

Shell Catalysts & Technologies



CATALYSTS AND TECHNOLOGY FOR LUBRICANT BASE OILS

WHITE PAPER



**LICENSED
TECHNOLOGIES**



CATALYSTS



**TECHNICAL
SERVICES**



**OFFTAKE
AGREEMENTS**

CONTENTS

1. The trend towards Group II and III base oils	3
2. Why the hydrocracker process configuration and catalyst system are key	4
3. Avoid these common problems	5
4. Our offer	6
5. Our lubricant base oil catalysts	7
6. Licensed technologies	7
7. Proof point: Hyundai Oilbank	8
8. Key takeaways	10
About the author	11
About Shell Catalysts & Technologies	11
About Shell Lubricants	11

Are you a refiner that is...

...keen to exploit the high margins that are available for lubricant base oil feed in some markets?

...looking for expertise to ensure that your catalyst system and process configuration are optimised to maximise the yield and quality of final base oil products?

...concerned about the inherent difficulties of producing haze-free, heavy base oils or of co-processing a difficult feed such as deasphalted oil (DAO)?

1. THE TREND TOWARDS GROUP II AND III BASE OILS

In some regions, lubricant base oils can provide better economics for refiners than middle distillates. And with the COVID-19 pandemic having brought a keen focus on margins, for many this continues to be a valuable opportunity to enhance their competitiveness.

In recent years, the lubricant base oil business has entered a state of transition with production moving away from solvent-based plants towards those based on catalytic hydroprocessing and hydrofinishing technologies.

This is chiefly because base oil quality and yields are much higher, there is less dependence on a specific crude source and it is easier to make the high-quality Group II and III base oils that the current market demands.

Consequently, there has been a significant drop in demand for Group I products, especially in Europe and North America, and several closures in Group I capacity in those regions. All the new base-oil capacity and additional projects that have been announced are exclusively for Group II and III base oils produced using catalytic technology.

Before the COVID-19 pandemic, Kline data suggested that demand for these would increase by 31% between 2017 and 2027.¹ Of course, in the prevailing situation, this growth is likely to be inhibited but, nevertheless, many operators of lubricants base-oil plants are finding that their assets are providing valuable opportunities to capture additional margin.

¹Global Synthetic Lubricant Basestocks 2017: Market Analysis and Opportunities, Kline & Co. (2018)



2. WHY THE HYDROCRACKER PROCESS CONFIGURATION AND CATALYST SYSTEM ARE KEY

Group II and III base oils are commonly derived from hydrocracker bottoms. Achieving the necessary viscosity indices of 120–130 requires the higher conversion that only a hydrocracker can provide, but its ability to generate a high-quality lubricant base oil feed depends on its design and operation.

The hydrocracker will provide the feedstock for most future base oils. However, producing lubricant base oil feedstock requires an in-depth understanding of what drives the properties of the unconverted material that comes off the bottom of the fractionator, especially its viscosity index and aromatics, sulphur and nitrogen contents. The hydrocracker process configuration and the application of the right catalyst system are important to maximising both the yield and the quality of the final base oil products.

Figure 1 shows a typical line-up. In the high-vacuum unit (HVU), deep-flash technology can be used to maximise feed heaviness. The hydrocracker's conversion can be fine-tuned to balance product qualities and yields, and the catalytic dewaxing/hydrofinishing (CDW/HF) unit can generate the base oils for Group II or III products, as appropriate.

