HOW HYUNDAI OILBANK'S REFINERY SHIFTED TO A HEAVIER, LOWER-COST CRUDE BLEND

DRIVERS

Hyundai Oilbank identified an opportunity to improve margins at its Daesan, Korea, refinery by moving from a medium-sour Middle East crude blend towards super-heavy crudes such as Maya and Basrah Heavy. These low-priced crudes can provide high margins but are extremely challenging to process.

ABOUT THE PROJECT

To enable such a crude slate while minimising capital investment and maximising returns, Hyundai Oilbank made a series of changes to the refinery configuration in a carefully designed combination of adding new hardware and revamping existing assets. The changes include:

- Installing a new C5 solvent deasphalting (SDA) unit (a residuum oil supercritical extraction, or ROSE™, unit licensed by KBR);
- Converting atmospheric residue desulphurisation (ARDS) Module 2 to deasphalted oil (DAO) mild hydrocracking (MHC) service to process 100% DAO from the SDA unit;
- Revamping the delayed coker to enable it to process pitch from the SDA unit instead of vacuum residue; and
- Revamping the ARDS Module 1 to increase capacity.

One of the key constraints for processing a more difficult crude slate had been the maximum allowable metals content that the existing ARDS modules 1 and 2 could process. The new configuration lifts this constraint significantly for module 2 because the SDA unit concentrates the crude impurities, such as sulphur, nitrogen and metals, in the asphalt stream that is routed to the delayed coker.

PHASING THE INVESTMENT – AN IMPERATIVE IN THE NEW REALITY

"As refiners are likely to adopt a more conservative approach to capital investment in the new reality, it may become more important to take a phased approach to projects. This is exactly how Hyundai Oilbank executed these projects. It followed a staged approach to generate cash through a series of small investments and then used that cash to fund additional investment in small increments."

John Baric, Licensing Technology Manager, Shell Catalysts & Technologies

PHASE 1

During Phase 1, Hyundai Oilbank revamped both ARDS modules:

- ARDS Module 1 was revamped to process 50% more AR above original design, at 20% conversion, producing residue fluidised catalytic cracker (RFCC) feed (0.5% sulphur, 4.5% micro-carbon residue);
- ARDS Module 2 was converted to MHC service and the capacity increased by 50% above original design, processing 100% DAO at 50% conversion. It produces feeds for the existing RFCC and the future petrochemicals complex.

In addition, Hyundai Oilbank installed a new C5 SDA unit, the largest-capacity ROSE unit ever licensed by KBR, and revamped the existing delayed coker to enable co-processing VR and ROSE pitch feed.

In order for the project to begin to generate returns, speed of implementation was also important. It took the Hyundai Oilbank / Shell Catalysts & Technologies project team just 30 months from the beginning of the feasibility study to startup.

NEXT

PHASE 2

During Phase 2, Hyundai Oilbank further revamped the ARDS module and MHC unit:

- ARDS Module 1 was revamped from a single train to two parallel trains and added more fixed-bed reactors, which increased capacity by an additional 30% and the cycle length by 50%;
- The MHC was revamped by adding more fixed-bed reactors, which increased capacity by an additional 10% and the cycle length by 50%.

These changes also enabled the refinery to be further integrated with a new heavy feed petrochemical complex that was being built.

The updated refinery flow scheme is shown in Figure 1.

