Opportunities for optimization of refineries using

Thermal Conversion technologies

by

F. Hollander, A. Keukens, M. van Es
ABB Lummus Global, The Hague, The Netherlands

&

B. Douwes
Shell Global Solutions, Amsterdam, The Netherlands

0. Summary

Thermal Conversion technologies remain dominant technologies in residue upgrading in most parts of the world. Their simple basic process layout has been refined in recent years to remain a reliable and economic technology with distinct advantages over more complex and high investment conversion technologies. Also for the near future Thermal Conversion processes are expected to play a key role in refinery operations relying on further improvements in technology, operation and unit management. Russia and the CIS Republics depend heavily on fuel oil and heavy distillates. Not surprisingly, demand for state-of-the-art Thermal Conversion technologies is growing, both in revamp situations and new applications. Shell, with ABB Lummus Global as authorized licensor, has developed innovative Thermal Conversion technologies that play a leading role in today's residue upgrading market, but also in the conversion of heavy and vacuum gasoils. That leading role of Shell and ABB has resulted in more than 80 operating units worldwide. Based on the latest projects, most of them in Russia and the CIS Republics, different case studies - including revamping of existing crude or visbreaking units, addition of the Shell Vacuum Flasher and grass-roots Shell Soaker Visbreaking, Shell Th ermal Gasoil Process and Shell Deep Thermal Conversion units - are presented showing the "opportunities for optimization of refineries using Thermal Conversion technologies".

1. Introduction

The Shell Soaker Visbreaker process has a long and successful history. The relationship between Shell and ABB Lummus Global in the field of visbreaking was first established in the early sixties, with the construction of a number of conventional coil visbreakers. By the early 1970's, the Shell Soaker Visbreaker concept was sufficiently developed to be commercially applied. The process was licensed for the first time in 1977. At this time, Shell appointed ABB as the authorized licensor for the process and to become more deeply involved in servicing this technology. The Shell Soaker Visbreaker Technology has subsequently become one of the more widely applied refining processes. The number of licensed units totals 90 with a total installed capacity of about 400,000 tons per day, approximating to more than 70 percent of the world's visbreaking capacity in the last decade.

Visbreaking has shown to be a robust technology in the dynamic refining market. Although other competitive processes have been developed, Shell Soaker Visbreaking remains of major importance in the upgrading of heavy residues. The installation of new visbreaking plants nowadays continues at the same pace as in the 1980's. This success is based on the fundamental strengths of the process. It remains a low cost, high conversion, long run length process that is very flexible with regard to feedstock and operational changes while producing valuable light products and stable fuel oil.

Over the years continued implementation of improvements in the Shell Soaker Visbreaker process, have resulted in designs geared to high reliability and performance. Shell's continuous effort in the development of new applications has resulted in new thermal conversion technologies such as vacuum flashing technology, deep thermal cracking and thermal gasoil conversion. These new technologies are emerging, well-proven and will widen the choice of refiners to optimize their refinery with Thermal Conversion solutions.

This paper describes in brief four different Shell Thermal Conversion technologies licensed by ABB as authorized licensor based on the latest projects in Russia and the CIS Republics, the Czech Republic, Germany, India and Saudi Arabia. Different case studies - including revamping of existing crude, vacuum or visbreaking units, addition of the Shell Vacuum Flasher and grass-roots Shell Soaker Visbreaking, Shell Thermal Gasoil Process and Shell Deep Thermal Conversion units - are presented.

Other technologies from the Shell Thermal Conversion portfolio, are Shell High Pressure Distillate Conversion and technologies that are developed to (co-)process slops and asphalts. These technologies are aimed to meet the future gasoil endpoint and environmental specifications.

2. Technologies

2.1 *Shell Soaker Visbreaking Technology (SSVB)*

The Shell Soaker Visbreaking (SSVB) Technology has been developed by Shell in the late seventies. The technology has since evolved further and has been successfully licensed and applied in over 80 units worldwide. Shell Soaker Visbreakers account for over 70% of the total Visbreaking capacity built or being built in the last 10 years. This makes it the most successful and widely applied residue upgrading technology in the world.

The main objective of the Shell Soaker Visbreaker is to reduce the viscosity of Atmospheric or Vacuum Residue, which significantly reduces the need of cutterstock for blending to commercial fuel oil. Besides the viscosity reduction, valuable products like LPG, Naphtha and Gasoil are produced. Other possible feedstocks that can be used are asphalt and slops.

By shifting the majority of the cracking process from the heater coils (as in all-coil designs) to the Soaker drum, prolonged residence time is achieved, allowing a lower cracking temperature. In combination with Shell's patented Soaker internals this assures better selectivity, longer runlength, lower energy demand and lower capital investment.

The main characteristics of the technology are:

- Typical feedstock is Vacuum Residue
- Large feed stock flexibility
- Compact unit comprising a residue conversion and a fractionation section
- Application of a soaking vessel with proprietary internals
- The amount and the viscosity of the residue (and hence of the fuel oil) are reduced, typically fuel oil production reductions of 25 wt.% can be achieved

The benefits of the Shell Soaker Visbreaking technology compared to the conventional furnace (coil) cracking technology can be summarized as follows:

- Longer run length and higher on stream time
- Improved selectivity towards Gasoil
- Reduced fuel and power consumption
- Lower capital expenditure
- Improved operability due to use of pressure (Soaker) and temperature (heater) as control variables

Figure 2.1 below presents the Shell Soaker Visbreaker process. Preheated residue feedstock is charged to the Visbreaker heater (1) and from there to the Soaker (2). The conversion takes place in both the heater and the Soaker. The operating temperature and pressure are controlled such as to reach the desired conversion level and/or unit capacity. The cracked feed is then charged to an atmospheric fractionator (3) to produce the desired products like gas, LPG, naphtha, kero, gasoil and cracked residue.

