5.2.1 Introduction

Visbreaking is the thermal decomposition of viscous crude oil straight-run vacuum or atmospheric residues at temperatures between about 430 and 485°C. The term visbreaking evolved as a short form of ‘viscosity breaking’, as one of the chief objectives of the process was to reduce the viscosity of a crude residue by thermally decomposing or cracking large oil molecules into smaller ones.

Today, visbreaking enables a refiner to reduce the amount of fuel oil produced, because in addition to reducing viscosity over the reaction, some conversion to lighter products also occurs and the amount of cutter stock required to meet a given viscosity is consequently reduced. Products from a visbreaker are visbroken tar, gas oils, naphtha and gas. In some countries such as Italy, visbroken tar is also, particularly in summer months, used as an important constituent of bitumens, after vacuum distillation.

Visbreaking represents a relatively mild form of thermal cracking process as conversion is limited to ensure stability of the resultant fuel oil, normally produced from the blending of cutter stock into the visbroken tar residue from the process.

Visbreaking was commercialised as a refinery process in the late 1930s as development of the earlier thermal cracking process and today can be regarded as a mature technology. Ironically, thermal cracking (see Chapter 5.3) now tends only to be used commercially in combination with visbreaking because thermal cracking has been to a great extent superseded by fluidized catalytic cracking as the preferred refinery process for the cracking of heavy gas oils and long residues.

The visbreaking process can be regarded as mixed-phase because although the reacting residue oil is in the liquid phase, some vapour generation occurs as gasoline range and lighter components are formed in the cracking reactions. Usual kinetic considerations apply in terms of temperature, pressure and residence time, but the absence of a catalyst simplifies both chemistry and engineering considerations.

Visbreaking reactions are carried out with a relatively short contact time of a few minutes either in the tubes of a furnace coil (simplified flowsheet of a coil visbreaker depicted in Fig. 1) or in the case of a soaker-type visbreaker, mainly in a separate soaker drum downstream of the furnace coil (simplified flowsheet of a soaker visbreaker is depicted in Fig. 2). For a coil-type visbreaker (typically twin cell), the furnace provides the slightly endothermic heat of reaction as well as heating the reactor contents from furnace inlet to outlet temperature.

For a soaker-type visbreaker, the slightly endothermic reactions mainly take place in a soaker drum (usually designed for upflow) with an approximate 20-25°C temperature drop over the drum. The temperature leaving the furnace coil is lower than in a coil visbreaker to enable most of the reaction to take place in the soaker drum.

The merits of each type of visbreaker (coil and soaker type) have been strongly advocated by their proponents within the refinery industry, and the pluses and minuses associated with each are reviewed in Section 5.2.4 which details visbreaker processes.

Sufficient pressure is required at the furnace inlet to keep gas oil and heavier reaction constituents in the liquid phase at the furnace outlet (minimum outlet pressure of 10-20 bar). The maximum reaction temperature is limited by the desired severity of cracking.

Severity of operation depends on the choice of visbreaker feedstock and is selected to ensure a stable fuel oil product. The choice of cutter stock also has significant influence on fuel oil stability. An adequate
length of operation between shutdowns for decoking of the furnace tubes is important commercially to minimize loss of production. Hence, coke laydown on the furnace tubes must be limited.

### 5.2.2 Process evolution

Visbreaking originated from the earlier thermal cracking processes such as the Dubbs process in the 1930s (see Chapter 5.3). Key feature of these early thermal cracking processes was the continuous thermal cracking under pressure of gas oils or reduced crudes in the tubes of a pipestill, followed by separation of resultant vapour from the liquid in a separator (Nelson, 1941).

Over the 20-25 years or so between the start of the Second World War and the early to mid 1960s, and against a backdrop of low oil prices, visbreaking technology was significantly developed with feedback from early commercial units assisting extensive design advances.

MW Kellogg Limited (MWKL) and its parent Kellogg Brown & Root (KBR) have designed many visbreakers over the last fifty years. By the early to mid 1960s, KBR (then MW Kellogg) commercial coil-type visbreaker designs included: 

- **a)** two radiant cell furnace design containing separate radiant heating and soaking sections;
- **b)** injection of steam into the visbreaker furnace to limit coking; 
- **c)** design of suitable special quench valves; 
- **d)** optimisation of bubble tower (main fractionator) design conditions; 
- **e)** use of vacuum flasher columns (containing trays) operating at 110-120 mbar pressure in the flash zone to further fractionate the atmospheric tar; 
- **f)** selection of suitable (non-paraffinic) cutter stocks to maintain fuel oil stability.