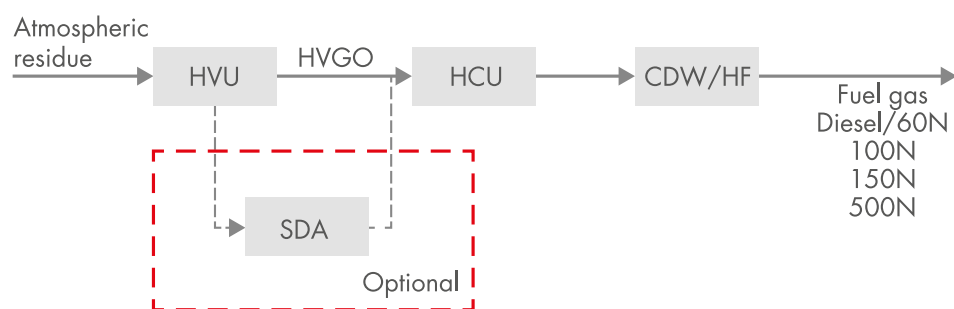


Figure 1: A typical hydrocracking–base oils line-up.

Read the expanded description for Figure 1 in the appendix on page 12

If there is sufficient demand for heavier (500N) base oils, DAO can also be added. The processing route using DAO will also enable the production of Group II bright stock, which is in extremely limited supply.

In this highly specialised sector, where quality is paramount, best-in-class technology and operating experience are precursors to added value. So, on the following pages, we detail the support that Shell Catalysts & Technologies provides to owners seeking to build new units or revamp or refill existing ones.

This includes leading-edge technology coupled with market-leading catalysts, and technical services. In addition, we can facilitate product offtake agreements with Shell Lubricants.

3. AVOID THESE COMMON PROBLEMS

With a strong reference list and the experience gained from supporting Shell operations around the globe, Shell Catalysts & Technologies has experience of overcoming many of the common challenges owners face.

Existing operators

PROBLEM 1: HAZE *"Since we started to co-process DAO, we have had recurring product haze issues; our products do not meet base oil specifications and we cannot sell them. It seems that no amount of process adjustments can solve this."*

We have accrued a wealth of experience in this area. We have many references in which our catalysts are in units co-processing DAO to make haze-free base oils. Our proprietary aromatic saturation and stacked dewaxing catalyst systems are key to this.

PROBLEM 2: FEED INCONSISTENCIES *"We process more than 40 different opportunity crude slates. Inevitably, we sometimes have difficulty controlling the quality of our base oil feed from the upstream hydrocracker."*

We have the ability to design catalyst systems that are both flexible and robust. Their versatility enables operators to make small temperature adjustments that can alleviate many product quality issues.

PROBLEM 3: VISCOSITY LOSS *"Dewaxing is essential for improving cold flow properties, but this sometimes leads to 'overdewaxing' and a consequent loss of viscosity."*

We leverage several different types of dewaxing catalyst and build catalyst systems based on the feed properties of the unit that maximise viscosity and viscosity index retention.

PROBLEM 4: CAPACITY *"We are keen to increase yields but need a cost-effective solution."*

A revamp involving state-of-the-art reactor internals or latest-generation catalysts can improve yields extremely cost-effectively and far quicker than a grassroots project.

Although the economics of a revamp can be highly attractive, it is substantially more complex than building a new unit. This highly specialised area calls for advanced process engineering skills and wide-ranging operating experience.

New entrants

PROBLEM 5: ACCESSING SECTOR EXPERTISE *"We are keen to exploit the high margins that are available in some markets for lubricant base oil feed. However, there is a concern that we lack sufficient knowledge of the base oil market or the technology to thrive in this highly specialised sector."*

We support customers throughout the entire project life cycle: from initial consultancy and front-end project design through to ongoing operational support. In this way, customers benefit from our leading-edge technology and catalysts, and our best practices and sector expertise.

PROBLEM 6: REDUCING CAPITAL EXPENDITURE *"We would like to build a new lubricant base oil plant. However, the capital expenditure required appears to be too high."*

We are experienced in finding novel ways to reduce capital costs. For example, we have created designs in which the intelligent integration of process units has brought down the capital intensity of such projects substantially. Whereas conventional base oil plant designs typically feature two units, a hydrotreating unit followed by a separate dewaxing/hydrofinishing unit, we have integrated both units into one, which enables several major equipment items to be removed from the line-up.

