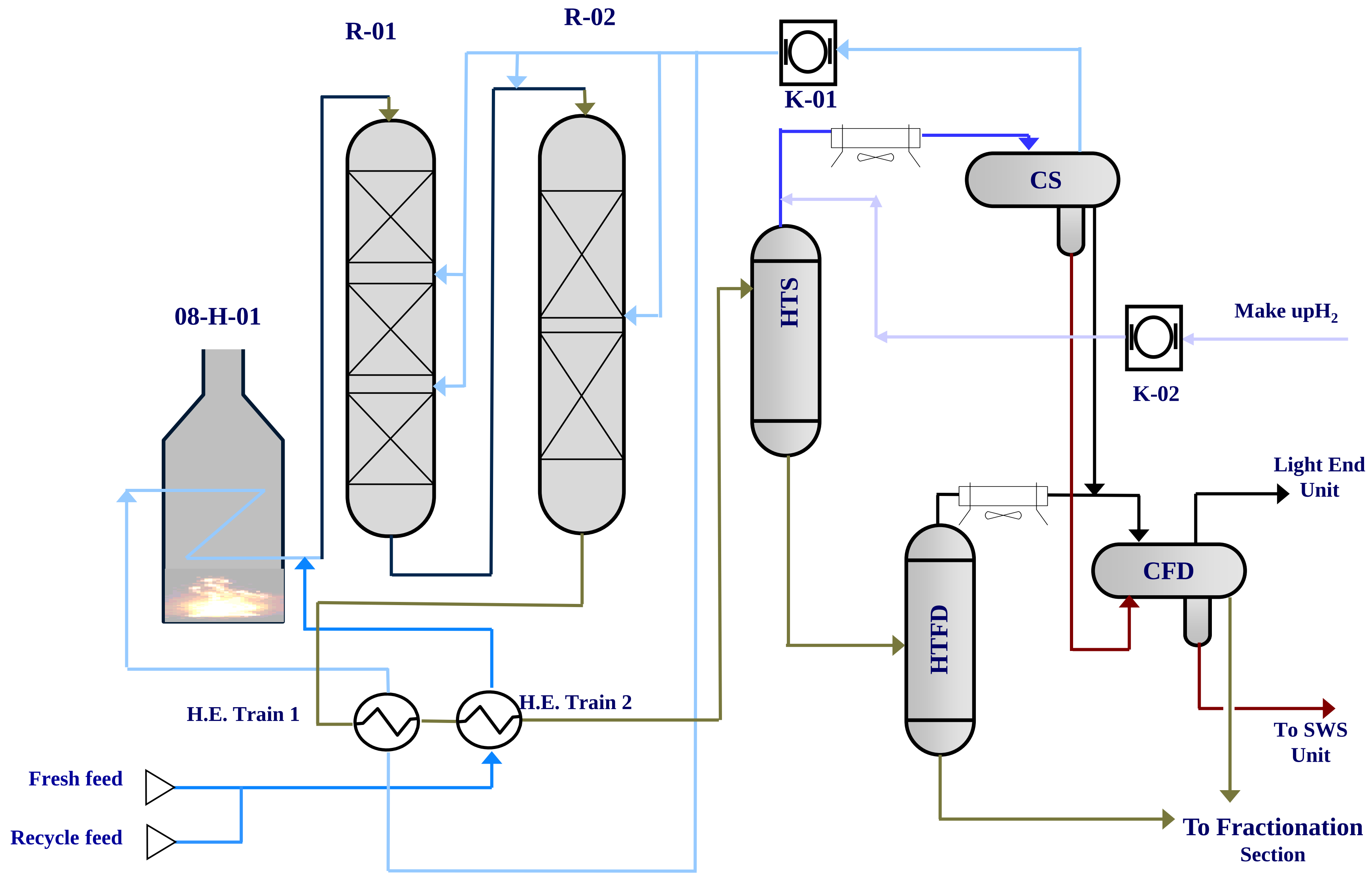
Separate Hydrotreat Flow Schemes



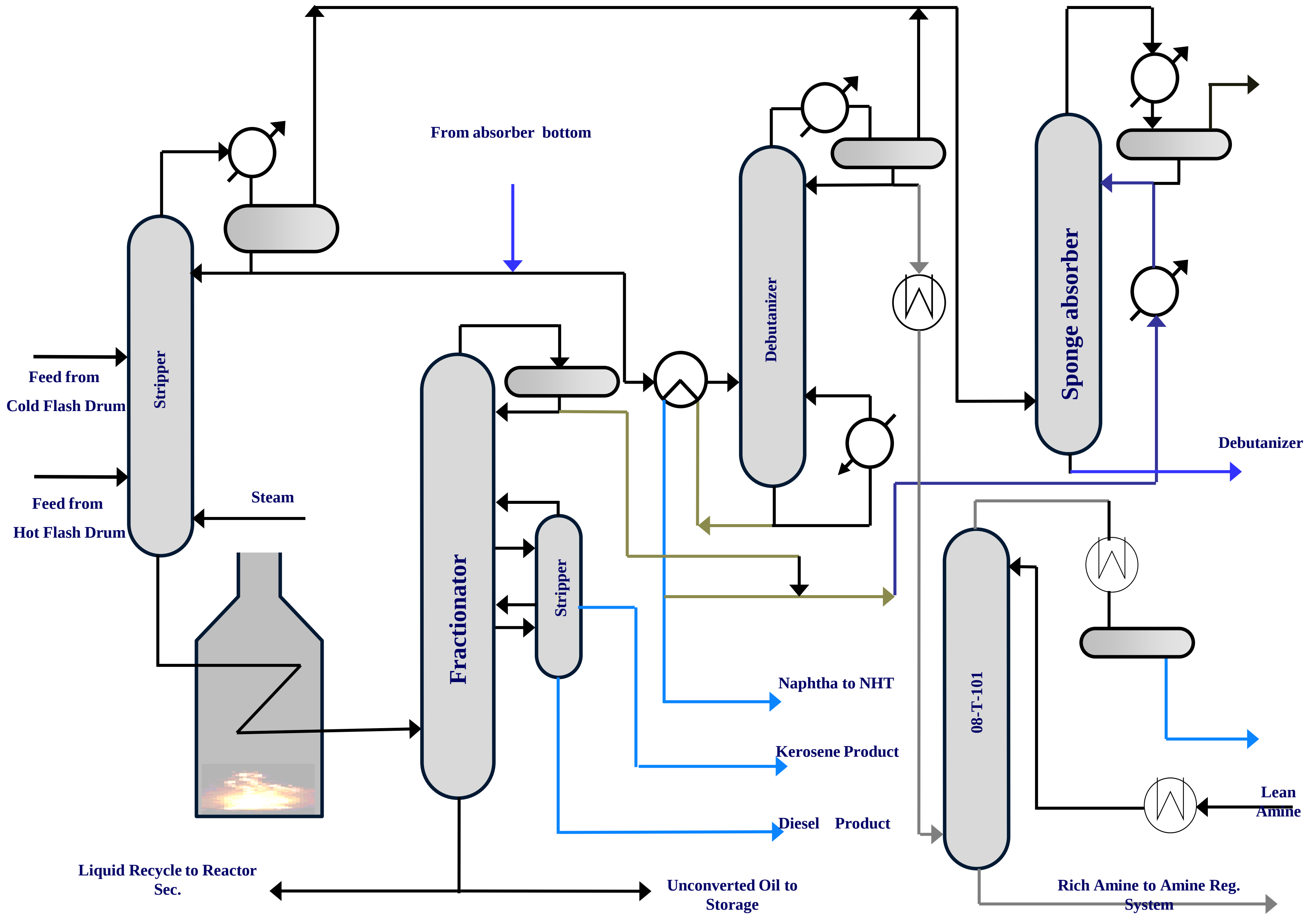
Separate Hydrotreat Flow Schemes Features

- Used when large amount of light hydrocarbons in feed.
- Used for high nitrogen in feed.
- Stage for hydrotreating only and another stage for cracking
- Used for special product quality or product slate requirement.

REACTION SECTION



FRACTIONATION SECTION



Hydrocracker Catalyst

Catalyst-What Is It?

- Catalyst is a substance that changes the rate of a reaction without itself being changed
- Enables a reaction to proceeded a faster rate.
