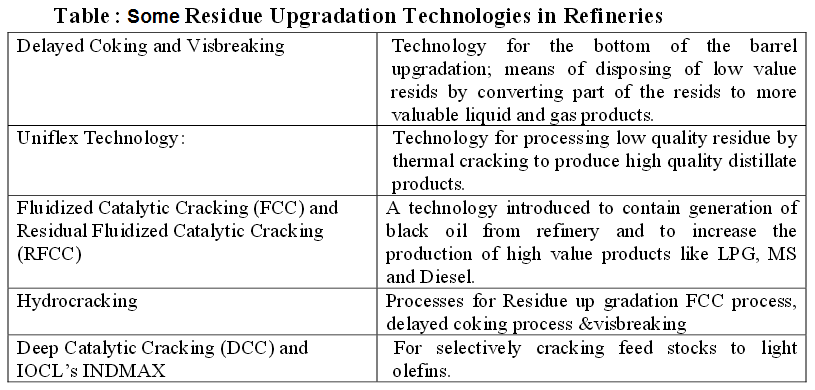
**Upgrading Processes**

With the continuous depletion in world oil reserves and increasing demand of petroleum products, the refiners are forced to process more and heavier crude .

The cost advantage of heavy crudes over light crudes has incentivized many refineries to process heavier crude, therefore increasing the heavy residue produced at a time when fuel oil demand is declining.  **Technological upgradation** have been carried out at refineries which takes care of processing heavy crudes as well as maximizing value added products and stringent product quality requirements.

Some of the residue upgradation technologies is given in Table below.



**Cracking Process:**

Cracking of heavy residue is most commonly used method for upgradation of residues. This involves of decomposition of heavy residues by exposure to extreme temperatures in the presence or absence of catalysts.

1. **Thermal Cracking:** Cracking at elevated temperatures in the absence of catalyst.

Examples: Visbreaking, delayed coking, Fluid coking etc.

1. **Catalytic Cracking:** Cracking in presence of catalyst.

Examples: FCC , Hydrocracking, DCC.

1. **Thermal Cracking Process:** Thermal cracking process for upgradation of heavy residue has been used since long and still it is playing an important role in the modern refinery through:

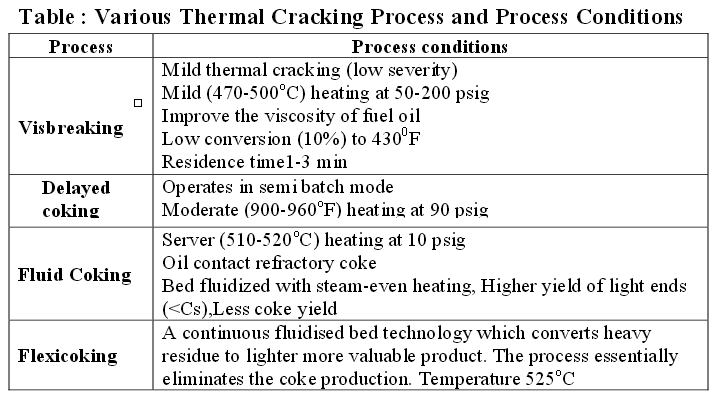
1- Upgradation of heavy residue, **and**

2- Improving the economics of the refinery through the production of lighter distillate and other valuable product like low value fuel gas and petroleum coke.

Heavy residues are a mixture molecules consisting of an oil phase and an asphaltene phase in physical equilibrium with each other in colloidal form. Asphaltenes are high molecular weight, relatively high atomicity molecules containing high levels of metals.

Under condition of thermal cracking, hydrocarbons, when heated, decompose into smaller hydrocarbon molecules.

Table below shows the various thermal cracking process and process conditions



**Visbreaking Process:**

Visbreaking is a mild thermal cracking operation at mild conditions where in long chain molecules in heavy feed stocks are broken into short molecules thereby leading to a viscosity reduction of feedstock.

• It is a non-catalytic thermal process.

•It reduces the viscosity and pour point of heavy petroleum fractions so that product can be sold as fuel oil.

• It gives 80 - 85% yield of fuel oil and balance recovered as light and middle distillates.

