Zero fuel oil

The global refining industry has faced many challenges over its long history, including meeting the increasing demand for petroleum-derived products, and meeting legislative requirements for cleaner transportation fuels specifications, such as ultra-low sulphur gasoline and diesel and the phasing out of undesirable product additives, such as lead in gasoline.

The challenge of lead removal has largely been met and technology solutions have been developed for the production of clean lower sulphur fuels, which are now being implemented in a phased manner in many countries.

So, what is the next major challenge to be faced?

Undoubtedly, in the future a major issue will be the disposal/processing of low value heavy residual product streams from the refinery, whilst simultaneously meeting the increasing demand for transportation fuels, hydrogen, petrochemicals and power.

The refining sector already has proven and mature solutions to meet this challenge in the form of residue upgrading technologies. Through the 1980s/90s, relatively few residue upgrading projects were implemented due to a slower than expected decline in global fuel oil markets and the availability of new sources of light, sweet crudes.

The licensors have not been idle during this time and technologies have been continuously improved.

Graham Phillips, technology manager refining, (left) and Iain McAlpine, senior process engineer, discuss the next big challenge facing refiners across the globe, and review some of the options that are available to meet this head on, 'towards zero fuel oil from refineries'.

Carbon rejection technologies

In these processes the residual stream is upgraded by the removal of carbon from the feed, thereby raising the hydrogen content and value of the upgraded product. Foster Wheeler/UOP license visbreaking, solvent deasphalting and delayed coking.

DEEP CUT VACUUM DISTILLATION

Over the last twenty years a better understanding of the causes of coking has evolved, leading to improved designs based on proprietary internals, allowing an increase in vacuum gas oil cut point from 525°C to 590°C or higher.

This improvement allows a significant increase in fluidised catalytic cracker (FCC)/hydrocracker feedstock (processes which can significantly increase the yield of transportation fuels) at the expense of fuel oil production.

VISBREAKING

This is a process which thermally cracks residue thus reducing viscosity and the requirement for expensive middle distillate viscosity cutter. On-line spalling and decoking techniques have been developed, based on successful, similar application on delayed coker heaters.

Foster Wheeler/UOP also offer commercial, proprietary technology (Woods) which allows operation of coil visbreakers to recover incremental heavy gas oil with an end point of around 450°C for FCC/hydrocracker feed without having to resort to costly vacuum flashing.

Towards zero fuel

DELAYED COKING

This mature thermal conversion process remains for many the preferred residue upgrading option because of its ability to handle the heaviest, most contaminated crudes. Globally, approximately one third of all installed residue upgrading plant uses delayed coking technology.

Although mature, many developments have taken place in recent years, for example:

- Development of automated coke drum unheading devices, allowing the operator to carry out the decoking procedure safely from a remote location
- Understanding of process parameters affecting yields, coker product qualities and coke qualities
- Design and operation of major equipment items, in particular coke drums (allowing increased capacity, CAPEX reduction) and the delayed coker heater (on-line spalling/decoking and minimisation of coking in furnace tubes)

SOLVENT DEASPHALTING (SDA)

This process uses a solvent (typically C_4, C_5) to separate vacuum residue into a relatively clean deasphalted oil (DAO) and a pitch stream which contains most of the contaminants in the vacuum residue feed (e.g. Ni + V, Conradson Carbon). DAO is normally used as FCC or hydrocracker feed.

In recent years attention has focused on maximisation of DAO yield and quality, and pitch utilisation. One option is to use the pitch as fuel to a circulating fluidised bed boiler (CFBB) raising power (Figure 1). CFBBs do not require the fuel to be steam atomised for combustion, so a heavy material can be combusted.

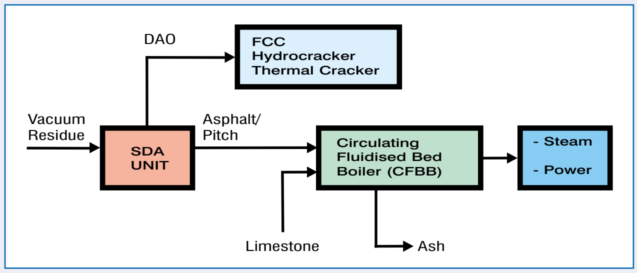

Figure 1: SDA/CFBB integration.