Laboratory analyses supported yield predictions and selection of furnace outlet operating conditions. Knowledge of various schemes for visbreaking in combination with thermal cracking was becoming more extensive with an awareness of pluses and minuses of each, and calculation procedures for recycle streams were being improved. Alternative configurations (all containing furnace coils, atmospheric tower and vacuum flasher) cited are summarised in Table 1.

Configuration 1, for a single vacuum residue feedstock, and either configuration 3 and 4, for recycling of VGO (Vacuum Gas Oil), were generally favoured, depending on whether a straight-run vacuum tower was already present. The two coil recycle arrangement of configuration 4 is depicted in Fig. 3 for which the feeds are vacuum residue and VGO. The configurations 3 and 4 are discussed under thermal cracking in more depth in Section 5.3.2.

In the 1970s and early 1980s many new visbreakers were built outside of the United States. The use of visbreakers containing soaker drums downstream of the furnace coil became more widespread. Upflow soaker drum designs were popularized, providing for a prolonged residence time and, therefore, a lower temperature leaving the furnace coil. This permits savings on fuel consumption (although against that, steam production from a coil visbreaker is higher) or allows a greater plant capacity for a given coil size. A soaker drum can be used to revamp an existing coil visbreaker for increased...
capacity. The relative merits of soaker versus coil visbreaking are discussed in Section 5.2.4.

By the mid 1980s, with a declining demand for heavy fuel oil, further improvement to visbreaker design included design of low pressure drop packed vacuum flashers containing structured packing and grids. This permits enhanced yields of Heavy Vacuum Gas Oil (HVGO). The use of low pressure drop packed sections in the main fractionator was also introduced.

Between the late 1980s and 2005, few new visbreakers have been built in Europe. This reflects the lack of any new grassroots refinery in Europe (with the one exception at Leuna, Germany). Despite addition of little extra grassroots capacity, there have been a number of further general process and operational improvements in what can now be regarded as a mature technology. These include:  
- a) optimizing of the process flowsheet;  
- b) major advances in process control and advanced process control aided by powerful but cheap computers;  
- c) use of pigging instead of steam-air decoking for furnace decoking;  
- d) various equipment improvements, including higher capacity trays/packings and the use of twisted tubes for heat exchanger revamps;  
- e) more sophisticated treatment measures to reduce fouling of heat exchangers.

One visbreaker variant which results in a lower capital cost than using a vacuum flasher but yields less heavy gas oil than the vacuum flasher is the Wood’s process which is offered by Foster Wheeler/UOP.

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**Table 1. Coil visbreaker/thermal cracking configurations**

<table>
<thead>
<tr>
<th>CONFIGURATION</th>
<th>FRESH FEED(S)</th>
<th>FEED TO COIL 1</th>
<th>FEED TO COIL 2</th>
<th>REMARKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Single pass</td>
<td>Atmospheric or vacuum resid</td>
<td>Atmospheric or vacuum resid</td>
<td>Not applicable</td>
<td>Preferred option for vacuum residue feed</td>
</tr>
<tr>
<td>2. One coil recycle</td>
<td>Atmospheric resid</td>
<td>Atmospheric resid + VGO recycle</td>
<td>Not applicable</td>
<td>Obsolete</td>
</tr>
<tr>
<td>3. Two coil recycle</td>
<td>Atmospheric resid</td>
<td>Atmospheric resid</td>
<td>VGO recycle</td>
<td>Preferred</td>
</tr>
<tr>
<td>4. Two coil recycle</td>
<td>Vacuum resid and VGO</td>
<td>Vacuum resid</td>
<td>Straight run/cracked (recycle) VGO</td>
<td>Preferred</td>
</tr>
<tr>
<td>5. Two coil recycle with split tar products</td>
<td>Atmospheric resid</td>
<td>Atmospheric resid</td>
<td>VGO recycle</td>
<td>Two vacuum towers required</td>
</tr>
<tr>
<td>6. Two coil with split feed and split tar products</td>
<td>Vacuum resid</td>
<td>Vacuum resid</td>
<td>Straight run/VGO recycle</td>
<td>Two vacuum towers required</td>
</tr>
</tbody>
</table>
This has been used in Russia and Pakistan and is described in Section 5.2.4. Some refiners have instead opted for complete bottom-of-the-barrel destruction using delayed coking or gasification of residues (against a background of falling demand for heavy fuel oil).