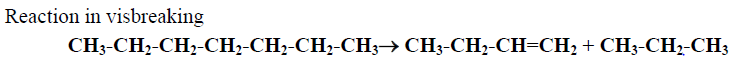
•The unit produces gas, naphtha, heavy naphtha, visbreaker gas oil, visbreaker fuel oil (a mixture of visbreaker gas oil and vsibreaker tar).

•A given conversion in visbreaker can be achieved by two ways:

1- Low temp., high residence time cracking: Soaker visbreaking.

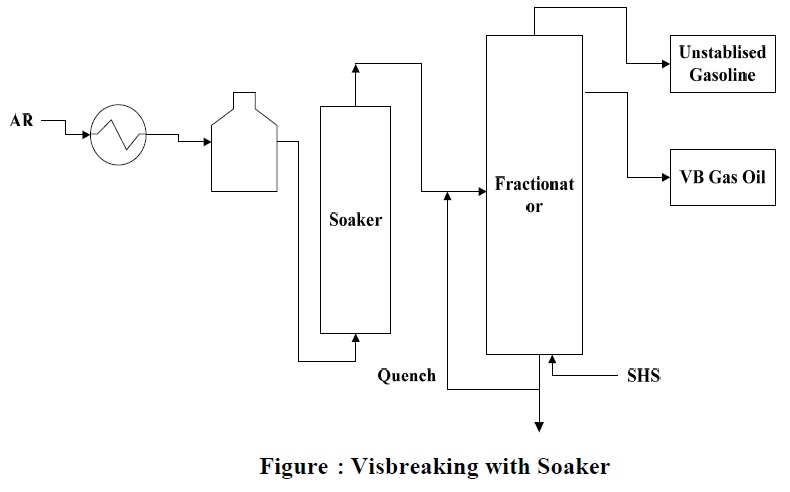
2- High temp., low residence time cracking: Coil Visbreaking.

• Reaction in visbreaking:



**1- Soaker Visbreaking Process:**

The furnace operators at a lower outlet temperature and a soaker drum is provided at the outlet of the furnace to give adequate residence time to obtain the desired conversion while producing a stable residue product, thereby increasing the heater run and reducing the frequency of unit shut down for heater decoking. The products from soaker drum are quenched and distilled in the downstream fractionator. Process diagram for visbreaking with soaker is shown in Figure below:



***Objective:*** To lower the viscosity of heavy residues under relatively milder cracking condition than the conventional cracking processes.



**Reaction:**

- Splitting of C-C bond.

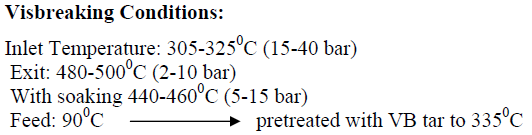
- Oligomerization and cyclisation to naphthenes of olefinic compounds.

- Condensation of the cyclic molecules to polyaromatics.

Side reactions: Foramation of H2S, thiophenes, mercaptans, phenol

**Products:**

The cracked product contains gas, naphtha, gas oil and furnace oil, the composition of which will depend upon the type of feedstock processed. A typical yield pattern may be gas 1-2%, naphtha 2-3%, gas oil 5-7%, furnace oil 90-92%.



**Soaking Drum**

Soaking drum is used to lengthen the feed residence time so that the furnace can operate at lower temperature. Soaker results in saving of energy because of the lower temperature with less coke tendency, larger gas oil yield.

**Advantages:**

- 15% reduction in fuel oil

- Larger running time between two decoking operations. coke deposit rate 3-4 times slower than in conventional units.

- Better selectivity towards gas and gasoline productivity.

**2- Coil Visbreaker:** In coil visbreaking process the desired cracking is achieved in the furnace at high temperature and the products of cracking are quenched and distilled in a downstream fractionator. Advances in visbreaker coil heater design now allows for the isolation of one or more heater passes for decoking, eliminating the need of shut the entire visbreaker down forfurnace decoking.

**Coking Process:**

Coking is very severe type of thermal cracking and converts the heaviest low value residue to valuable distillates and petroleum coke.

• Used to convert residual oil products

• Represents the complete conversion of petroleum residues to coke and lighter product.

• Recycle is used to further convert heavy distillate fractions to lighter products.