- Can selectively favor certain reaction mechanisms over others

Keys of catalyst selection?

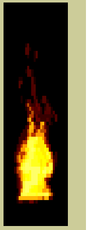
Initial activity

Stability

Selectivity

Product quality

Catalyst Deactivation



Catalyst Poisons

Permanent

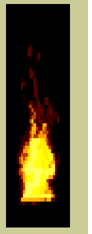
Metals entrainment

Temporary

Coke formation

HPNA fouling

NH_3

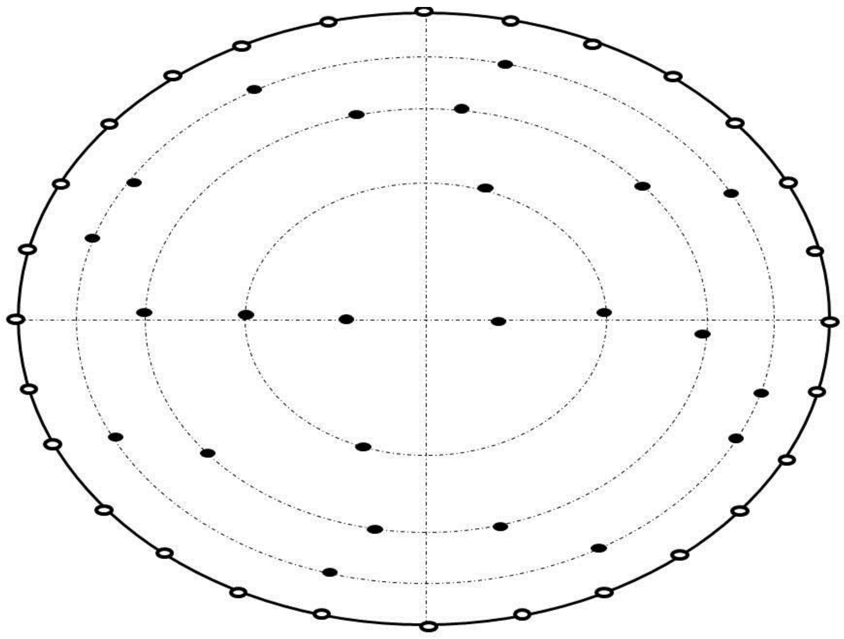


Catalyst deactivation prediction

The rate of catalyst deactivation can be followed by plotting the average catalyst temperature required for conversion at daily conditions of charge rate, conversion and feed quality versus catalyst life or operating days-on-stream.