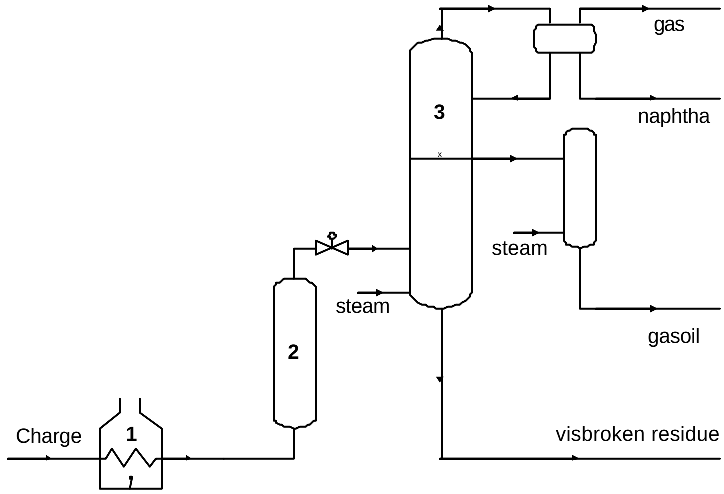

Figure 2.1 Simplified Flow Scheme of Shell Soaker Visbreaker Unit

Revamping of existing crude and (coil) Visbreaker units is possible, ABB has revamped succesfully several existing coil visbreakers and crude units into Shell Soaker Visbreaker. The Russian market shows great potential with a growing number of crude and visbreaking units nearing the end of their economic life span. With an investment of between 30% and 60% of a new grass roots unit, revamping towards a Shell Soaker Visbreaker is a fast and low cost solution to reduce the amount of cutterstock required for the production of fuel oil.

2.1.1 Case 1: Grass-roots Shell Soaker Visbreaker Unit

Client: Kirishinefteorgsintez
Project: Basic Design and Engineering / Detailed Engineering
Time: 1994 / 2001

Background:

The project involved the implementation of a new Shell Soaker Visbreaker Unit, consisting of the following elements:

- Feed heating and reaction
- Fractionation and residue stripping
- Gasoil stripping
- Naphtha stabilization
- Off-gas amine absorbe

Currently, the project is in the detailed engineering phase. Expected start-up is in 2003.

Feedstock:

The Shell Soaker Visbreaker Unit will process a blend of vacuum residues from West Siberian and Ukhta origin. The unit capacity is 5789 MT/SD.

Yields and Properties:

The following product yields can be obtained. Main product properties are also shown:

Feedstocks		
Vacuum Residue		241.2 t/h
	Viscosity	1941 cSt @ 100°C
Products		
Offgas (C_4^-)	Yield	1.8 wt%
	H_2S content	< 0.005 wt% (Note 1)
	C_5^+ content	8.2 wt%
Stabilized Naphtha (C_5 – 173°C) Yield		4.4 wt%
	RVP	< 0.7 kg/cm^{2}a
Visbreaker Residue (173°C$^+$)	Yield	93.8 wt%
	Viscosity	173 cSt @ 100°C
	Flashpoint	> 65 °C

Table 2.1 Yields and Properties of Shell Soaker Visbreaker products

Note 1: After Amine treatment.

Blending details:

The final fuel oil product will fulfil the Mazut M100 specifications of which viscosity is the governing parameter. In this example, blending with typical Light Cycle Oil (LCO) from a Fluid Catalytic Cracker is shown.

In the Table 2.2, the required amount of LCO is given for the situation with and without a Shell Soaker Visbreaker Unit.

Saving 60 t/h on LCO and producing more than 70 t/h less Fuel Oil clearly underlines the benefits of a Shell Soaker Visbreaker Unit.

	LCO Requirements	*Fuel Oil Production*
Vacuum Residue (w/o SSVB)	90 t/h (27.2 % of total)	331 t/h
Visbreaker Residue (with SSVB)	31 t/h (13.5 % of total)	257 t/h

Table 2.2 Cutterstock requirements and fuel oil production comparison

2.1.2 Case 2: Revamp to Shell Soaker Visbreaker Unit

Client: LUKOIL Permnefteorgsyntez
Project: Basic Design and Engineering Package
Time: 2001

Background:

The project involves the revamp of an existing thermal cracker into a Shell Soaker Visbreaker Unit. The main objective of this project is to re-use as much of the existing equipment as possible. The unit includes the following sections:

- Feed heating and reaction
- Fractionation and residue stripping
- Gasoil stripping
- Naphtha stabilization

Feedstock:

While the current feedstock consists of residual material of varying nature and various refinery slops, the revamped unit will process a mixture of vacuum residue originating from West Siberian and Local Perm crudes. The design unit capacity is 2800 MT/SD.

Process Scheme:

The current process scheme with respect to the separation and fractionation of the heater effluent is given in the Figure 2.2 below. The Rectifier operates at elevated pressure compared to the Stripper, which operates at near atmospheric conditions. Steam is used for stripping of the residue.

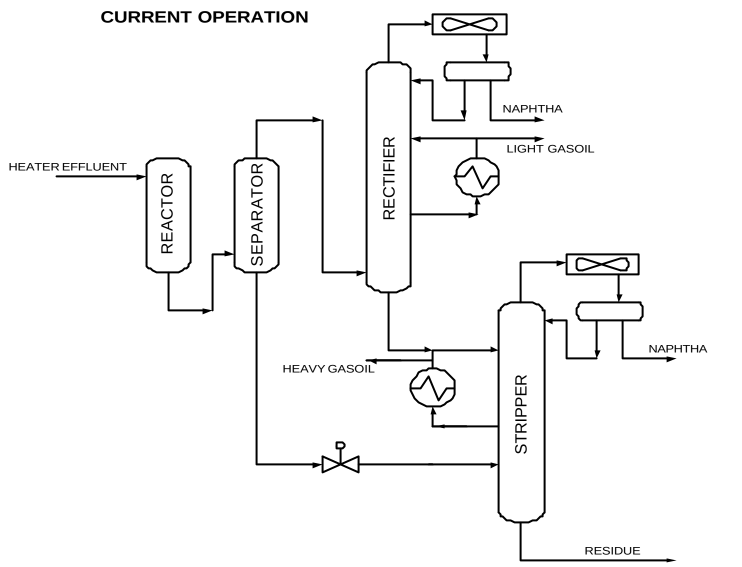

Figure 2.2: Current situation

In an attempt to redeuce investment cost, by re-using as much of the existing equipment (specifically the columns) as possible, the following flow scheme was developed and proposed to the client:

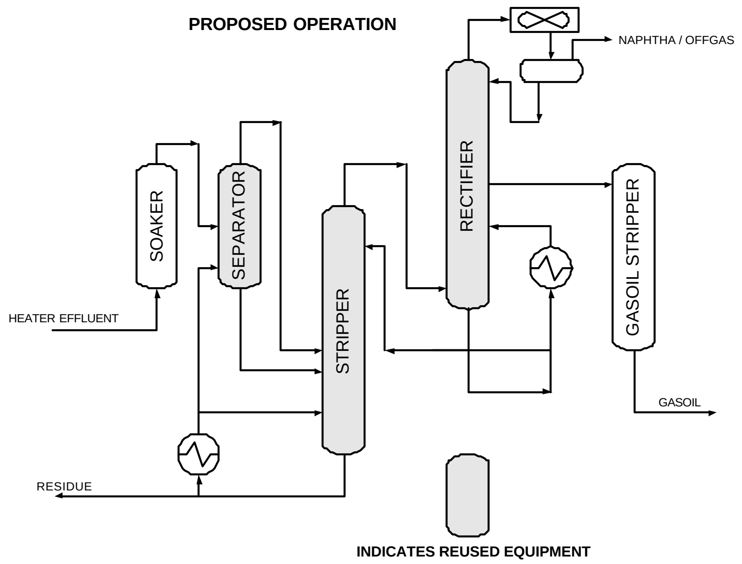

Figure 2.3 Proposed new scheme

As can be seen from Figure 2.3, the Separator, Stripper and Rectifier will be re-used. As advanced construction materials are required for such high temperature equipment, re-using these columns is of primary importance for reducing the required investment. A new stripper is foreseen for quality control of the Visbreaker Gasoil.

The complete fractionation section is operating near atmospheric pressure in the new situation. This highly improves the quality of separation between Residue, Gasoil and Naphtha. The Naphtha is further processed in a Naphtha Stabilizer (the existing column and associated equipment will be re-used for that purpose) producing Stabilized Naphtha, LPG and Fuel Gas. The Fuel Gas is treated to remove H_2S in a central amine absorber unit.

Yields and Properties:

With the proposed scheme, the following product yields can be obtained. Main product properties are also shown:

Feedstocks		
Vacuum Residue		118 t/h
	Viscosity	460 cSt @ 100°C
Coker Naphtha (note 1)		20 t/h
Products		
Offgas (C_2^-)	Yield	1.4 wt%
	C_5^+ content	< 5 wt%
LPG (C_3/ C_4)	Yield	1.0 wt%
	C_5^+ content	< 3 wt%
Stabilized Naphtha (C_5 – 165 °C)	Yield	17.3 wt%
	C_4^- content	< 1 wt%
Gasoil (165 – 350 °C)	Yield	10.0 wt%
	Flashpoint	> 65°C
Visbreaker Residue (350 °C+)	Yield	70.3 wt%
	Viscosity	260 cSt @ 100°C

Table 2.3 Yields and properties of Case 2

Note 1: Unstabilized Naphtha from the Delayed Coker Unit is stabilized together with the Visbreaker Naphtha in the common Naphtha Stabilization section.

Blending details:

The final fuel oil product will fulfil the Mazut M100 specifications of which viscosity is the governing parameter. In this example, blending with typical

Light Cycle Oil (LCO) from a Fluid Catalytic Cracker with and without a Shell Soaker Visbreaker Unit is shown.

In Table 2.4, the required amount of LCO and the total fuel oil production is presented.

	LCO Requirements	*Fuel Oil Production*
Vacuum Residue (w/o SSVB)	30 t/h (20% of total)	148 t/h
Visbreaker Residue (with SSVB)	6.4 t/h (5.5% of total)	117 t/h Note 1

Table 2.4 Cutterstock requirements and fuel oil production comparison, Case 2

Note 1: Includes gasoil produced by unit.

From Table 2.4, the benefits of a Shell Soaker Visbreaker Unit can be seen.

2.2 *Shell Vacuum Flasher (VF) Technology*

To maximize the recovery of distillates from the Thermal Conversion effluents Shell has developed proprietary Flashing Technology for integration/combination with Thermal Conversion Units. Shell has developed a proprietary transfer line that maximizes the recovery of distillates and avoids entrainment of residue. The other draw back of open art flashing technology in thermal conversion service is the short run length of the vacuum columns due to severe coking and fouling. Due to the application of proprietary column internals the fouling and coking has been reduced substantially resulting in vacuum flasher run lengths up to several years.

The main characteristics of the technology are listed below.

- Proprietary transfer line and column internals
- No residue entrainment
- Long run length
- High Flashed Distillate Yield
- No feed heater
- Effective cutpoints up to 550°C can be achieved
- Production of Light Flashed Distillate to Gasoil specification
- Can be applied to all Thermal Conversion Technologies except Delayed Coking
- Can be added to existing thermal conversion units

The main benefits of Shell Thermal Conversion Flashing Technology compared to open art flashing technology can be summarized as follows:

- Longer run length and higher on stream time

- Higher distillate yields
- Lower capital expenditure
- Additional Gasoil recovery

Figure 2.4 below presents the Shell Soaker Visbreaker process including the Shell Vacuum Flasher. Similar to the SSVB, preheated residue feedstock is charged to the Visbreaker heater (1) and from there to the Soaker (2). The cracked feed is then charged to an atmospheric fractionator (3). The cracked residue is fed into the Shell Vacuum Flasher (4) which separates the light vacuum gasoil (LVGO) and heavy vacuum gasoil (HVGO) from the vacuum flashed cracked residue (VFCR).