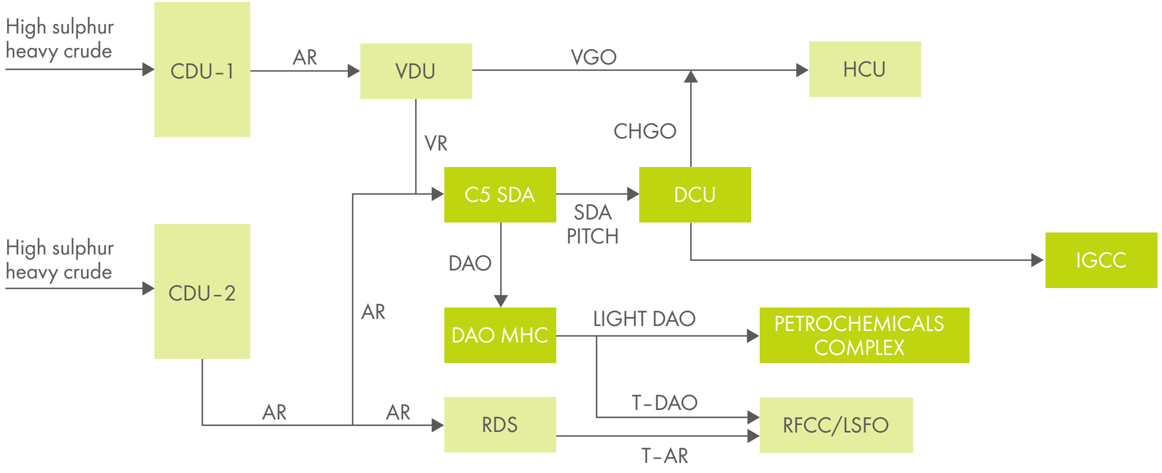

Figure 1: Block flow scheme of Hyundai Oilbank refinery after the revamps.

For this phase, it took just 20 months from starting the feasibility study to starting up the revamped unit.

VALUE DELIVERED

Enabling the processing of super heavy crudes has helped Hyundai Oilbank to unlock a major improvement in its refining margin. Crucially, it achieved this for only modest capital investment by leveraging revamps.

In 2018, Hyundai reported that it has the nation's highest heavy oil upgrading ratio, and in 2019 it posted the industry's highest ratio of net income to sales. The Phase 1 project, which concluded in 2018, was a key contributor to these achievements.

TAKE THE NEXT STEP

Schedule a revamps consultation

SHELL CATALYSTS & TECHNOLOGIES
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HOW SHELL'S PERNIS REFINERY REVAMPED ITS HYCON RESIDUE HYDROPROCESSING UNIT TO A DAO HYDROCRACKER

DRIVERS

Ahead of the IMO 2020 marine fuel oil mandate, it was business critical for Shell's Pernis refinery in the Netherlands to find a way to reduce its fuel oil production. To improve margins further, it also wanted to enhance the yield of ultra-low-sulphur diesel and increase its crude flexibility.

ABOUT THE PROJECT

In 2018, Shell's Pernis refinery brought an integrated project online that involved:

- The construction and startup of a solvent deasphalting (SDA) unit (a residuum oil supercritical extraction, or ROSE™, unit licensed by KBR) that typically produces high-quality deasphalted oil (DAO) that is suitable as a fixed bed hydrocracker feedstock;
- A revamp of the HYCON unit from vacuum residue hydrocracking to DAO hydrocracking mode featuring Shell Hycon Moving Bed technology upstream of the fixed-bed reactors to enable it to process 100% DAO; and
- Minor modifications to the gasification plant to enable it to handle a heavier stream.

Figure 2 shows a simple flow scheme for the Pernis refinery bottom of the barrel before and after project implementation.

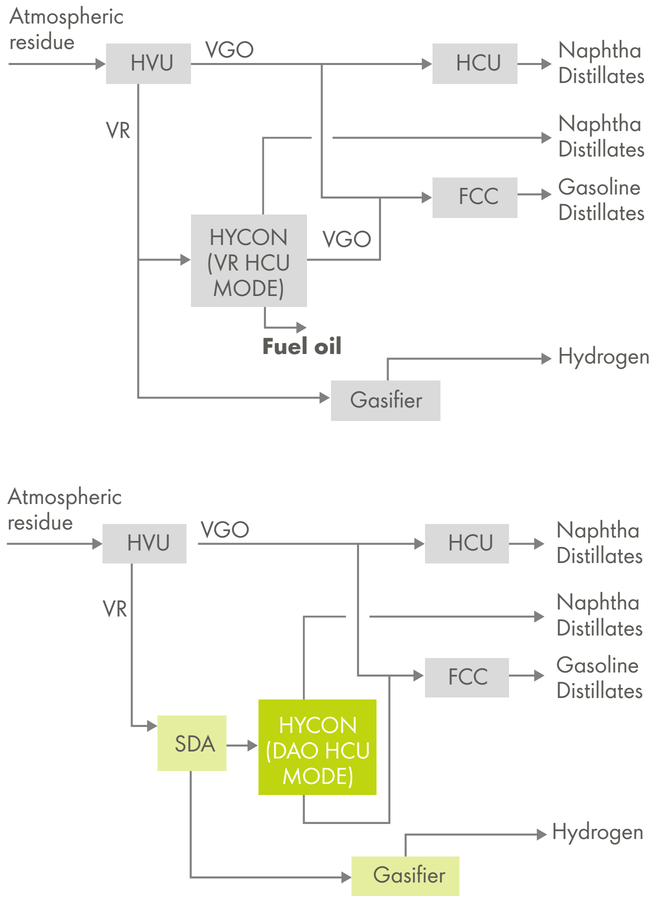

Figure 2: Block flow scheme of Pernis refinery's residue upgrading scheme before and after the revamp.