Temperature Monitoring

- Top and bottom of each bed
- Additional point in middle of long beds



Temperature Monitoring

- **Peak temperatures**
- **Radial Temperatures**
- **WABT**

Reactor Temperatures

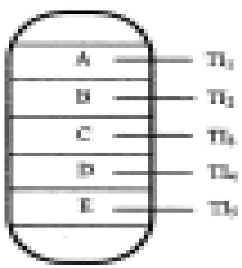
Weight Average Bed Temperature

Catalyst activity correlates to average bed temperature

SOR/EOR: 397 / 438 C

Attribute A Weight Fraction Of The Catalyst Bed To Each TI

For Example



A = 10% Catalyst Weight
B = 25% Catalyst Weight
C = 30% Catalyst Weight
D = 25% Catalyst Weight
E = 10% Catalyst Weight

Sum = 100% Catalyst Weight

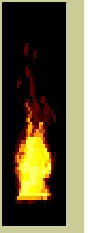
Therefore

$$
\begin{aligned}
& 0.10 \times TI_1 \\
+ \; & 0.25 \times TI_2 \\
+ \; & 0.30 \times TI_3 \\
+ \; & 0.25 \times TI_4 \\
+ \; & 0.10 \times TI_5 \\
\hline
& WABT = 397°C
\end{aligned}
$$

$TI_1 = 385°C$
$TI_2 = 391$
$TI_3 = 398$
$TI_4 = 402$
$TI_5 = 407$

Provides Common Variable For Deactivation and Operating Conditions

Hydrocracker Process Variables



Reactor Temperatures

Reactor Inlet

Controlled to adjust the amount of conversion

Peak Temperatures

Maximum temperature on each bed

Temperature Rise

Represent Exothermic heat generated from each bed

Bed Radial Temperature

Measure the temperature difference in one elevation of the bed

Unit Conversion

Volume Percentage of feed that is converted to products in the unit

(All material boiling above 370 C converted to materials boiling below 370 C).

$$\textit{Conversion} = \frac{\textit{Fresh Feed} - \textit{UCO}}{\textit{Fresh Feed}} \times 100$$

Liquid Recycle

Recycle increases mass flow without increasing temperature rise, reducing reactor severity

$$CFR = \frac{\text{Feed Rate} + \text{Liquid Recycle Rate}}{\text{Feed Rate}} \times 100$$

Liquid Hour Space Velocity

Catalyst is designed for specific hydrocarbon flow

$$LHSV = \frac{\text{Volumetric feed rate}}{\text{Catalyst volume}}$$

Hydrogen Partial Pressure

- Promote saturation of olefin and aromatics
- Saturate the cracked hydrocarbons
- Prevents coke formation