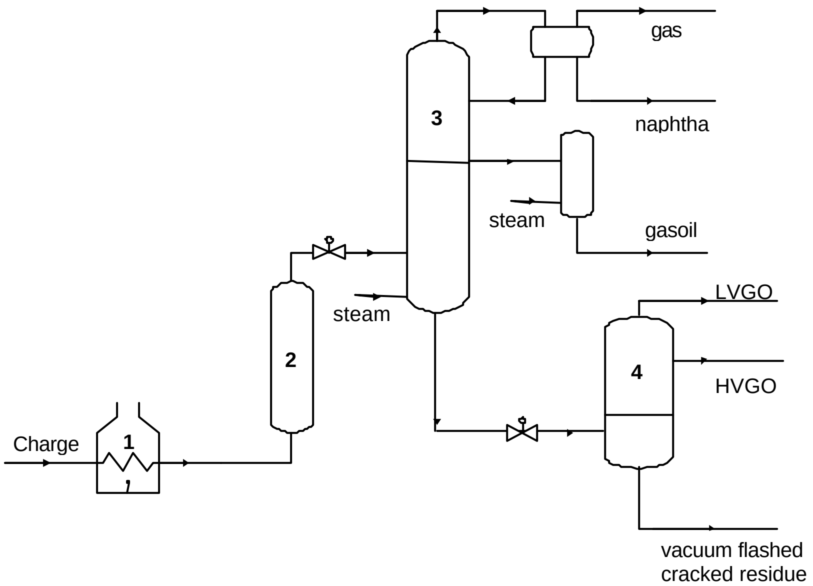

Figure 2.4 Shell Soaker Visbreaker with Shell Vacuum Flasher

A calculation has been done for a typical Visbreaker unit with a capacity of 4000 MT/SD, processing Middle East Vacuum residue with a viscosity of 3900 cSt at 100°C. Figure 2.5 presents the difference in blending of a Visbreaker unit and a Visbreaker unit with Vacuum Flasher.

The Shell Vacuum Flasher is an option for refineries were Heavy or Vacuum Gasoil can be processed in a Hydrocracker or an FCC unit or Shell Thermal Distillate Conversion unit. Visbroken Vacuum Gasoil, by its parrafinic nature, is a good feedstock for FCC's.

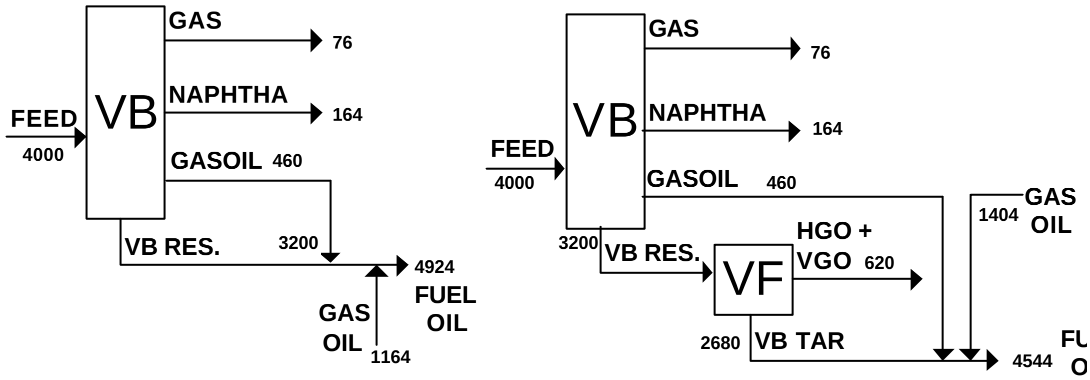

Figure 2.5 Blending example

The Shell Vacuum Flasher can be built in a modular way and added next to the visbreaker plot. Figure 2.6 shows a 3D-model of a visbreaker unit originally built by Shell and to which a Shell Vacuum Flasher was added later on. The Shell Vacuum Flasher section has been highlighted.

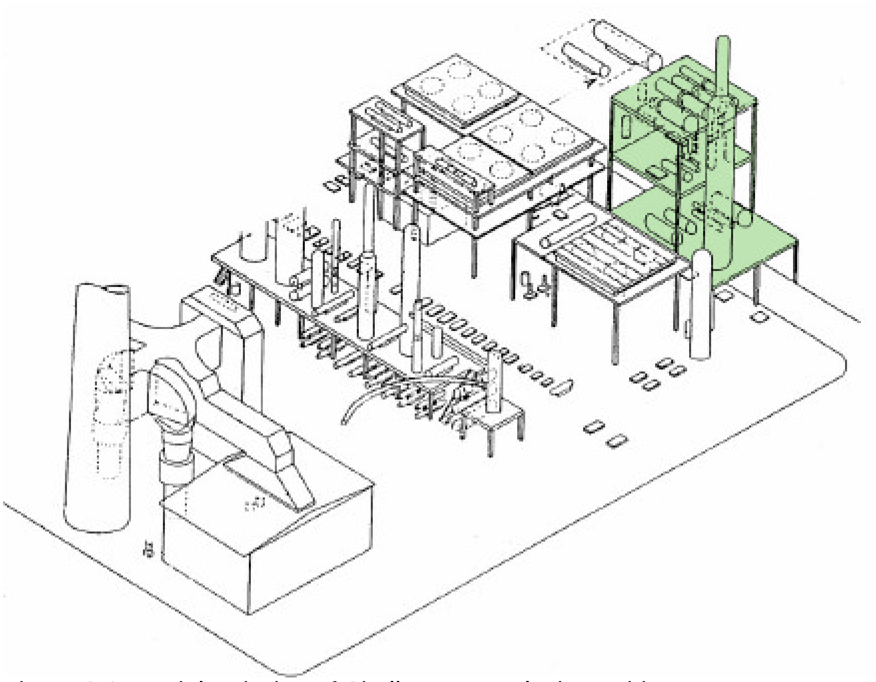

Figure 2.6 Modular design of Shell Vacuum Flasher Add-on

2.2.1 Case 3: Shell Soaker Visbreaker Unit with Vacuum Flasher

Client: Indian client
Project: Basic Design and Engineering Package
Time: 2000

Background:

The project involved the basic design of a new Shell Soaker Visbreaker Unit including Shell Vacuum Flasher Technology, consisting of the following elements:

- Feed heating and reaction
- Fractionation and residue stripping
- Overhead product compression (recontacting) section
- Gasoil stripping
- Naphtha stabilization
- Vacuum Flasher

Currently, the project is in the EPC phase. Expected start-up is in 2002.

Feedstock:

The Shell Soaker Visbreaker and Vacuum Flasher Unit will process a feedstock comprising of 85% Vacuum Residue and 15% PDA pitch originating from a 50:50 Arab mix crude. The unit capacity is 3600 MT/SD.

Yields and Properties:

Table 2.6 shows the product yields and main properties that will be obtained in this unit.

Light and Heavy Vacuum Gasoils are used as feed to the Hydrocracker. The Vacuum Flashed Cracked Residue is blended to meet refinery fuel oil specifications.

Feedstocks		
Vacuum Residue		150 t/h
	Viscosity	7,251 cSt @ 100°C
Products		
Offgas (C_4^-)	Yield	2.0 wt%
	H_2S content	11.1 wt%
Stabilized Naphtha (C_5–165°C)	Yield	4.1 wt%
	RVP	< 0.7 kg/cm^{2}a
Visbreaker Gasoil (165–350°C)	Yield	11.2 wt%
	Flashpoint	60 °C
Light Vacuum Gasoil (350–420°C)	Yield	1.8 wt%
	C_7-insolubles	< 0.2 wt%
Heavy Vacuum Gasoil (420–520°C)	Yield	10.0 wt%
	C_7-insolubles	< 0.2 wt%
Vacuum Flashed Cracked Residue (520°C$^+$)		
	Yield	70.9 wt%
	Viscosity	36,100 cSt @ 100°C

Table 2.5 Yields and properties of Case 3

2.2.2 Case 4: Shell Vacuum Flasher added to existing SSVB

Client: Shell Harburg
Project: by Shell
Time: 1979

Background:

The project involved the addition of a Shell Vacuum Flasher to an existing Shell Soaker Visbreaker Unit including, consisting of the following elements:

- Vacuum Flasher

The revamped plant was started-up in 1981.

Feedstock:

The Shell Soaker Visbreaker and Vacuum Flasher Unit process a mix of Deutsche Roh Oel and Tia Juana Pesado vacuum residue. The unit capacity is 2500 MT/SD.

Yields and Properties:

The following product yields can be obtained. Main product properties are also shown:

Feedstocks		
Vacuum Residue		104 t/h
	Viscosity	536 cSt @ 100°C
Products		
Offgas (C_4^-)	Yield	2.8 wt%
Stabilized Naphtha (C_5–165°C)	Yield	5.0 wt%
	RVP	< 0.7 kg/cm^{2}a
Visbreaker Gasoil (165–365°C)	Yield	14.0 wt%
	Flashpoint	60 °C
Vacuum Gasoil (365–530°C)	Yield	13.0 wt%
	C_7-insolubles	< 0.2 wt%
Vacuum Flashed Cracked Residue (530°C$^+$)		
	Yield	65.2 wt%
	Viscosity	1,400 cSt @ 100°C

Table 2.6 Yields and properties of Case 4

The Vacuum Flashed Cracked Residue is blended to meet European fuel oil specifications.

2.3 *Shell Thermal Gasoil Process (STGP)*

As highlighted in Section 2.2, by implementation of a vacuum flasher in the Shell Soaker Visbreaker Process, considerable amounts of valuable vacuum distillate can be recovered from the Visbroken residue. The recovered vacuum distillate can be further processed in a conversion unit, like for instance a Hydrocracker (HCU) or a Fluid Catalytic Cracker (FCC).

In refineries with no vacuum distillation unit, or in refineries withfully loaded HCU or FCC, an interesting solution is to convert the recovered vacuum distillate in an integrated recycle thermal cracker heater system. The combination of a Shell Soaker Visbreaker for residue conversion and a separate thermal conversion heater system for distillate conversion is called the Shell Thermal Gasoil Process (STGP). This technology was originally developed in the sixties as an alternative for conversion of atmospheric residue by FCC and HCU, and has since then been continuously improved and developed further. Shell currently operates nine (8) such units.

Description

Although there can be very significant differences with respect to choice of feedstock and the recovery of different products, most units applying the Shell Thermal Gasoil Process follow the same concept, which is shown in Figure 2.7.