PROBLEM 7: MITIGATING TRADING RISK *"Our investors and their banks are offering suboptimal terms, in part because other capacity is coming on stream in the region."*

Some of our licensees have found that an offtake deal with Shell Lubricants, which we can facilitate, provides valuable trading risk mitigation and investor assurance.

4. OUR OFFER

Shell Catalysts & Technologies has supported a wide range of customers around the world as they have built new units or revamped or refilled existing units.

Customers can benefit from a powerful combination of:



licensed technologies. We will work with you to design a catalyst system and a process configuration that are optimised to your feeds, operational constraints and strategic objectives. Furthermore, we license not only the lubricants unit, but also the upstream hydrocracker that provides the hydrowax feeds.



catalysts. We have market-leading products at all three stages: lubricant hydrotreating/hydrocracking, catalytic dewaxing and hydrofinishing (see boxed text, Our lubricant base oil catalysts).



technical services. Our experienced catalysts scientists and process technologists provide support at every stage of the process cycle to help maintain the long-term performance of a unit. Our state-of-the-art pilot plant facilities, which are located strategically around the globe, can be used for troubleshooting and technical estimation validation.



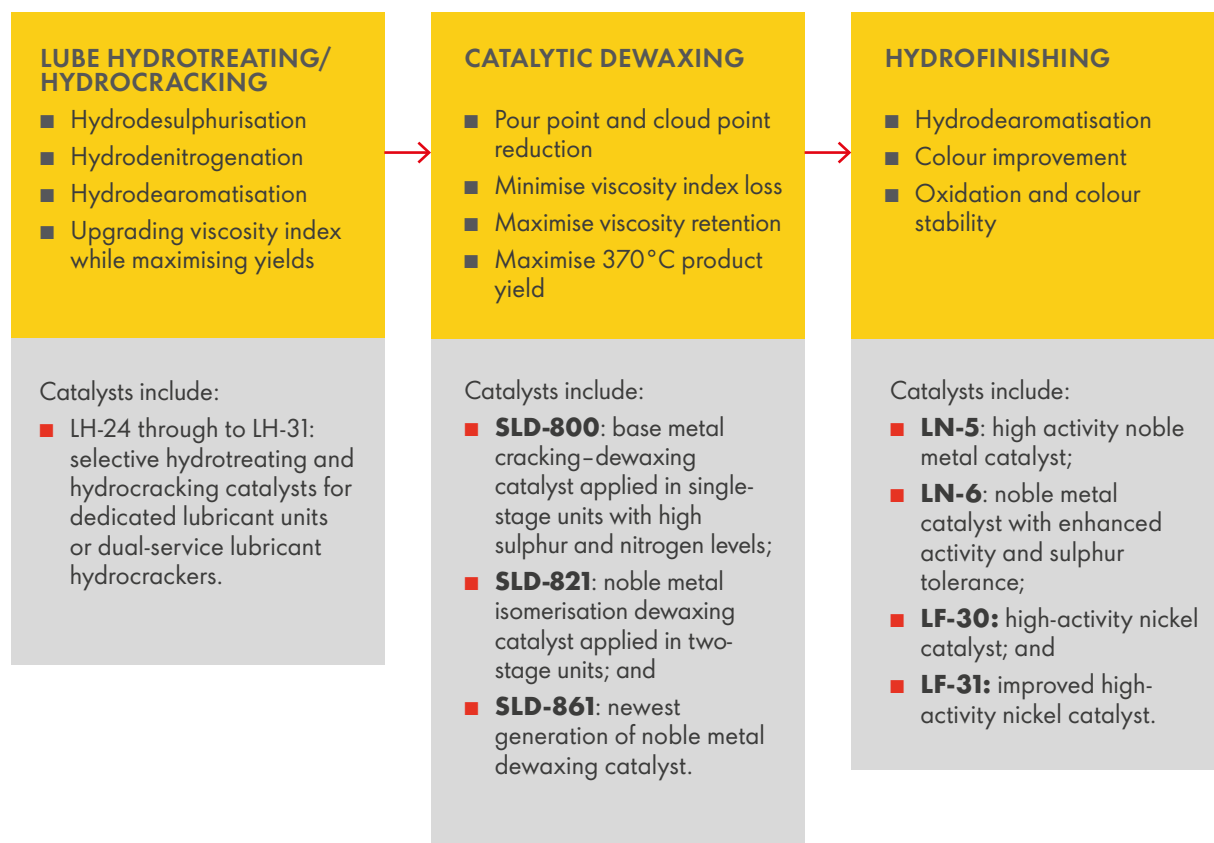
product offtake agreements. Shell Lubricants, a net buyer, may be interested in taking some of the base oil to create high-quality finished lubricants at its own blending plants. We can facilitate such commercial agreements and work with you to ensure that your products meet Shell's exacting quality requirements.