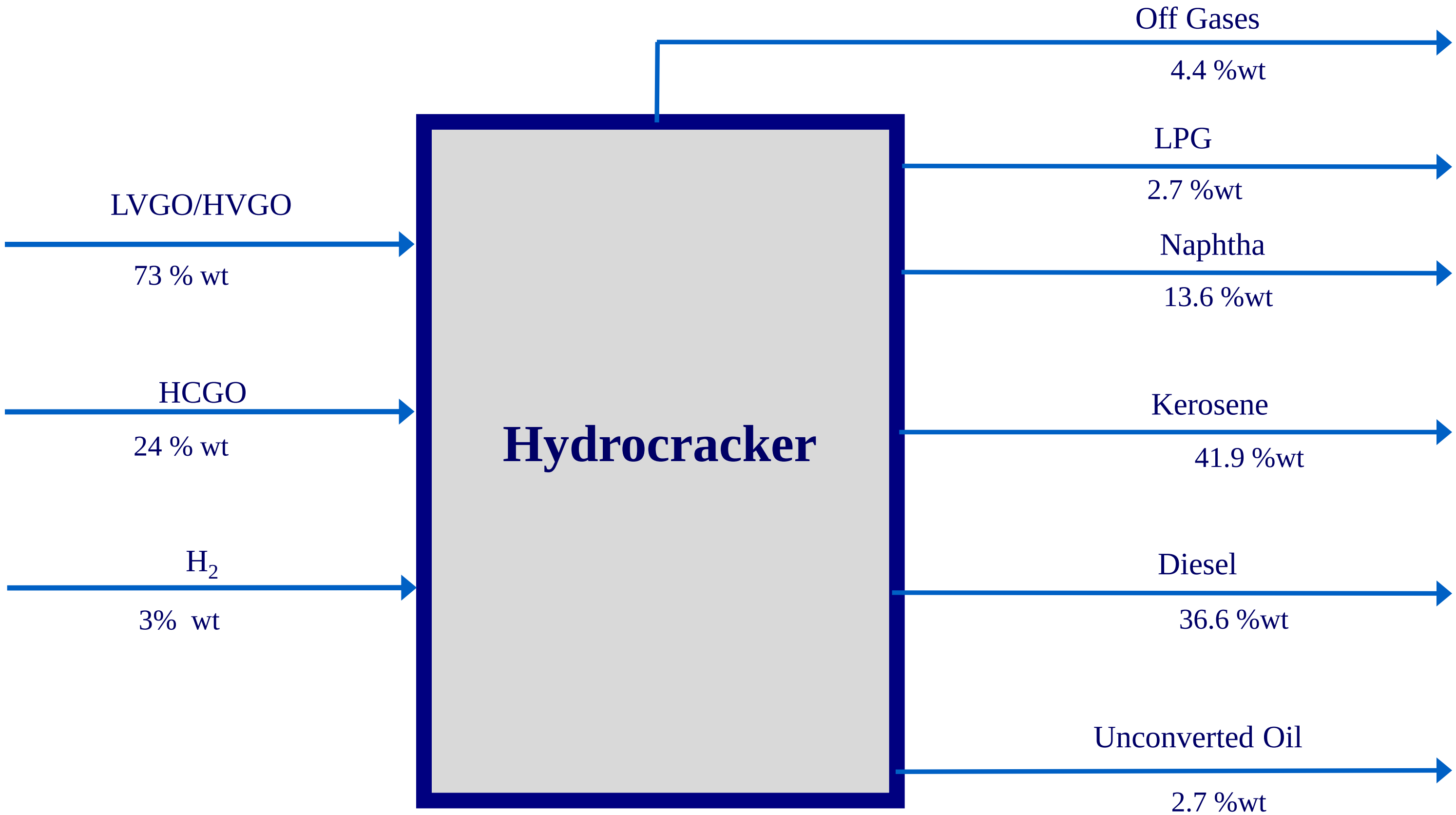
Recycle Gas Rate

- Required to maintain physical contact of the hydrogen with the catalyst and hydrocarbons
- Saturate the cracked hydrocarbon
- Provide heat sink

$$\textit{H2/HC Ratio} = \frac{\textit{RG Purity X Recycle Gas Rate, } Nm^3/hr}{\textit{Fresh Feed, } m^3/hr}$$