• Mechanism of coke formation: The colloidal suspension of the asphaltenes and resin compounds is distorted, resulting in precipitation of highly cross linked structure of amorphous coke. The compounds are also subjected to cleavage of the aliphatic groups. Polymerization and condensation of the free aromatic radicals, grouping a large number of these compounds to such a degree that dense high grade coke is eventually formed

• The process involves thermal conversion of vacuum residue or other hydrocarbon residue resulting in fuel gas, LPG, naphtha, gas oil and coke and essentially a complete rejection of metals.

• Various types of coking processes are delayed coking, fluid coking and flexi coking.

**Delayed Coking Process:**

Delayed coking process is used to crack heavy oils into more valuable light liquid products with less valuable gas and solid coke as byproducts.

• Consists of thermal cracking of heavy residue in empty drum where deposition of coke takes place. The product yield and quality depends on the typed feedstock processed.

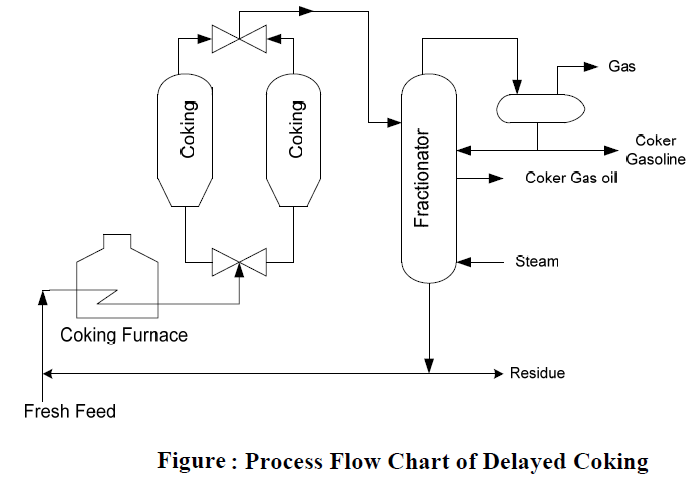
Typical delayed coking consists of:

1. Furnace to preheat the feed, and
2. Coking drum where the fractionation of the product takes place.

The feed is first preheated in furnace where the desired cooking temperature is achieved and fed to the coking drums normally installed in pairs where the cracking reaction takes place and the coke is deposited in the bottom of the reactor.

The coke drums overhead vapour flows to the fractionating column where they are separated into overhead streams containing wet gas LPG and naphtha and two side gas oil streams.

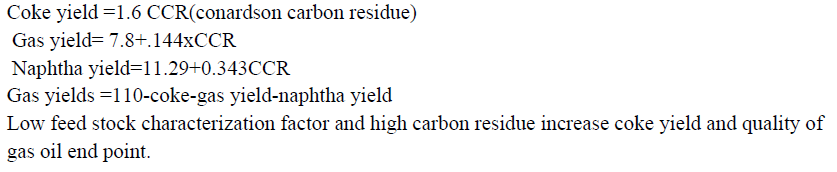
Recycled stream from the fractionating column combines with the fresh feed in the bottom of the column and is further preheated in coke heaters and flows to the coke drums. Process flow diagram for delay coking is shown in Figure below:



The reaction involved in delayed coking is resulting in formation of coke in the drum.

***Feed:*** Vacuum residue, FCC residual, or cracked residue.

***Product:*** Gases, Naphtha, Fuel oil, Gas oil and Coke.



**Fluid Coking Process:** Fluid coking is non- catalytic fluid bed process where residue is coked by spraying into a fluidized bed of hot, fine coke particles. Higher temperature with shorter contact time than delayed coking results in increased light and medium hydrocarbons with less cake

generation. Shorter residence time can yield higher quantities of liquid less coke, but the product have lower value.

**Flexi Coking Process:**

It is continuous process involves thermal cracking in a bed fluidized coke and gasification of the coke produced at 870 oC.

This process contains an additional step of gasification (The gas leaving the gasifier is burned in the furnace or power plants). It can be applied to wide variety of feed stocks.

**UOP UniflexTM Process**:

It is high conversion technology, that processes low quality residue streams, like vacuum residue, to make very high quality distillate products.

The process utilizes thermal cracking to reduce molecular weight of the residue in the presence of hydrogen and a nano sized catalyst to *stabilize the cracked products and inhibit the formation of coke precursors.*

The main products from uniflex are naphtha and diesel with a yield of greater than 80 vol%.