Several hybrid technologies have been developed. Two of these are Shell’s Deep Thermal Conversion (DTC) process (Douwes et al., 1999) and Aquaconversion (Pereira et al., 1998). These are discussed further in Section 5.2.4.

KBR and MWKL have been active in recent years at studies which adapt spare visbreaker furnace capacity to thermally crack other stocks such as deasphalted oil from a ROSE (Residuum Oil SuperCritical Extraction) unit or to visbreak an asphaltene-rich stream (Simons and Ersanilli, 1997).

The future

Environmental and, hence, legislative pressure on the sulphur content in heavy fuel oils and bunker fuels is increasing. The EU inland limit of 1% sulphur on heavy fuel oil has already come into force (1 January 2003) with some exemptions and these exemptions will be of finite duration.

Limits to sulphur content have also been established for marine fuels and there is evidence that EU policy will be tightened up in future. These regulatory pressures are likely to lead to more owners of visbreakers combining their units with other technologies to substantially reduce or completely eliminate high sulphur fuel oil production.

Technology options for this include: combining visbreaking with solvent deasphalting of the visbroken vacuum tar followed by gasification of the asphaltenes (Simons et al., 1997); use of Shell’s Deep Thermal Conversion technology (Douwes et al., 1999) to revamp a visbreaker, producing a liquid coke which is then gasified. The gasification process can also be applied directly to visbreaking tar.

5.2.3 Chemistry, thermodynamics and kinetics

The main reactions taking place in thermal processing, such as visbreaking and thermal cracking, are many and their interactions complex. Visbreaking is carried out under low severity conditions. The following reactions take place (Murphree and Ciprios, 1962; Asinger, 1968) although C—C scission is considered by both authors as most important: C—C bond scission which usually results in the formation of smaller paraffinic and olefinic molecules; dehydrogenation (C—H bond scission) giving rise to the formation of olefinic molecules, aromatics and hydrogen.

C—C bond scission is favoured thermodynamically (rather than dehydrogenation) as the C—C single bond enthalpy is lower than that of a C—H (Asinger, 1968).

Once formed, the products of these reactions, particularly olefins, can further react by polymerization/condensation reactions. The reactions, which proceed by a free radical mechanism involving initiation, propagation and termination steps, are slightly endothermic.
C — C bond scission
An example is a long paraffin chain decomposing into two smaller chains which are a paraffin and an olefin.

\[
\text{R—CH}_2—\text{CH}_2—\text{CH}_2—\text{CH}_2—\text{CH}_2—\text{R'} \rightarrow
\text{R—CH}_2—\text{CH}_2—\text{CH}—\text{CH}_2+\text{R'}—\text{CH}_2—\text{CH}_3
\]

In the case of alkylated naphthenes with long paraffinic side chains, the side chains crack first to produce a saturated and an unsaturated chain due to the greater thermal stability of the ring system. Again, in the case of higher boiling aromatics with the long paraffinic side chains, the side chains tend to crack first due to the unreactive (refractory) nature of the aromatic ring system.

Dehydrogenation
Olefins and aromatics are also produced by dehydrogenation of paraffins and naphthenes respectively. An example for paraffins is:

\[
\text{R—CH}_2—\text{CH}_2—\text{CH}_2—\text{CH}_4
\rightarrow
\text{R—CH}_2—\text{CH}—\text{CH}_2—\text{CH}_2—\text{CH}=\text{CH}_2+\text{H}_2
\]

The reaction is reversible and the propensity to dehydrogenate tends to decrease as the chain length increases.

Isomerization reactions
Isomerization reactions also take place to a limited extent but are not favoured thermodynamically when compared to C — C bond scission.

Polymerization/condensation reactions
Side reactions occur in all thermal cracking processes. These involve polymerization and condensation reactions. A proportion of newly formed hydrocarbons recombine to give relatively stable high molecular weight products.

One group of polymers include polyaromatics which have a condensed aromatic structure; these are coke precursors. As polymerization continues, the polymer becomes increasingly dehydrogenated and, hence, richer in carbon. The higher the level of dehydrogenation, the more solid they become, ultimately forming a coke.