Material Balance

Process Material Balance

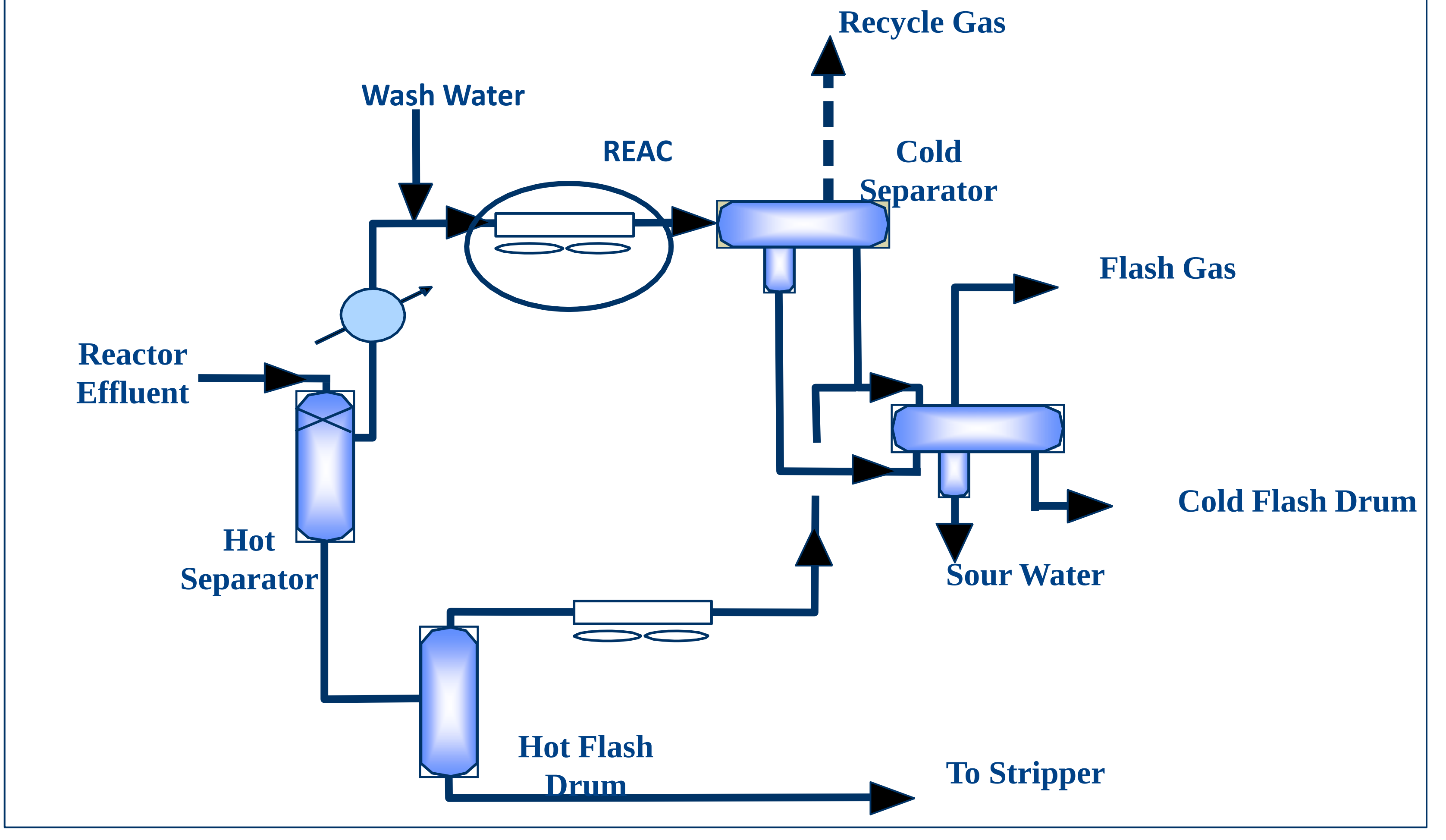


Main Equipments

Reactor Effluent Air Cooler

REAC

REAC Location



Factors Affecting REAC Performance

Material

Carbon steel which is easily affected by corrosion OR alloy

Sulfur & Nitrogen Concentration in Feed

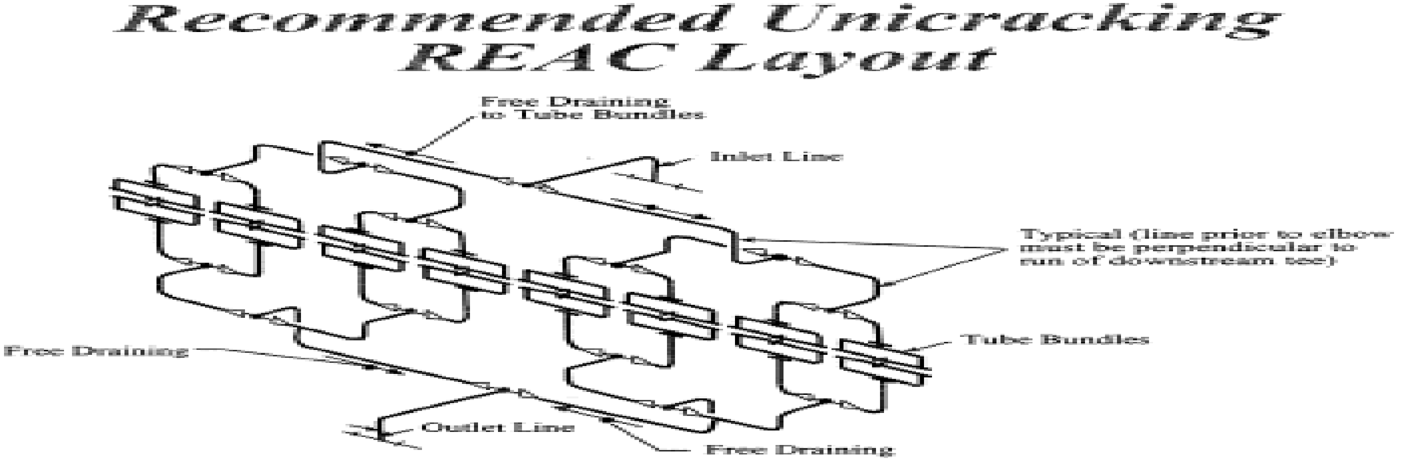
High concentration of S & N2 in feed leading to excess NH4HS production which accelerate the corrosion-erosion. NH4HS should be < 8 % wt in sour water

Factors Affecting REAC Performance

Factors Affecting REAC Performance

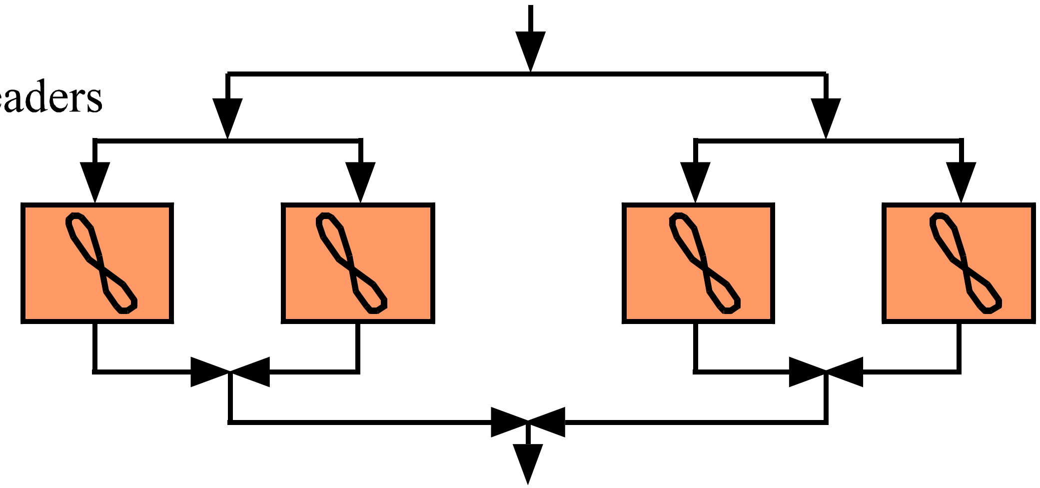
Piping Symmetry

The intent of the balanced design is to achieve equal distribution of oil, water and vapour phases between bundles and to minimize differences in fluid velocity from one bundle to another.