CUSTOMERS CAN BENEFIT FROM A POWERFUL COMBINATION OF CATALYSTS, LICENSED TECHNOLOGIES AND VALUE-ADDING TECHNICAL SERVICES FROM SHELL CATALYSTS & TECHNOLOGIES.

5. OUR LUBRICANT BASE OIL CATALYSTS

Shell Catalysts & Technologies has various catalysts dedicated to lubricant base oil manufacture. Owing to the uniqueness of lubricant processing operations, we encourage you to contact us for assistance in selecting and applying the proper catalyst for your application.



6. LICENSED TECHNOLOGIES

Shell Catalysts & Technologies' licensed technology portfolio includes:

- **base oil units**, including the lubricant hydrotreating/hydrocracking, catalytic dewaxing and hydrofinishing reactors;
- **a dual-service hydrocracking process**, which partially converts feedstocks to produce lubricant base oils (or catalytic cracker or ethylene cracker feedstocks) and high-quality distillates; and
- **reactor internals**, which are designed to maximise the volume of catalyst that can be loaded in the reactor and improve its utilisation to, for example, increase cycle life and improve product yields.

7. PROOF POINT: HYUNDAI OILBANK

Situation

Hyundai Oilbank identified a strategic opportunity to build a 20,000-bbl/d Group II lubricant base oil manufacturing plant adjacent to its Daesan refinery in South Korea because demand for Group II products was robust in the region.

Hyundai was exploring the technical and economic feasibility of this concept with Shell Global Solutions when it became apparent that Shell Lubricants was looking for a stable, high-quality producer to supply base oil in Asia. This led to the creation of a joint venture.

A base oil plant located at the Daesan refinery would be close to key lubricants markets. The plant would export a significant proportion of its products to China, the largest consuming market, and other countries in Asia through Shell's global distribution network.

Solution

To integrate the new base oils plant with the existing line-up, it was necessary to revamp the hydrocracker, which would provide the feed for the new facility. To get the right amount of feed (hydrowax) at the right quality, the team needed to find a way to increase the hydrocracker's throughput by 15%, decrease its conversion from 68 to 50%, increase its viscosity index to 125, and increase the cycle length from three to four years to align with the new base oil plant.

It achieved this by making several relatively inexpensive changes. For example, it installed new reactor internals and catalysts, and added a new high-pressure effluent exchanger. In the fractionator, it upgraded the hydrowax rundown hydraulic system.

To get sufficient and suitable feed for the hydrocracker, it was also necessary to go further back into the processing stream and revamp the HVU. Figure 2 shows how the project changed the refinery configuration. It increased the unit's capacity and enhanced the potential for making heavy base oils as opposed to light ones. A hydrocracker on a diet of conventional vacuum gas oil (VGO) typically makes very light base oils, mostly in the 2–6-cSt range and some in the 6–8-cSt range. In contrast, Hyundai Oilbank is producing a substantial amount of base oil in the 10–12-cSt range. This is only possible because the HVU can lift very heavy VGO and closely control the levels of asphaltene, Conradson carbon residue (CCR) and metals.