KEY RESULTS

The design DAO feed quality is given in Table 1.

	Design Case Urals	Check Case I Arab Light	Check Case II WAF
Specific gravity	0.960	0.973	0.953
Sulphur, wt%	2.48	3.45	1.67
Nitrogen, ppm wt	4,000	2,709	4,273
Vanadium, ppm wt	32	13	19
Nickel, ppm wt	10	5	10
Metals (Ni+V), ppm wt	42	18	29
CCR, wt%	7.4	8.7	6.5

Table 1: DAO feed quality.

Shifting the feed from vacuum residue to DAO reduced the levels of all the feed contaminants, especially metals. This enabled changes in the design and operation of the HYCON unit. The lower metals level resulted in only the single moving-bed lead reactor being necessary for demetallisation. This enabled conversion of the next two three-bed reactors from moving to fixed mode. Overall, optimisation of the entire catalyst system has resulted in higher conversion (up to 75%) for the same two-year catalyst cycle length while producing on-specification, ultra-low-sulphur diesel. The site is now evaluating minor unit changes to the HYCON unit that would help to increase future cycle lengths to three years.

In DAO hydrocracking mode, the unit has achieved the targeted higher conversion and an increased yield of high-value products.

In addition to much-improved refinery yields, the DAO hydrocracker generates high-quality finished products, as Table 2 shows.

VALUE DELIVERED

The project helped the site to:

- Reduce fuel oil production by 35%;
- Increase middle distillate yield; and
- Process heavier, cheaper crudes that contain high concentrations of nickel and vanadium.

Revamping existing units and tight integration with the rest of the refinery meant that the project could achieve a return on investment above 15%, a factor of two higher than the prediction for the industry-standard solution, a delayed coker.

The project was fully commissioned and started up in July 2018, one month ahead of schedule and 30 months after the final investment decision. Modular construction was successfully used for the new SDA unit; the modules were fully tested in China before shipping to Netherlands.

CUSTOMER QUOTE

"Pernis refinery is now ready to meet the anticipated demand growth for cleaner transport fuels that will help keep to Europe's people and economy moving. This unit pushes the boundaries of refining technology and seamlessly integrates with almost every part of the site to unlock the full value of each barrel of oil."

Robin Mooldijk, Executive Vice President for Manufacturing, Shell

Download the white paper to learn more

TAKE THE NEXT STEP

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	Naphtha (C_5–160°C)	Kerosene (160–225°C)	Gas oil (225–360°C)	DAO hydrowax (360°C +)
Sulphur, mg/kg	3–10	3	5	20
Cetane number			58	
Cetane index			60	
Smoke point, mm		20		
Cold flow pour point, °C			–10	

Table 2: DAO hydrocracker product qualities.

SHELL CATALYSTS & TECHNOLOGIES
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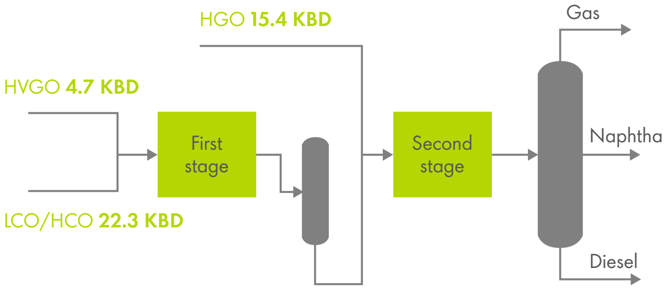
HOW SHELL'S NORCO REFINERY REVAMPED ITS HYDROCRACKER TO MAXIMISE DIESEL INSTEAD OF NAPHTHA

DRIVERS

The two-stage hydrocracker at Shell's Norco refinery in Louisiana, USA, was originally designed to convert distillates to naphtha for motor gasoline production via the reformer. Over time, however, demand for distillates increased and the refinery reacted by using the bottom product from the second-stage fractionator as a diesel component (Figure 3).