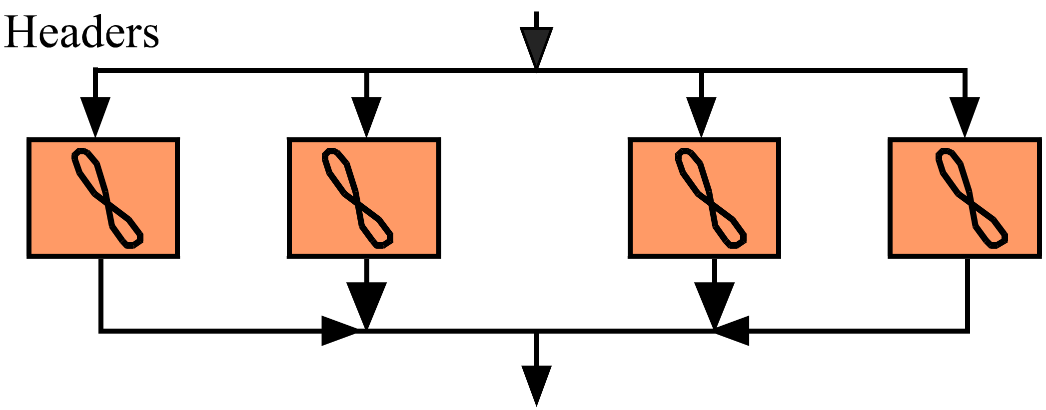


Header Arrangement

Balanced Headers



Unbalanced Headers



Factors Affecting REAC Performance

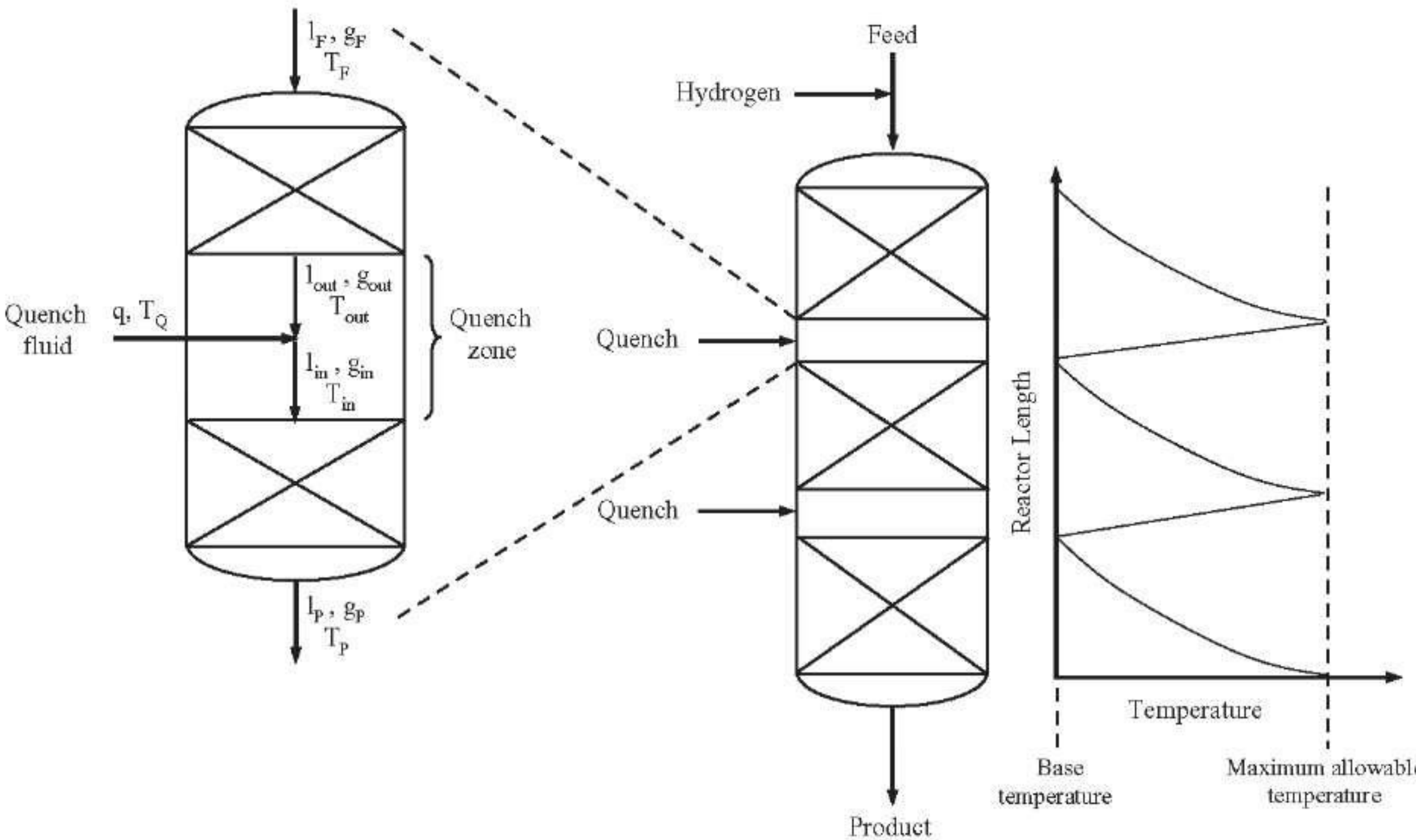
Wash Water Injection (more than 5% **)**

Temperature (Higher than the sublimation temperature)