Fuel oil stability
One critical aspect of operating a visbreaker is fuel oil stability. Heavy oils and resins in the feed peptize the asphaltenes present so that they are collooidally dispersed. Visbreaking converts the heavy oils and maltenes to lighter products and also produces some additional asphaltenes via the above polymerization reactions. The asphaltenes present in the feed undergo little or no change in visbreaking and are said to be refractory. As visbreaking severity increases, the peptizing power of the maltenes is insufficient to maintain the asphaltenes in colloidal dispersion, and the asphaltenes are mutually attracted and flocculate to produce an unstable fuel oil. The exact level of severity at which the asphaltenes flocculate varies with the crude from which the residue is derived.

The choice of cutter stocks can also have a major impact on fuel oil stability. Fuel oil stability can be measured using a P (Peptizing)-value test. Results from this test can typically be classified as follows:

- P-value less than or equal to 1.0, fuel oil is unstable;
- P-value between 1.0-1.1, indicates borderline fuel oil stability;
- P-value greater than 1.1, fuel oil is considered stable.

Stability of fuel oils can be confirmed using internationally recognised hot filtration tests for residue fuel oils such as ISO 10307-1 and ISO 10307-2.

Overall reaction kinetics
At low conversion per pass (see below) the cracking reactions are first order. The reaction rate can be represented by the following reaction rate expression:

\[
k_1 = \frac{1}{t} \ln \left(\frac{100}{100-x}\right)
\]

where \(k_1\) is the first order reaction rate constant (s\(^{-1}\)), \(t\) residence time (s), \(x\) percentage of reactants converted by time \(t\). The first order reaction rate constant \(k_1\) can be represented by a standard Arrhenius type temperature relationship. At high conversions, the reaction deviates from first order as polymerization becomes more important.

Feedstock conversion
Conversion per pass is defined by KBR and MWKL as the volume per cent conversion per pass of feed converted to 0-200°C range material from 530°C+ TBP (True Boiling Point) material. Conversion per pass for a given feedstock is selected to achieve a stable fuel oil product.

Reaction severity
Reaction severity for a visbreaker can be measured in terms of conversion per pass. The higher the conversion per pass, the higher the severity. For a coil visbreaker, conversion is strongly influenced by coil exit temperature (main operating variable) and feedstock type. High severity operation involves a high coil exit temperature and results in a high conversion per pass and vice versa.

For commercial visbreaking of a vacuum residue feedstock, a single reaction pass is used.
with no recycle. Typical yields from a single pass coil visbreaker (without a vacuum flasher to further separate the atmospheric tar) are given in Table 2 for a vacuum residue (530°C-TBP) feedstock derived from a high sulphur crude with the objective of minimizing the residue viscosity from the process.

Cracking conditions in a commercial coil visbreaker are relatively mild with a coil exit temperature of about 460-485°C and a coil exit pressure in the range of 10-20 bar. The reaction is normally carried out as a single pass (i.e. without recycle). Sufficient residence time (reckoned in minutes) is provided in the visbreaker furnace in two parts: in the preheat (heater) cell to heat the feedstock to the reaction temperature; in the soaker (reaction) cell to provide the desired reaction residence time at the reaction temperatures.

For a soaker type visbreaker, the coil exit temperature is lowered to about 450°C so that most of the reaction takes place in the soaker drum. As severity is increased by increasing the soaker cell outlet temperature, the yield of tar (fuel oil) is reduced and yields of gas oil and lighter products increase to give a lower cutter stock requirement for blending the tar product to a given viscosity. However, fuel oil stability decreases and there is an increased tendency to deposit coke in the furnace which, taken to extremes, could shorten the run length between shutdowns. Coke forming polymerization reactions are favoured by high conversion, high pressure and relatively long residence time.

Sufficient pressure is needed in the furnace coil (typically 10-20 bar) so that heavier reaction components (gas oils and heavier) are kept in the liquid phase. This avoids increased vapour phase reactions which result in increased yields of light gases and also increased coke formation. Provided this is achieved, pressure has little impact on the main C—C bond scission reactions within the typical range of visbreaker operating pressures mentioned above.

