



T H E C L E A N F U E L S T E A M

Criterion Catalysts & Technologies Catalysts and Processing Experience

Value - Performance - Reliability

Refiners are faced with formidable challenges to meet changing fuels specifications and supply the clean fuels market demand at expected margins. Criterion Catalysts & Technologies can provide the help you need to accomplish your production and margin goals.

Knowledge is POWER

Criterion Catalysts & Technologies is a leading hydroprocessing catalyst supplier with a portfolio that covers all applications ranging from light ends to the bottom-of-the-barrel. Each year, we help refiners optimize performance on hundreds of units.

We have been fulfilling the industry's hydrotreating needs for 50 years. During this time, we have developed an extensive database of hydroprocessing information with computer models built on real experience. This experience, our vast arsenal of research resources, and our breadth of capabilities provided via our affiliated companies, Shell Global Solutions, Zeolyst International and CDTech, ensures that we can provide the solutions you need.

Criterion gives you:

Value.

Resources to help you get the maximum value from your assets

Performance.

High performance catalysts & know-how to achieve maximum results

Reliability.

Catalysts and experience to help you accomplish your production goals



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DC-2531 – For Ultra Low Sulphur Diesel Production



Overview

DC-2531, manufactured with our new ASCENT Catalyst Technology, is the ideal catalyst for increased operational flexibility when producing ULSD at low-to-moderate operating pressures, especially when it is critical to limit hydrogen addition to the feed. DC-2531 is easily regenerated to near fresh activity using conventional regeneration technologies, creating options to improve multi-cycle life economics. DC-2531 has a lower density than many competitive ULSD catalysts and is available in either the oxide or presulfided form. DC-2531's strong physical characteristics reduce the risk of pressure drop problems and catalyst losses during regeneration and reuse.

ULSD HDS Activity

The success of a catalyst to aid in the production of diesel to the 10ppm sulphur levels is dependent on many variables including feedstock composition & chemistry and unit process conditions. In order to truly understand the range of a catalyst's capability for producing ULSD, it must be evaluated across a wide range of factors. Figure 1 below summarizes the ULSD HDS activity advantage of DC-2531 versus current market leading ULSD catalysts, over a broad range of conditions found in commercial units.

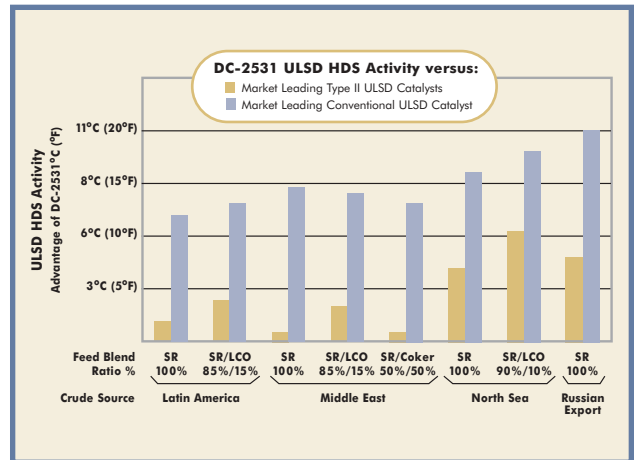


Figure 1: DC-2531 Demonstrates High ULSD HDS Activity Over Wide Range of Feed & Conditions

Regeneration

Regeneration of high activity ULSD catalysts creates options to improve multi-cycle life economics for many refiners. Regeneration of catalysts can allow re-use in the same application, cascading to other units & services or sales to third parties. In order to assess regeneration effectiveness, the regenerated catalyst must be compared to fresh catalyst at ULSD production conditions. Conventional regeneration (oxidic removal of carbon and sulphur) has been demonstrated to return spent DC-2531 to 90%+ activity of fresh.

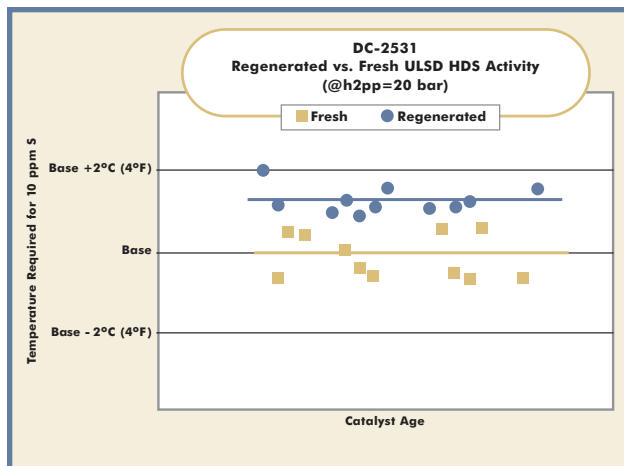


Figure 2: Conventional Regeneration Returns DC-2531 to 90%+ of Fresh Activity

Physical Properties

DC-2531 is a strong catalyst with very high crush strength and low attrition. These physical characteristics minimize production of fines and dust during all types of catalyst handling (e.g. reactor loading/unloading, regeneration, etc.). The net benefit to the refiner is improved cycle life cost through lower losses and higher retention of active catalyst along with reduced risk of pressure drop problems.