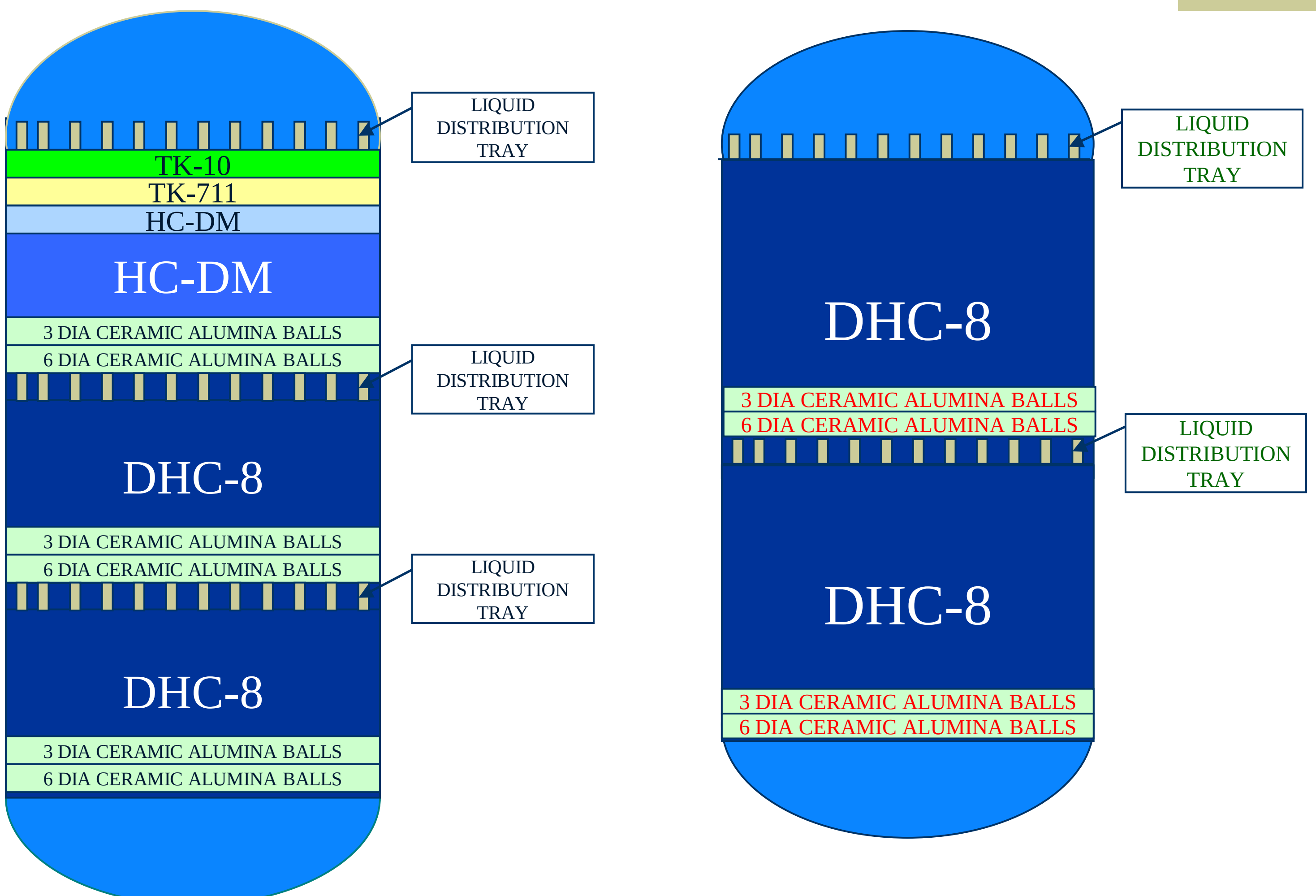
Velocity (3- 6 m/s max. for c.s and 3-9 m/s for alloy tubes)