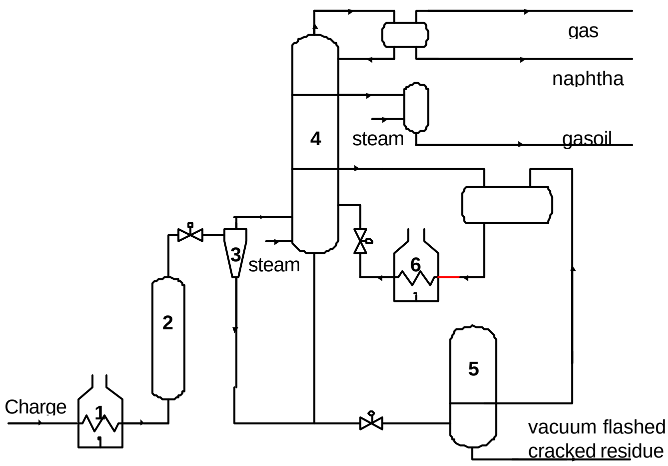

Figure 2.7 Simplified Flow Scheme of Shell Thermal Gasoil Process

The preferred feedstock for the Shell Thermal Gasoil Process is atmospheric residue, although vacuum residue can be used as well. The preheated feedstock is charged to the visbreaker heater (1) and from there to the soaker (2). The conversion takes place in both the heater and the soaker. The operating temperature and pressure are controlled such as to reach the desired conversion level and/or unit capacity. The cracked feed is then charged hot to a cyclone (3) to separate the majority of the residue from the valuable distillate products. The cyclone overheads are routed to the atmospheric fractionator (4) to produce the products like gas, naphtha, gasoil, heavy distillate and a residue. Cyclone bottoms and fractionator bottoms are routed to a vacuum flasher (5) together. In this vacuum flasher, vacuum distillate is recovered from the residue. The temperature and pressure in the flashzone determine the cutpoint between the distillate and residue. The recovered heavy and vacuum distillates from the fractionator and the vacuum flasher are converted in the distillate cracking heater (6) at elevated pressure. Conversion levels, defined here as 165 - 350°C TBP material on feed, can be as high as 30 - 40 wt%. To fully convert the distillate, the unconverted material is recycled via the atmospheric fractionator and vacuum flasher. Consequently, the distillate furnace feed consists partly of fresh feed and partly of recycled material.

Benefits

The benefits of the Shell Thermal Gasoil Process compared to other conversion technologies (Fluid Catalytic Cracking and Hydrocracking) can be summarized as follows:

- Due to the highly integrated compact two stage thermal conversion unit design, comprising of a residue and a recycle distillate conversion section, a combined fractionation and vacuum flashing section, substantial lower capital expenditure is required.
- In a STGP large feedstock flexibility is possible, ranging from atmospheric residue to vacuum residue, due to the nature of the process. In contrast to FCC and HCU technologies, which are limited in their feedstock flexibility.
- Complete conversion of the waxy distillate fraction, although a slightly lower conversion is achieved on the overall conversion compared to FCC and HCU technologies; the only products are gas, naphtha, gasoil and vacuum residue, typically 55-60 wt% of the atmospheric residue is upgraded to gasoil minus products.
- No up-front vacuum distillation unit is required, as the majority of the vacuum gasoil in the atmospheric residue can be recovered in the vacuum flasher.

2.3.1 Case 5: Shell Thermal Gasoil Process

Client: Saudi Client
Project: by Shell
Time: 1994/2000

Background:

The project involved the installation of a new Shell Thermal Gasoil unit integrated with a gasturbine for power production. The unit consists of the following elements:

- Integrated heat recovery and feed heating and reaction
- Cyclone
- Fractionation and residue stripping
- Vacuum Flasher
- Gasturbine

Successful Start-up of the unit took place in 2000.

Feedstock:

The Shell Thermal Gasoil Unit processes a mix of atmospheric and vacuum residue from Arab Light Crude. The unit capacity is 5,250 MT/SD.

Yields and Properties:

Table 2.7 shows the product yields and properties that are obtained.

Feedstocks		
Vacuum Residue Viscosity		219 t/h 74 cSt @ 100°C
Products		
Offgas (C_4^-)	Yield	2.3 wt%
Stabilized Naphtha (C_5–165°C)	Yield RVP	10.8 wt% < 0.7 kg/cm^{2}a
Visbreaker Gasoil (165–365°C)	Yield Flashpoint	36.5 wt% 35 °C
Vacuum Flashed Cracked Residue (520°C$^+$)	Yield Viscosity	65.2 wt% 900 cSt @ 100°C

Table 2.7 Yields and properties of Case 5

About two thirds of the Visbreaker Gasoil is blended with the VFCR to make European spec fuel oil. The remainder is sent to the refienry gasoil pool.

2.3.2 Opportunities for Russian refineries

The main objective of the Shell Thermal Gasoil Process is the reduction of the viscosity of the residue feedstock while maximizing the production of gasoil by thermally cracking the recovered heavy and vacuum distillates. For hydroskimming refineries, i.e. refineries without upgrading potential of the atmospheric residue or in refineries withfully loaded HCU or FCC, this option has some very interesting features.

A phased approach can be applied to this unit. Initially only the residue upgrading part, i.e. the Shell Soaker Visbreaker part, will be installed, with some pre-investment for the next step. In the next step the vacuum flasher and recycle distillate conversion heater are incorporated. Not only is the initial investment lower, also a gradual reduction in fuel oil production and associated gasoil production increase, will be achieved. This is certainly very interesting for refineries producing for markets where there is still a vast demand for fuel oil, like the Russian market.

Additionally the installation of a Shell Thermal Gasoil Process will eliminate the requirement of installation of a vacuum distillation unit and upgrading facilities for the produced vacuum gasoil, like a fluid catalytic cracker or a hydrocracker. Both of these units require huge investments (over 100 million US$), while the investment required for a Shell Thermal Gasoil Process will be substantially lower. This will facilitate an easier financial closure of a project.

For refineries already converting atmospheric residue in a visbreaker, implementation of the Shell Thermal Gasoil Technology is a low cost option to reduce fuel oil production and increase production of valuable distillate products. A revamp of a coil type visbreaker unit to a STGP Unit would require installation of a soaker, cyclone, vacuum flasher and a recycle distillate cracking heater. Also some modifications to the feed preheat and the atmospheric fractionator and its overhead system, due to the changes in yield, need to be implemented.

Based on aboves STGP, Shell has developed Shell's High Pressure Distillate Conversion Process, to convert heavy tails of gasoils. With 80% conversion of the 330°C - 370 °C (heavy) gasoil fraction into lighter materials (< 330 °C), this technology enables refiners to meet tighter future gasoil specifications.