5.2.4 Processes

Modern KBR and MWKL coil visbreaker
A modern KBR and MWKL designed commercial coil visbreaker process which includes an atmospheric fractionator and a vacuum flasher tower is described below (a simplified flowsheet is depicted in Fig. 4).

Feed is a residue from a vacuum distillation unit which is preheated against vacuum tower bottoms and Heavy Gas Oil (HGO) pumparound before entering the convective section of the visbreaker furnace. The visbreaker furnace is a two-pass arrangement. In the convective section, the feed is heated again before entering the radiant heater cell where further heating takes place to achieve a temperature at which the thermal cracking reactions are initiated. Thermal cracking reactions are then completed in the adjacent radiant soaker cell.

The visbroken products leave the soaker cell and enter the transfer line. Quench is immediately provided through a quench valve by recirculating HGO from the main fractionator. The temperature of the furnace effluent is lowered by the quenching and further cooling in the transfer line before entering the flash zone of the main fractionator. In the main fractionator, the furnace effluent is separated into fractionator bottoms, HGO, Light Gas Oil (LGO) and overhead products.

Fractionator overhead vapour is partially condensed before entering a reflux drum. In this drum, liquid hydrocarbon is separated from visbreaker gas and sour water. Part of the hydrocarbon liquid from the drum is pumped to the top of the main fractionator as reflux, and the balance of the hydrocarbon liquid (unstabilized

<table>
<thead>
<tr>
<th>PRODUCT</th>
<th>YIELD (wt %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H₂S</td>
<td>0.3</td>
</tr>
<tr>
<td>C₁-C₃</td>
<td>1.6</td>
</tr>
<tr>
<td>C₄</td>
<td>0.7</td>
</tr>
<tr>
<td>C₄+ Gasoline (200°C cut point)</td>
<td>6.7</td>
</tr>
<tr>
<td>Gas oil (350°C cut point)</td>
<td>12.4</td>
</tr>
<tr>
<td>350°C+ residue (tar)</td>
<td>78.3</td>
</tr>
</tbody>
</table>

These yields are typical for a particular feedstock and conversion level.
visbreaker naphtha product) is pumped to battery limits for further processing. Flashed vapour flows to the battery limit for gas processing elsewhere. Sour water is pumped to the battery limit for treatment. Provision is made for the injection of corrosion inhibitor and a neutralizing agent into the fractionator overhead lines.

Main fractionator bottoms feed a vacuum flasher tower. Typically, the vacuum flasher contains four beds (plus stripping trays) that separate the atmospheric tar into overhead vapour (routed to a steam ejector system), Light Vacuum Gas Oil (LVGO), Heavy Vacuum Gas Oil (HVGO), slop wax and tower bottoms (visbroken vacuum residue).

Most of the LVGO is used in a top pumparound from which the LVGO product is taken downstream of an air cooler, with the remainder used as reflux to the top bed. Part of the HVGO is used as reflux to the wash section (bottom bed). The slop wax stream which is withdrawn from below the bottom bed is typically recycled as a quench flux medium to the main fractionator, or alternatively, can be routed to the vacuum flasher bottoms.

Stripping steam is injected below the bottom tray. Steam is used to recover vacuum distillate from the vacuum residue and also to reduce the hydrocarbon partial pressure in the flash zone. Additional steam, if desired, can be added to the transfer line between the main fractionator and the vacuum flasher.

Vacuum tower bottoms are pumped through filters and cooled against visbreaker feed preheat exchangers. Some of the cooled vacuum tower bottoms are recycled to the base of the main fractionator as a quench to minimize coking. The remainder is routed to fuel oil blending. Cutter stock is added and the blended fuel oil is further cooled before being routed as product to storage. In the case of bitumen production, no cutter stock is required, and part of the flow is bypassed around one of the rundown heat exchangers.

Off-gas from the ejector system is contacted with a lean amine solution in a packed absorber. The overhead gas from the amine absorber is released to the firebox of the furnace. The rich amine solution from the absorber is sent via pumps to the battery limits to be regenerated elsewhere.

**Furnace coil design**

There are many important considerations in designing a coil visbreaker furnace. The twin cell horizontal tube box type furnace design (KBR and MWKL) includes a convection section. The twin cells referred to, which comprise radiant heater and radiant soaker cells, do not use vertical tube furnace designs in this service.