RESIDUE FLUIDISED CATALYTIC CRACKING (RFCC)

This is an evolution of the traditional FCC process. To accommodate residue, licensors and catalyst suppliers have modified the traditional FCC technology in key areas, for example:

- Catalyst designs to accommodate higher metals feed
- More efficient feed injection nozzles giving better feed/catalyst contact
- Riser design and catalyst/oil product separation to minimise overcracking
- Regenerator design improvements to minimise catalyst coke and avoid damage to catalyst structure
- Lower cost reactor/regenerator design concepts
- Novel designs to produce high value petrochemicals on the FCC rather than gasoline

GASIFICATION

This is the conversion by partial oxidation of a carbon containing gas, liquid or solid into a synthesis gas, in which the major components are hydrogen and carbon monoxide.

Synthesis gas from a wide spectrum of feedstock can be used to produce hydrogen, steam and/or power. It can also be a building block in the manufacture of transportation fuels (via Fischer-Tropsch) or a wide range of petrochemicals (Figure 2).

The capital cost of residue upgrading schemes based on gasification continues to fall steadily. The capital cost of gasification for power production (Integrated Gasification Combined Cycle, IGCC), for example, is now reported to be in the 850/950 $/kW range compared to 1,500/2,500 $/kW just 5-10 years ago.

Gasification, if used to make electrical power by IGCC, is the cleanest method of power production from amongst the liquid/coal-based power generation technologies.

Hydrogen addition technologies

This family of processes upgrades heavy residues by adding hydrogen, thereby reducing the carbon to hydrogen ratio in the products (making them lighter in density) and increasing their value and usefulness.

Processes can be based on reactors where catalyst is held in fixed beds or designs which allow for on-line catalyst withdrawal/addition. All processes involve relatively high pressure operation (typically >150 bar).

FIXED BED

Designs for processing vacuum residue essentially all now run on lighter feed or atmospheric residue for FCC feed. This is because fixed-bed designs have suffered from short catalyst lives (six months or less) even though large catalyst volumes are used.

EBULLATING BED

These technologies were first introduced in the 1960s in an attempt to overcome problems of catalyst ageing and mal-distribution in fixed bed designs.

In this approach, hydrogen and feed enter at the bottom of the reactor, thereby expanding the catalyst bed. Although catalyst performance can be kept constant because catalyst can be replaced on-line, the ebullation results in a back mixed reactor so desulphurisation and hydroconversion are less than obtainable in a fixed-bed unit.

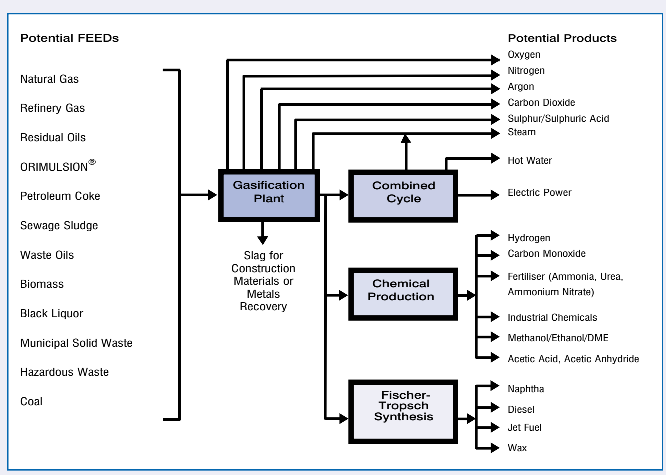

Figure 2: Potential gasification feeds and products.

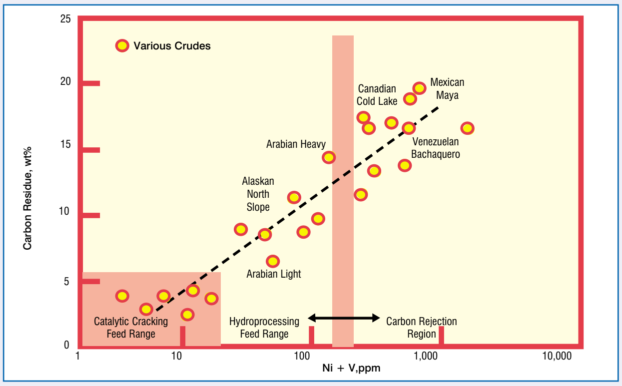

Figure 3: Properties of 343°C residues.