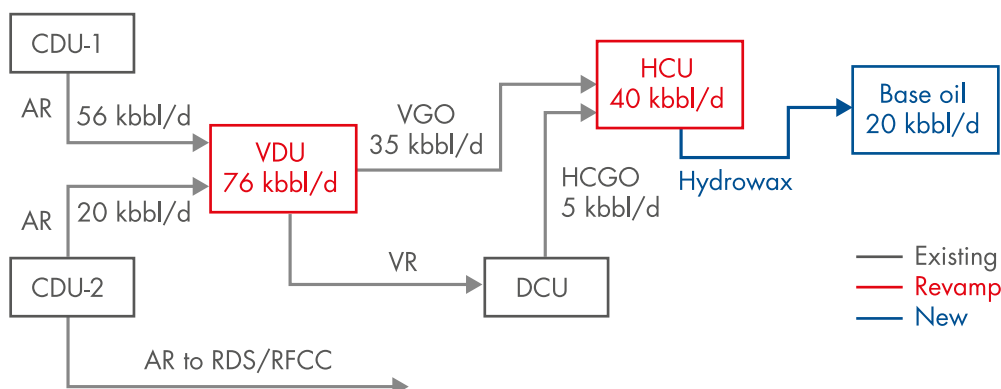


Figure 2: Hyundai's HVU and hydrocracker were revamped and configured to work with the new base oil plant as a value chain.

Read the expanded description for Figure 2 in the appendix on page 12

As a result, the VGO yield increased and its quality specifications were met. The improvement in quality parameters is shown in Table 1.

VGO quality parameter	Before revamp	After revamp
D1160 T95%, °C	540	562
Nickel + vanadium, wppm	0.3	0.5
CCR, %wt	0.4	0.5

Table 1: How the revamp changed the VGO product qualities.

These changes enabled:

- the HVU to deliver the VGO feed to the hydrocracker at the right yield and heaviness: the profile was exactly as per design;
- the hydrocracker to operate at target conversion to deliver the hydrowax quantity and quality that the base oil plant needs; and
- the base oil plant to deliver the right product quality.

Value delivered

Hyundai Oilbank expects the project to deliver substantial ongoing value: ahead of the start-up in 2014, it targeted lubricant base oil sales of almost \$1 billion a year.

Moreover, Hyundai Oilbank did not stop there. Subsequently, it worked with Shell Global Solutions and Criterion to perform an additional revamp. It added a new reactor and increased the feed rate, which further increased product yields and improved product quality.

8. KEY TAKEAWAYS

SHELL CATALYSTS & TECHNOLOGIES SUPPORTS OWNERS SEEKING TO:

- build new units;
- revamp existing units; or
- refill existing units.

IN LUBRICANT BASE OILS, PRODUCT QUALITY IS KEY

We have developed special insights in key areas that can help customers to obtain the stable, highly saturated, very heavy, haze-free Group II and III base oils that the market requires at maximum yield. These insights include how to:

- design catalyst systems to help ensure products are haze free;
- co-process difficult feeds such as DAO;
- expand capacity cost-effectively;
- reduce capital and operating costs; and
- ensure key product properties such as the viscosity index meet the specifications.

CUSTOMERS CAN BENEFIT FROM A POWERFUL COMBINATION OF:



licensed technologies;



catalysts;



technical services; and



product offtake agreements.

ABOUT THE AUTHOR

Jeff Pro is the Market Specialist for Shell Catalysts & Technologies' hydrocracking and lubricant base oil business. He is based in Houston, TX, USA, and supports the global business and product development and technology applications in particular. Jeff joined Shell in 2008 and has performed many roles, including research and development deployment, manufacturing support, refinery technical services and commercial account management. He has a bachelor's degree in chemical engineering from the University of Texas at Austin, USA.

ABOUT SHELL CATALYSTS & TECHNOLOGIES

Shell Catalysts & Technologies exists to provide Shell and non-Shell businesses with tools, technologies and insights to help navigate the energy transition.

We are...