The dimensions of the radiant heater and soaker cells are similar, but during operation the heat transfer rates achieved in the soaker cell are lower than those in the heater cell. This tends to reduce the coke laydown in the soaker cell at the expense of greater coking in the heater cell, but as the heater cell temperatures are lower, these prevailing effects tend to cancel each other out. Adjustment of the heater to soaker crossover temperature has the effect of changing the reaction volume in the furnace.

After the type of heater and a suitable set of mechanical specifications have been selected, it is
important to select the major process design variables, in this case, tube size and design heat transfer rate for each cell.

Major and minor design variables (Alderton, 2004) include: a) type of furnace; b) furnace mechanical specifications (including tube metallurgy); c) selected tube size and number of parallel process streams; d) design heat transfer rates for each radiant cell; e) cold oil velocity (see definition below); f) tube spacing; g) choice of fuel; h) excess of air; i) ratio of furnace duties between heater and soaker cell; j) number of burners and heat liberation per burner; m) peak furnace tube skin temperatures (clean/fouled) for each radiant cell; n) tube design basis.

Cold Oil Velocity (COV) in metres per second is defined as follows:

\[
COV = \frac{\text{bbl/d at } 60 \, ^\circ\text{F}(15.56 \, ^\circ\text{C})}{435.8 \cdot \text{total flow area}}
\]

where total flow area = number of streams \cdot flow area per tube in \text{m}^2.

The conversion for the visbreaker coil is normally set by the thermal stability requirements of the fuel oil. If no stability specifications have been given, the operational limitations may be the coking tendency in the furnace tubes. It is usually safe practice to limit conversion to the highest value that still results in a fuel of borderline stability. In actual plant operation, it has been observed that steam injection into the furnace coil tends to alleviate coking difficulties to some extent.

The furnace outlet temperature is controlled to a temperature typically not exceeding 480-485°C. However, the film temperature can be significantly higher, which leads to some overcracking and coke build-up over time in the tubes. The design metal temperature cannot be exceeded.

The tube wall thickness should be considerably greater than that calculated for regular heaters. This is because there is always the chance of a local coke deposit with resultant hotspots.

**Soaker visbreaker**

The alternative to carrying out the visbreaking reactions in a furnace coil is to add a soaker drum downstream of the coil and carry out most of the visbreaking reactions in the soaker drum. Soaker drums were used in the earlier Dubbs thermal cracking process but modern soaker designs are of an upflow type, whereas the Dubbs process used downflow soakers. In order to carry out most of the reaction in the soaker drum rather than the furnace coil, the exit temperature from the furnace coil is lowered to about 450°C.

Because the soaker drum is not heated, and visbreaking cracking reactions are slightly endothermic, there is a fall in temperature over the soaker drum of about 20°C. To limit backmixing, the use of proprietary internals, such as a system of perforated plates used in the Shell Soaker Visbreaking Process (Akbar and Geelen, 1981), may be adopted.

**Relative merits of coil and soaker visbreaker designs**

Advantages of the coil visbreaker are that there is not the degree of back-mixing and, hence, an uneven residence time distribution. This results in overcracking in the soaker visbreaker design. Also, because the conversion level achieved is more sensitive to coil exit temperature in the coil visbreaker design, it is easier to adjust operation to significant changes in feedstock quality in the coil design by varying the coil exit temperature.

Advantages of the soaker visbreaker design (Akbar and Geelen 1981) means a smaller furnace is required than in a coil visbreaker, resulting in savings in both capital expenditure and operating costs. A longer run length is achieved due to the lower operating and skin temperatures in the soaker design and less coking in the coil. The addition of a soaker drum to an existing coil visbreaker can be used as part of a strategy to revamp for increased unit capacity.

**Wood’s technology**

This is a variant of the coil visbreaker offered by Foster Wheeler/UOP (Sieli, 1999) which offers a cheaper alternative than a vacuum flasher to achieve an incremental yield of (heavy) visbroken gas oil compared with a conventional coil visbreaker unit without a vacuum flasher.

Wood’s technology delays the quench from the furnace coil until after the vapour and liquid effluents have disengaged. The technology utilizes a low main fractionator pressure to produce a heavy gas oil cut and incorporates proprietary fractionator internals to minimize coking in the flash zone. The bottom stripping trays have also been modified. A larger diameter fractionator and a wet gas compressor are needed, but capital expenditure is reported to be lower than that of a vacuum flasher. The incremental yield of heavy gas oils is lower than with a vacuum flasher, but the heavy gas oil produced is of superior quality.