REACTORS

Reactors Temp profile



Reactors internal

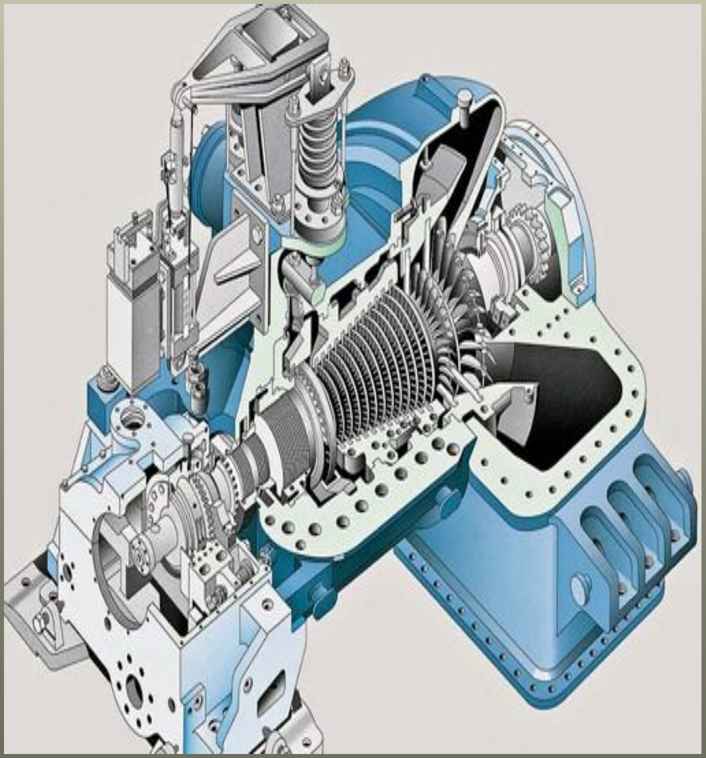


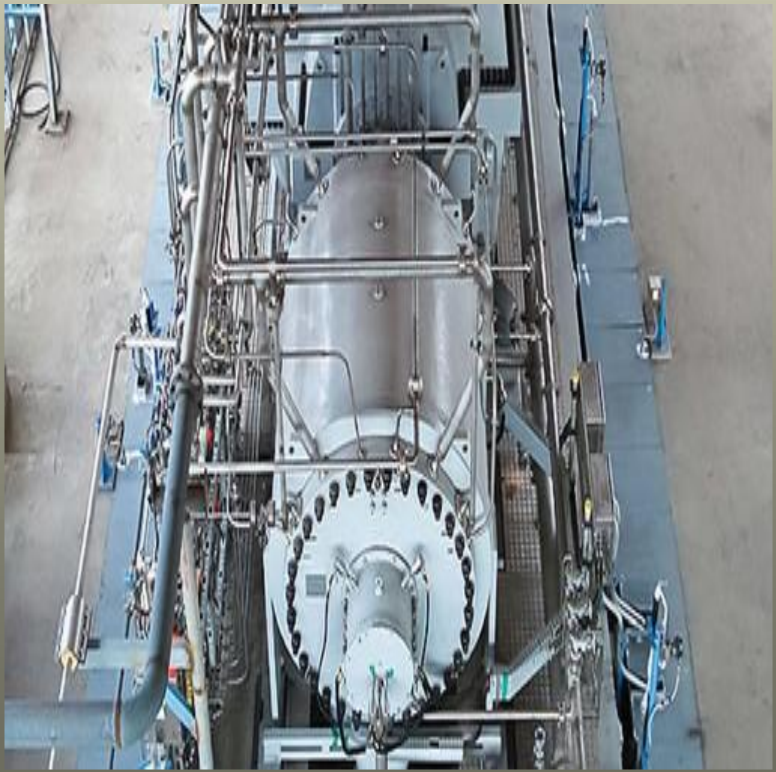
Feed Pump

Feed pump

- Feed pump is required to increase hydrocracker feed to the required pressure for reactions.
- Normally a multistage centrifugal pump is utilized for this issue.
- Pressure drop across this pump is about 190 barg
- Motor or power recover turbine

Recycle gas compressor

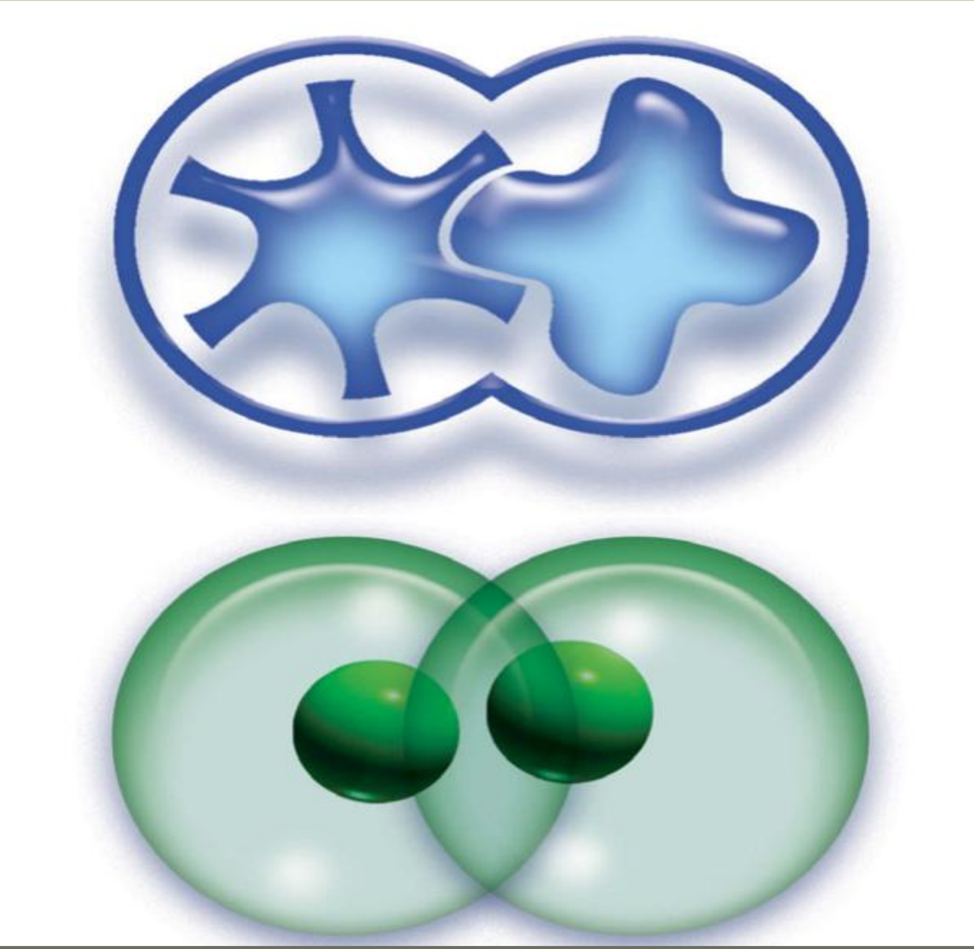




Recycle gas compressor

- Centrifugal compressor for re-circulate H2 in reaction section.
- Motor driven or steam turbine driven.
- Large volume of gas at a relatively low compression ratio. (500000 nm3/hr)
- Very complex multi stage machine, used in a critical service

Makeup compressor



Makeup compressor

- Rereciprocating compressors used in increasing pressure from 19 to about 165 bar g.
- Each stage of the compressor is protected and controlled by a separate spillback control system.
- spillback gases are cooled down using inter-stage air and trim coolers.

Special Notes

Depressurization system

The Unicracking unit is equipped with two reactor section depressuring systems to remove the reactants from the catalyst and stop further reactions in case of emergency.

Low rate 7 bar/min depressurize to flare within 20 minutes

High rate 21 bar/min depressurize to flare within 8 minutes

Thank You

Any Question