2.3.3 Case 6: Comparison of SSVB and STGP

Client: Russian Client
Project: Feasibility study
Time: 2001

Background:

Hydroskimming refineries and refineries that process atmospheric, vacuum or a combination of atmospheric and vacuum residues in thermal cracking units or exisiting visbreakers can benefit clearly from the Shell Thermal Gasoil Process.

The example below is a study for a Russian refiner, processing Ukhta crude, considering to revamp an existing crude unit into a Shell Soaker Visbreaker. Comparison of the SSVB and STGP technologies indicates the possibilities when choosing for the latter.

While both technologies produces stable on-spec Mazut M100 without the requirement of additional cutterstock, the Shell Thermal Gasoil Process produces 350 MT/SD of high cetane gasoil that, after treatment, is an outstanding component in the gasoil blending pool.

Feedstock:

Comparison is made on the basis of Ukhta crude.

Yields and Properties:

Feedstock		Shell Soaker Visbreaker	Shell Thermal Gasoil Process
Mix of Atmospheric and Vacuum Residue		2400 MTD	2400 MTD
	Viscosity	188 cSt @ 100°C	188 cSt @ 100°C
Products			
Offgas (C_4^-)	Yield	2.0 wt%	4.4 wt%
	C_5^+ content	< 5 wt%	< 5 wt%
Stabilized Naphtha (C_5-165°C) yield		4.1 wt%	10.3 wt%
	C_4^- content	< 1 wt%	< 1 wt%
Gasoil (165 – 350 °C)	Yield	12.6 wt%	37.9 wt%
	Flashpoint	> 65°C	> 65°C
Visbreaker Residue (350°C$^+$)	Yield	81.3 wt%	-
	Viscosity	135 cSt @ 100°C	
Visbreaker Residue (520°C$^+$)	Yield	-	47.4 wt%
	Viscosity		3,900 cSt @ 100°C

Table 2.8 Yields and properties of Case 6

After blending the Visbroken Residue with Visbroken Gasoil following products remain:

	Gasoil Production (net)	*Fuel Oil Production (M100)*
Shell Soaker Visbreaker	50 MTD	2205 MTD
Shell Thermal Gasoil Process	410 MTD	1638 MTD

Table 2.9 Gasoil and fuel oil production comparison, Case 6

2.4 *Shell Deep Thermal Conversion Technology*

The latest development by Shell in the area of Thermal Conversion is the Shell Deep Thermal Conversion Technology. Due to the increase in non-fuel oil outlets of thermally cracked residues new opportunities have arisen for thermal conversion. Shell has been able to improve the design and operation of the unit such that high conversion levels can be achieved while maintaining an acceptable unit run length.

This technology closes the gap between visbreaking and delayed coking (Figure 2.8). It realizes most of the delayed coking upgrading while avoiding the drawbacks of solids handling. The residual product of Shell Deep Thermal Conversion remains liquid and stable and is referred to as 'liquid coke'. Liquid coke can no longer be blended into a stable fuel oil and is processed directly in gasifiers (in power production or Partial Oxidation units) or is used as refinery fuel.

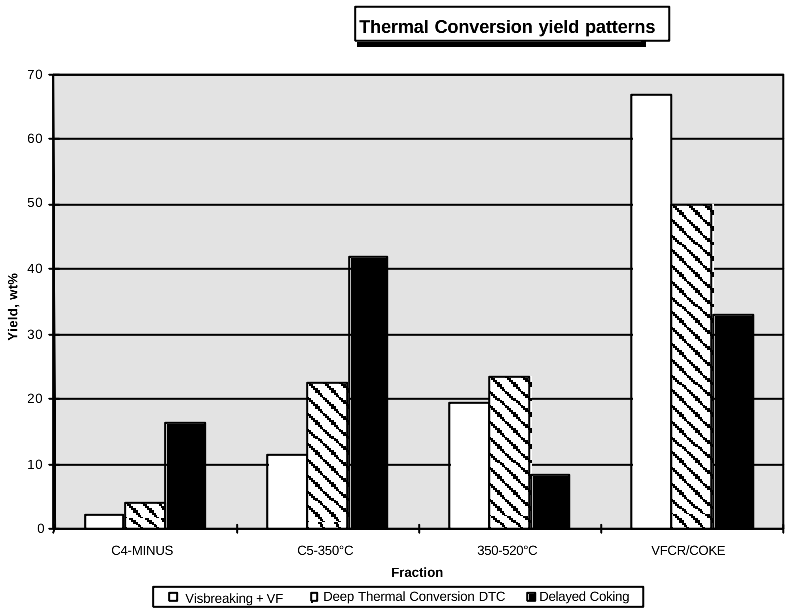

Figure 2.8 Closing the gap between Visbreaking and Delayed Coking

The main characteristics of the technology are listed below:

- Can be applied to both Shell Soaker Visbreaking as well as Shell Thermal Gasoil units
- Typically 45-60 wt% of Vacuum Residue is converted to distillate products
- Revamp of an existing unit is possible
- Liquid residual product
- Includes both design and operational know how

The main benefits of Shell Deep Thermal Conversion technology compared to traditional Thermal Conversion technology can be summarized as follows:

- Substantially higher conversion
- Competitive run length and on-stream time

- Higher distillate yields from Vacuum Flasher
- Lower capital expenditure
- Improved operability due to use of pressure and temperature as control variables

On the other side the main benefits of Shell Deep Thermal Conversion technology compared to delayed coking technology can be summarised as follows:

- Higher quality products (needing less hydrotreating)
- Higher selectivity to gasoil
- Substantially lower capital expenditure
- No solids handling

Figure 2.9 below presents the Shell Deep Thermal Conversion process. Preheated short residue is charged to the heater (1) and from there to the soaker (2), where the deep conversion takes place. The conversion is maximized by controlling the operating temperature and pressure. The cracked feed is then charged to an atmospheric fractionator (3) to produce the desired products like gas, LPG, naphtha and gasoil. The fractionator bottoms are subsequently routed to a vacuum flasher (4), which recovers additional gasoil and waxy distillate. The residual liquid coke is routed for further processing depending on the outlet.