**Other related processing routes**

Visbreaking/solvent deasphalting/gasification

An approach to eliminating the bottom-of-the-barrel produced by a visbreaker is to combine the coil
visbreaking technology (including vacuum flasher) with Solvent DeAsphalting (SDA; ROSE) of the visbroken vacuum tar, followed by gasification/power generation from the asphaltenes (Simons et al., 1997) (Fig. 5).

Shell deep thermal conversion plus gasification

The Shell Deep Thermal Conversion (DTC) process (Douwes et al., 1999) is a development of the Shell Soaker Visbreaking process. Severity is increased in the soaker drum to produce a liquid coke as the bottoms stream from the vacuum flasher. The liquid coke is not suitable for blending to a commercial fuel oil, but can be used as the feed to gasification and power generation. The process can handle either an atmospheric residue or vacuum residue feed. Yield of distillates is higher than that of a visbreaker and the yield of residue (as liquid coke) is correspondingly lower.

Aquaconversion

Aquaconversion (Pereira et al., 1998) is an extended catalytic visbreaking process in the presence of steam developed by PDVSA (Petróleos De Venezuela Sociedad Anónima) Intevep. Maximum conversion is increased by adding a novel homogeneous catalyst in the presence of steam. This system allows hydrogen from the water to be transferred to the residue in a coil-soaker visbreaking system. This reduces precursors for polymerization reactions which lead to the production of more asphaltenes.

5.2.5 Operating variables

Visbreaker furnace operation

For a twin cell (heater plus soaker cell) coil visbreaker, the main operating variables are the following: coil crossover temperature (temperature leaving heater cell); soaker cell outlet temperature.

The crossover temperature is normally selected such that the heater cell brings the feed up to a temperature at which significant cracking begins and the entire reaction takes place in the soaker cell. The soaker cell outlet temperature is adjusted based on the desired level of conversion for a given feedstock such that the fuel oil produced from blending of the visbroken tar with cutter stock is stable. The desired level of conversion varies with the crude type; for example: operating with a vacuum residue feed from a light sweet North Sea Crude, typically can be at a higher conversion than a residue feed derived from a heavy sour Middle East crude, whilst still producing a stable fuel oil. A soaker cell outlet temperature of not more than 480–485°C is generally preferred.

Given first order kinetics, if the visbreaker feed throughput is reduced significantly from the design rate (increasing feed residence time in the coil), the soaker cell exit temperature must be reduced to prevent increased conversion and, hence, the fuel oil produced becoming unstable.

For a soaker type visbreaker to respond to changes in feedstock or to the desired level of conversion, adjustments to both coil exit temperature and throughput (i.e. residence time) are usually necessary. Alternatively, a bigger adjustment to the coil exit temperature alone would be needed than for a coil visbreaker.

Quench plus main fractionator

The temperature of the coil effluent must be lowered using HGO quench to a temperature low enough to stop the cracking reactions. The temperature of the atmospheric tar leaving the bottom of the main fractionator needs to be controlled to an optimum value using the quench flux material. If this temperature is too hot, excessive coking will occur in the bottom of the tower; if this temperature is too cold, the yield of vacuum gas oils in the vacuum flasher will be sub-optimal.

Vacuum flasher

Critical to operation of the vacuum flasher is the need to maintain a sufficiently high liquid wash rate at all times, leaving the bottom of the wash bed (bottom bed 4 of a vacuum flasher containing four beds) to prevent the bed coking. Use of a grid type packing is recommended for this bed.
Fuel oil blending

Residue streams from a visbreaker can generally be used for the following applications: fuel oil; road bitumen (in some countries such as Italy); feed to a solvent asphalting unit or to a gasifier. Fuel oil has to meet a number of specifications: a) viscosity; b) sulphur; c) specific gravity; d) stability, on the basis of a number of test methods.

Visbroken residues often exceed fuel oil specifications for density, sulphur content and viscosity, and cutter stocks are needed to blend with the residues to meet the specifications. These are usually higher value streams from within the refinery. In general, aromatic cutter stocks such as light cycle oil are to be preferred to the use of paraffinic stocks such as straight run kerosene on fuel oil stability grounds. Visbroken gas oils are also commonly used cutter stocks.

References


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Kellogg, Brown & Root
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