...pushing boundaries in the energy transition space. For decades, we have been developing game-changing technological innovations to solve seemingly insurmountable challenges. Now we have, or are developing, numerous differentiated solutions that offer attractive decarbonisation opportunities, including biofuels, carbon capture and blue hydrogen technologies.

...one of the world's leading catalyst providers. We invest heavily in catalyst R&D and offer a wide portfolio of high-performance zeolites and catalysts.

...an owner-operator-licensor. Our corporate heritage as the operator of refineries and petrochemical plants around the world provides valuable real-world insights.

...a leader in the molecular engineering of hydrocarbons. Our world-class catalyst and R&D expertise has helped us establish an enviable track record for leading-edge zeolites and catalysts, advanced solvents and pioneering processes.

Highly complex business and technological challenges lie ahead for the sector. But, with ingenuity, technical prowess and – crucially – collaboration, we can overcome them: **Together, we can shape the energy landscape.**

For further information, please visit our website at www.shell.com/ct.

ABOUT SHELL LUBRICANTS

Shell Lubricants has a global lubricants supply chain with a network of 4 base oil manufacturing plants, 32 lubricant blending plants, 8 grease plants and 4 gas-to-liquids base oil storage hubs.

For further information, please visit our website at www.shell.com/lubricants.

APPENDIX

Figure 1

Figure 1 shows a flow diagram of a typical hydrocracking-base oils line-up.

The diagram illustrates that atmospheric residue enters the high-vacuum unit. From the high-vacuum unit, hydrogenated vacuum gas oil flows to the hydrocracker unit. Alternatively, the hydrogenated vacuum gas oil flows through an optional solvent deasphalter before entering the hydrocracker unit. Finally, the flow is fed through the catalytic dewaxing/hydrofinishing unit to generate the base oils for:

- Fuel gas
- Diesel/60N
- 100N
- 150N
- 500N

[Return to page 4](#)

Figure 2

Figure 2 shows a flow diagram illustrating the changes to Hyundai's refinery configuration to support the new base oil plant.

The diagram shows the integration and modification of Hyundai's refinery units, highlighting the revamp of the vacuum distillation unit and the high-vacuum unit within the existing plant configuration, and the new base oil production capability.

The plant configuration and processing capabilities are as follows:

1. Crude distillation units CDU-1 and CDU-2 process 56,000 barrels per day and 20,000 barrels per day of atmospheric residue, respectively, which is sent to the vacuum distillation unit. Atmospheric residue is also directed from CDU-2 to the residue desulphurisation unit and the residual fluid catalytic cracker.
2. The revamped vacuum distillation unit processes 76,000 barrels per day of feedstock. It separates the feed into vacuum gas oil at a rate of 35,000 barrels per day and vacuum residue, which is sent to the delayed coking unit for processing into heavy coker gas oil at a rate of 5,000 barrels per day.
3. The vacuum gas oil and the heavy coker gas oil are sent to the revamped hydrocracker unit for processing at a total rate of 40,000 barrels per day into hydrowax, which is used as feedstock for the new base oil plant.
4. The newly introduced base oil plant processes the hydrowax into 20,000 barrels per day of base oils.

[Continue on page 9](#)

Shell Catalysts & Technologies is a network of independent technology companies in the Shell Group. In this material, the expressions "the Shell Group" and "Shell Catalysts & Technologies" are sometimes used for convenience where reference is made to these companies in general, or where no useful purpose is served by identifying a particular company.

The information contained in this material is intended to be general in nature and must not be relied on as specific advice in connection with any decisions you may make. Shell Catalysts & Technologies is not liable for any action you may take as a result of you relying on such material or for any loss or damage suffered by you as a result of you taking this action. Furthermore, these materials do not in any way constitute an offer to provide specific services. Some services may not be available in certain countries or political subdivisions thereof.

Copyright © 2025 Shell Global Solutions International BV. All rights reserved. No part of this publication may be reproduced or transmitted in any form or by any means, electronic or mechanical including by photocopy, recording or information storage and retrieval system, without permission in writing from Shell Global Solutions International BV.