



RESIDUE UPGRADING USING FIXED-BED HYDROCONVERSION

Dealing more effectively with the bottom of the barrel is high on the refining industry's agenda for a several reasons. Crude oil feedstocks are becoming heavier, which is making lighter crudes more expensive. Environmental pressures are undermining the market for heavy fuel oil. In addition, the demand for clean transportation fuels is growing, with countries such as China and India taking the lead.

There are several processes available to refiners seeking an upgrading solution. One of them is fixed-bed residue hydroconversion. It has many advantages over thermal technologies such as delayed coking, but getting the most out of the process is not easy. Effective use of catalysts is the key to success. This is an area where Criterion Catalysts & Technologies has much to offer.

CHALLENGE FOR THE OPERATOR

Most fixed-bed residue upgrading units are used to make fluidised catalytic cracking feedstock; the rest produce low-sulphur fuel oil. Conversion to lighter fractions in these units is generally on the low side (20–30%, 520°C+). Efforts to raise conversion levels, especially with heavier oils, create all kinds of problems, particularly instability in the unconverted material, which leads to sediment-induced fouling. Catalysts also deactivate more rapidly, product quality deteriorates, pressure drop becomes a bigger problem and the end-of-run temperature is reached more quickly. All of these factors combine to reduce the achievable cycle length to uneconomic levels.

GLOBAL RESIDUE UPGRADING HYDROCONVERSION CAPACITY

There are 49 fixed-bed residue upgrading units (comprising 73 trains) in operation in 37 refineries around the world. The total processing capacity of these units is estimated at 2.2 MMbbl/d.

THE SARA MATRIX

Sediment falls into two classes: Type I inorganics and coke, and Type II, arguably the worse culprit, precipitated asphaltenes. High in sulphur, nitrogen, oxygen and metals, and relatively insoluble, asphaltenes are the most complex and least characterised of all the heavy oil macromolecules. They are colloiddally dispersed in the oil and sit at the heart of the so-called SARA matrix (saturates, aromatics, resins and asphaltenes) that characterises all heavy oils. The colloidal instability index, defined as

$$\frac{(\text{asphaltenes} + \text{saturates})}{(\text{resins} + \text{aromatics})}$$

is particularly important, as it largely dictates the extent of sedimentation and also the maximum level of conversion that can be achieved before fouling limits operations. Understanding the SARA matrix, which is different for each heavy oil, and its behaviour is crucial to designing effective catalysts for successful residue upgrading.

THE INSTABILITY OF UNCONVERTED MATERIAL LEADS TO SEDIMENT-INDUCED FOULING, WHICH CAN REDUCE CYCLE LENGTHS TO UNECONOMIC LEVELS.

PERNIS REFINERY IS A PERFECT EXAMPLE OF CRITERION WORKING WITH SHELL GLOBAL SOLUTIONS TO PROVIDE **DIFFERENTIATED, CUSTOMISED SOLUTIONS FOR RESIDUE UPGRADING** COMPRISING WORLD-CLASS CATALYSTS AND INNOVATIVE REACTOR INTERNAL TECHNOLOGY.

CUSTOMISED SOLUTIONS

Choosing the best catalysts to function under the specific conditions prevailing in a fixed-bed residue upgrader requires considerable understanding. At Criterion, we take what we call the 4Cs approach. It is important to be clear about the **chemistry** of what you are trying to achieve: removal of metals, sulphur, Conradson carbon residue (CCR) and asphaltenes. The **composition** of the feed is key, especially the nature and behaviour of the SARA matrix (see boxed text overleaf). In addition, the **conditions** in the unit, the operating constraints and the way the process is configured will clearly have a bearing on the way forward. By getting to grips with these numerous variables on an individual unit basis, we can customise **catalyst** systems that meet each refiner's needs.

REACTOR INTERNALS

Customised catalyst systems need to be properly arranged in the unit if they are to perform to their full potential. Criterion is part of Shell Global Solutions and the two organisations work closely on reactor internal designs to provide the optimum environment for the catalyst. For example, we can offer proprietary high-dispersion trays that aid liquid and gas distribution throughout the catalyst bed and special filter trays to trap physical foulants entrained in the residue feed that would otherwise cause pressure drop and limit cycle lengths.

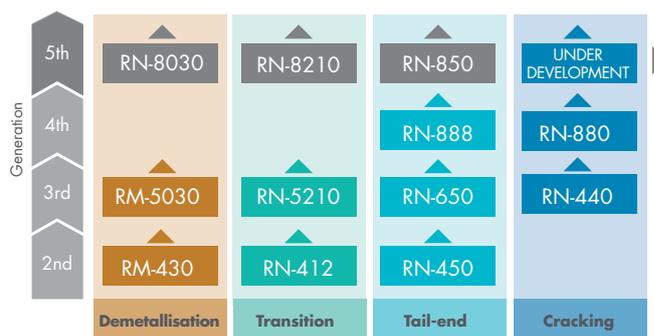
CATALYST DEVELOPMENT

Supplying fixed-bed residue upgrading catalyst systems is not an off-the-shelf business. Criterion is constantly developing new catalysts within a technology framework from which it can formulate the most effective combination of catalysts for a particular unit. Fixed-bed residue upgraders generally have several reactors in series, each one performing a different role in progressively upgrading the feed. Initial hydrodemetallisation (HDM) is normally followed by a transition stage with a catalyst designed for HDM and hydrodesulphurisation (HDS). Then there will be a tail-end

PROOF POINT: SHELL PERNIS

Pernis refinery in the Netherlands runs Shell Global Solutions' HYCON residue upgrading process using Criterion customised catalysts. The HYCON process is differentiated by having multiple beds in each reactor with a quench stage between them, which enables very effective temperature control and reduces catalyst deactivation. The Pernis unit is unusual in being able to process 100% vacuum residue. Its design also features a proprietary HDM section that ensures very reliable performance and allows a customised HDS/HDCCR catalyst to be used in the second stage. The unit achieves a bottom-of-the barrel conversion of up to 65% at cycle lengths of nearly two years.

catalyst, predominantly designed for deep HDS and deep CCR removal through hydrogenation (HDCCR). Finally, if higher conversion is required, a cracking catalyst will also be included. Criterion offers a range of highly active and stable NiMo/alumina catalysts for each of these stages, all designed with the acute demands of residue processing in mind.



CONTACT US

For more information about how we can help you to enhance operational performance, meet increasingly stringent environmental regulations and increase revenues, visit us at www.criterioncatalysts.com.

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CRITERION and its affiliates are dedicated to providing a broad customer base with effective and cost-efficient catalysts and technologies available in focus areas that include the entire range of hydroprocessing applications.

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