HGO: Heavy gas oil
HVGO: Heavy vacuum gas oil
LCO: Light cycle oil
HCO: Heavy cycle oil

Figure 3: Original hydrocracker configuration.

However, the quantity of heavy vacuum gas oil (HVGO) that could be incorporated into the unit feed was constrained by the final boiling point requirement of the diesel product draw.

ABOUT THE PROJECT

The refinery was keen to explore ways to unlock this constraint and significantly increase the unit's diesel yield, so commissioned a masterplanning study.

After evaluating several options, the team opted for a solution (Figure 4) that involved:

- Rerouting distillates (light cycle oil and diesel range material) from the hydrocracker to the diesel hydrotreater (DHT);
- Increasing the DHT's utilisation through backing out imported cold feed and replacing with hydrocracker distillates via a separate project; and
- Revamping the hydrocracker to process significantly more HVGO and maximise diesel yield.

This required:

- Adding a new fractionation column with diesel draw so that the distillate end point could be controlled independently of the feed quality;
- Modifying the catalyst system in the second-stage reactors to enable the processing of fresh HVGO feed with higher nitrogen and other contaminant contents (see boxed text, "New catalysts, new possibilities");
- Installing latest-generation reactor internals and catalysts; and
- Rerating equipment (see boxed text, "Using HITLOP to minimise the capital cost").

NEW CATALYSTS, NEW POSSIBILITIES

"To enable the second-stage reactors to handle the increased nitrogen and other contaminants in the new feed, it was necessary to modify the catalyst system significantly. This involved moving from 100% cracking catalyst to a stacked system of pretreatment and cracking catalysts.

"Underlying this is that the state of the art in pretreatment catalysts is continuously improving. Typically, a new-generation catalyst is developed every four years that is about 20% more active. This provides many improvement possibilities for old units; in this case, Norco is using some of the catalyst volume for pretreating the heavier feed that it wanted to introduce."

Simon Cackett, Licensing Technology Manager, Shell Catalysts & Technologies

USING HITLOP TO MINIMISE THE CAPITAL COST

"We had to rerate the equipment in the first and second stages to enable the heavier feed to be charged; much of the equipment was only rated for 400°C (750°F) maximum allowable working temperature, but processing the additional HVGO required operating at up to 425°C (800°F) maximum allowable working temperature.

"To achieve this cost-effectively, we leveraged the high-temperature, low-pressure (HITLOP) technique, which involves evaluating each piece of equipment for the actual combination of operating temperature and pressure and replacing only the items that cannot be safely run at these conditions. It is a challenging technique that requires high-quality interaction between the process operations and inspection functions, but it can have a major impact on project cost because it minimises the equipment that has to be replaced. For this project we achieved a full 28°C (50°F) increase in design temperature window in each stage by reducing the maximum pressure rating by only 2.8 barg (40 psig) in the first stage and 3.1 barg (45 psig) in the second stage."

Ward Koester, Licensing Technology Manager, Shell Catalysts & Technologies

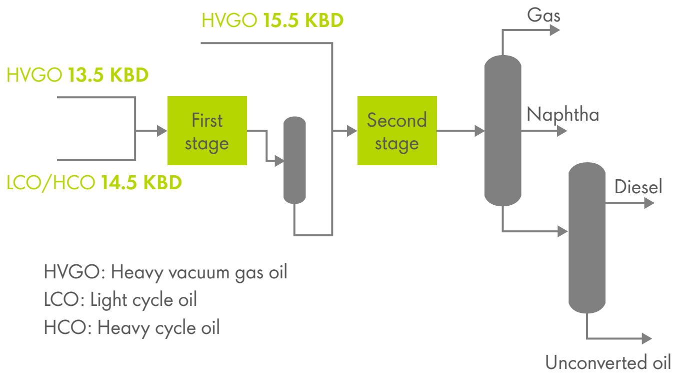


Figure 4: Revamped hydrocracker with additional fractionator and increased feed heaviness. In addition, the LCO:HCO ratio changed from 50:50 to 25:75.

VALUE DELIVERED

The revamped hydrocracker can process a significantly higher amount of HVGO. This has increased from 4,700 to 29,000 bbl/d (13,500 bbl/d in the first stage and 15,500 bbl/d in the second stage).