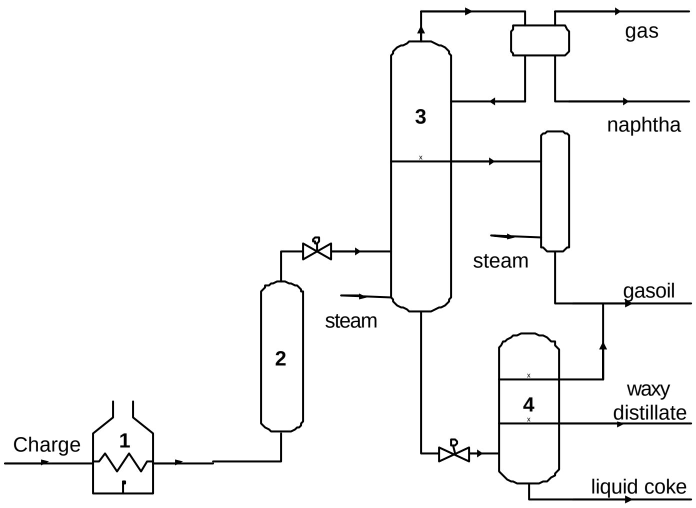

Figure 2.9 Shell Deep Thermal Conversion

The Shell Deep Thermal Conversion can also be combined with the Shell Thermal Gasoil Process. Similar to STGP, an additional furnace will convert the heavy distillates into gasoil.

2.4.1 Case 7: Deep Thermal Conversion

Client: CRC Litvinov, Czech Republic
Project: BDEP, EPC, Start-up
Time: 1997-1999

Background:

The project involved the basic design, EPC and start-up of a new Shell Deep Thermal Conversion Unit including Shell Vacuum Flasher Technology, with the possibility to operate in Visbreaking and Deep Thermal Conversion mode. The unit consists of the following elements:

- Feed heating and reaction
- Fractionation and residue stripping
- Overhead product compression (recontacting) section
- Gasoil stripping
- Vacuum Flasher

Successful Start-up took place in 1999.

Feedstock:

The Shell Deep Thermal Conversion Unit processes a mixture of black distillate and vacuum residues originating from a Ural crude. The unit capacity is 2500 MT/SD.

Yields and Properties:

Table 2.10 presents the product yields and main properties of this unit running in SDTC mode.

When running in the SDTC mode, all vacuum distillates are sent to the FCC unit; the VFCR is sent to the POX.

In SSVB mode conversion of the feed is significantly less severe, enabling the unit to produce commercial fuel oil after blending with the vacuum distillates and a small amount of cutterstock.

This unit demonstrates the maturity of the Shell Thermal Conversion technologies, as it maximizes yields while maintaining a remarkable flexibility toward the need of the client.

Feedstocks		
Vacuum Residue		104 t/h
	Viscosity	998 cSt @ 100°C
Products		
Offgas (C_4^-)	Yield	3.3 wt%
	C_5^+ content	< 12.0 wt%
Unstabilized Naphtha (C_5–165°C)	Yield	7.6 wt%
	RVP	< 0.7 kg/cm^{2}a
Visbreaker Gasoil (165–370°C)	Yield	16.3 wt%
	Flashpoint	60 °C
VB Vacuum Gasoil (370–420°C)	Yield	1.3 wt%
	CCR	< 0.8 wt%
Heavy Vacuum Distillate (420–520°C)	Yield	14.7 wt%
	CCR	< 0.8 wt%
Vacuum Flashed Cracked Residue (VFCR) (520°C$^+$)	Yield	56.8 wt%
	Viscosity	36,100 cSt @ 100°C

Table 2.10 Yields and properties of Case 7

2.4.2 Link to Russian market

Implementation of an IGCC is a high investment that can only be justified in refineries that can consume all the power produced or in liberalized power markets where refiners can export their excess production to the public grid. Still, even without an IGCC, Shell Deep Thermal Conversion is an interesting solution for refiners having an outlet for the residual product of this process. Russian and other refineries alike, depending on the crude, especially when not too heavy, can use the residue of SDTC economically as refinery fuel, for the production of carbon black or in cement kilns.

Another outlet can be as fuel for neighbouring power plants. With a typical heating value 40,000 kJ/kg, the only real constraint is maximum viscosity that can be handled by the burners. Currently, burners are able to handle viscosities up to 300 cSt.

3. Economy

Shell Thermal Conversion Technologies are, in general, low cost solutions with very short payback times (normally in the order of one year). Of course, this all depends on feedstock, configuration and prices for products. The table below presents a (rough) comparison of the TIC for four different technologies. This comparison is based upon a 3,000 MT/SD unit processing Atmospheric and/or Vacuum Residue from a typical Ural crude.

	SSVB	*SSVB+VF*	*STGP*	*SDTC*
Feed	VR	VR	AR/VR	VR
Typical TIC MM US$	20.6	25.5	28.3	28.2

Table 2.11 Estimated TIC for Shell Thermal Conversion Technologies

The estimated TIC's are based on new brown field unit including engineering, equipment, instrumentation, piping, structures, buildings, etc. The estimated TIC's are CIS based and have an accuracy of 30%. Excluded from the estimated TIC's are other processing units for treatment, etc, utility systems and license fees.

4. Conclusion

With the improvements and wider applicability of Shell's present Thermal Conversion technologies good opportunities exist to process cheaper crude oils and/or cheaper feedstocks (such as asphalt) and meeting future gasoil specifications while maintaining the well-proven robustness. Shell's continuous development in Thermal Conversion technologies provide higher distillate yields, while increasing unit reliability and operability. The co-operation of ABB and Shell guarantee the best possible provision of proven experience and know-how in the Thermal Conversion area.

Depending on refinery layout, crude, product slate and environmental legislation there is a Shell Thermal Conversion option for every refinery.