However, R&D continues and significant improvements in the process include:

- Catalyst rejuvenation allowing spent catalyst to be reused
- New reactor designs raising single-train size to around 50,000 bpsd
- Integration of hydroprocessing reactors to further improve the quality of break-down products (for example, kerosene and diesel)

Process selection

Selecting the most appropriate process for individual refinery applications can be a complex decision - as crude quality declines the residue upgrading technology which is most appropriate and economic will tend to change.

Figure 3 shows the contamination of various atmospheric residues, defined by their Conradson Carbon residue, the tendency of a feedstock to produce carbon (in wt%), and metals content, Ni + V, (in wtppm), a catalyst poison.

Figure 3 indicates that once atmospheric residue Conradson Carbon exceeds approximately 10 wt% and metals 100-150 wtppm, then carbon rejection technologies such as delayed coking and gasification become the preferred choice. This is largely because traditional catalytic cracking and the hydrogen addition technologies incur increasingly onerous catalyst costs and unit downtime as contamination levels increase.

An advantage of carbon rejection technologies is that they can be used in a phased approach to residue upgrading investment and also can be combined to optimise the capacity of the upgrading unit so that it fits the needs of the specific refinery and the market.

An example of this is presented below (Figure 4) based on the use of solvent deasphalting, delayed coking and gasification.

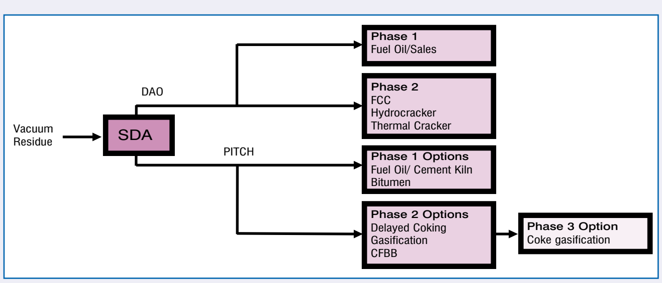

Figure 4: Phased approach to investment.

Economic evaluation and justification of a major residue upgrading project requires a structured, methodical approach taking account of all factors, both inside and outside the refinery fence.

Investment planning

Foster Wheeler has carried out many investment studies of this type in its business sectors (refining, petrochemicals, power, upstream oil and gas, LNG, gas-to-liquids and pharmaceuticals) and has developed an approach to investment analysis, presented in Figure 5.

Because of the many factors involved in the investment decision, it is important to carry out a structured, methodical approach to investment analysis.

Foster Wheeler's approach encourages full client involvement and the development of a 'roadmap' to ensure that phased investment is fit for purpose and early investment does not become obsolete, 'regrettable' or constrain future options.

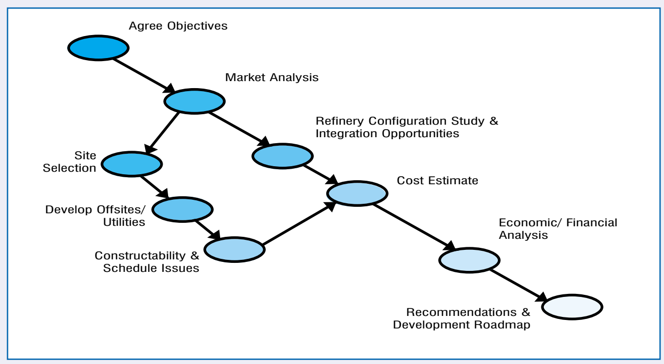

Figure 5: Approach to investment analysis.

Some important lessons have been learnt during these many studies, which have been built into Foster Wheeler's work processes:

- Work closely with the client at all stages
- Get the market analysis right and involve specialist consultants if appropriate
- Think "outside the box" and "over the refinery fence" to identify potential opportunities
- Look for novel but sound finance opportunities

The investment 'roadmap' which results from this methodology is a key deliverable as this will indicate and record the phased approach to investment.

In summary, reducing refinery fuel oil production in a cost-effective and profitable way is the next major challenge facing the industry, but opportunities do exist to enable this to be achieved whilst meeting growing demands for transportation fuels, hydrogen, power and petrochemicals.

The carbon rejection technologies allow the refiners to do this whilst, at the same time, providing the opportunity to process cheaper, heavier crudes. Where reasonable quality crude is available long-term, hydrogen addition technologies can be attractive.