The amount of diesel that the hydrocracker can produce has increased from about 14,000 to 24,000 bbl/d. The proportion of diesel that the hydrocracker produces has increased from 33 to 55 vol% now limited by the diesel cloud point specification and equipment constraints on the minimum achievable naphtha/diesel cut point.

In addition, greater utilisation of the DHT through the processing of hydrocracker distillates has allowed for elimination of 12,000 bbl/d of imported cold feed distillate.

Revamping the hydrocracker and enabling fuller utilisation of the DHT have allowed the refinery to process an extra 24,300 bbl/d of imported vacuum gas oil (VGO) and produce predominantly additional diesel, with gross margin impact of about $60 million per annum (based on typical $7/bbl VGO–low-sulphur diesel price differential).

TAKE THE NEXT STEP

[Schedule a revamps consultation]

SHELL CATALYSTS & TECHNOLOGIES
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HOW SAUDI ARAMCO SHELL REFINERY CO. (SASREF) INCREASED DIESEL YIELD, CYCLE LENGTH AND SAFETY THROUGH A LOW-COST HYDROCRACKER REVAMP

DRIVERS

When it was built in 1982, the hydrocracker at SASREF, one of the largest in the world, was configured for maximum naphtha. By 2012, however, middle distillates, not naphtha, had become the highest-value product stream, so SASREF launched a project to repurpose the unit.

It also wanted to take the opportunity to enhance its profitability by increasing the unit's capacity and cycle length.

ABOUT THE PROJECT

SASREF installed latest-generation reactor internals throughout the unit. These include Shell HD trays, which achieve near-perfect wetting of the catalyst (Figure 5).

Other important changes that it made include modifying the bed configuration in each reactor, installing new thermometry and customising the catalyst system.

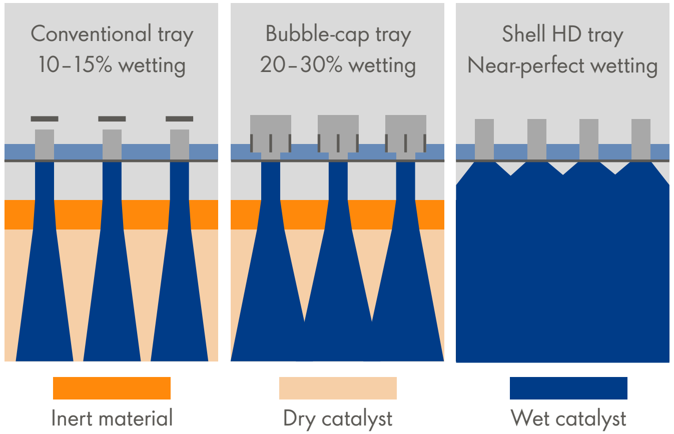

Figure 5: Shell HD trays feature proprietary customised nozzles that use the gas flow momentum to disperse the liquid as a fine mist to achieve almost 100% catalyst wetting.

KEY RESULTS

The hydrocracker had been using conventional distribution trays, which are notorious for low uniformity of vapour–liquid distribution and undesirable radial temperature maldistribution.

Replacing these with Shell HD trays helped to improve catalyst utilisation by:

- 21% in the pretreatment reactors; and
- 52% in the cracking reactors.

Merging beds, and the hardware's slimmer profile, helped to increase the reactors' catalyst volume by:

- 16% in the pretreatment reactors; and
- 22% in the cracking reactors.

VALUE DELIVERED

The project, which required little capital expenditure, delivered value in several ways. For example, it:

- Increased middle distillates yield by 4%, which enhanced the site's profitability by over $10 million a year;[1]
- Enabled the unit to have the flexibility to swing between naphtha and middle distillates;
- Cut the time required for shutdowns by some four days, which is worth about $2.56 million per turnaround; and[2]
- Enhanced staff safety by, for example, reducing the time required for confined space entry by 75% compared with conventional hardware.

[1]Assumes $14/bbl diesel–naphtha price differential, 7,500 t/d intake, 350 operating days a year and 4% shift from naphtha to diesel.
[2]Assumes $80/t margin.

CUSTOMER QUOTE

"It was a great pleasure for SASREF to work with Shell Catalysts & Technologies on this initiative. The project is helping us to derive the intended value, which is quite timely considering the current economic conditions and tightening refinery margins."

Ali Al-Hazmi, President, SASREF

Download the white paper to learn more

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