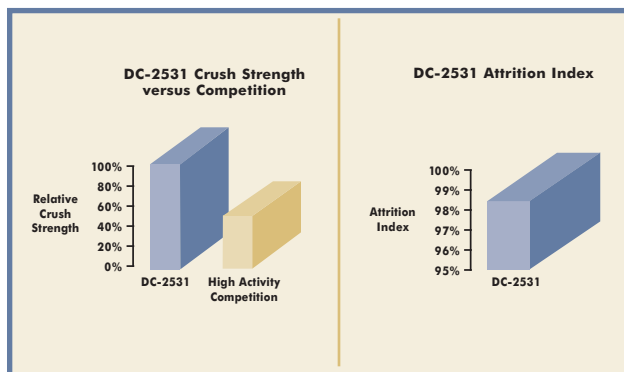


Figure 3: DC-2531 Has Nearly Twice the Crush Strength of Competitive High Activity ULSD Catalysts & Outstanding Attrition Resistance

Hydrogen Consumption

Production of diesel fuel to ultra low sulphur levels requires removal of sulphur from less reactive (i.e. more refractive & aromatic) compounds. Additional hydrogen can be required for these reactions and thus hydrogen consumption may increase with lower product sulphur requirements. However, hydrogen consumption can be managed by use of catalyst systems that are selective to removing sulphur versus saturation of aromatic species, whether or not required for production of ULSD. DC-2531 demonstrates selective hydrogen consumption for ULSD production.

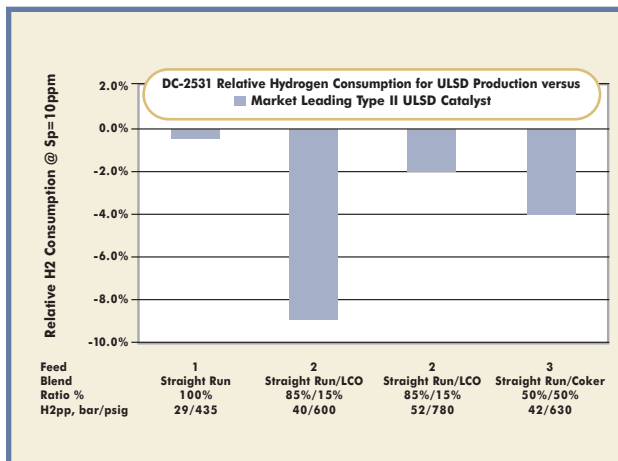


Figure 4: DC-2531 Has Selective Hydrogen Consumption for ULSD Production

Summary

DC-2531 is a catalyst that provides refiners benefits by delivering many additional requirements over other catalysts currently available today. DC-2531's combination of:

- High ULSD HDS Activity
- Selective Hydrogen Consumption
- Standard Regeneration & Activation
- Strong Physical Characteristics

results in outstanding overall value.





The Value of Gold is Rising

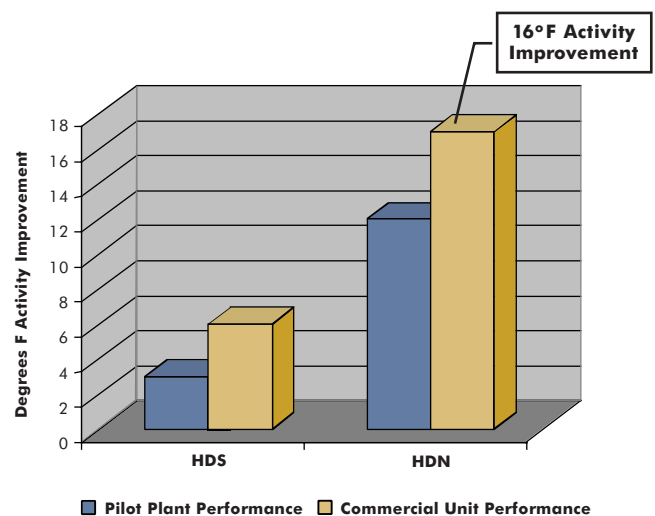
Increasing Fluid Catalytic Cracker Unit (FCCU) conversion can produce significant financial gains. Criterion's new CENTINEL GOLD DN-3310 catalyst is helping refiners raise the bar on FCCU conversion.

CENTINEL GOLD DN-3310 is the latest and most advanced catalyst for FCC Pretreat units. Criterion's latest invention builds upon the best features of the DN-200 technology, the most widely used FCC Pretreat catalyst in the industry's history, and the CENTINEL DN-3110 technology. DN-3310 provides the same exceptional stability as its predecessors, but it delivers even more denitrification and aromatic saturation.

Earlier this year, a Gulf Coast USA refiner installed DN-3310 in its FCC Pretreat unit to increase nitrogen removal and polyaromatic saturation. By improving the FCC Pretreat unit's performance, the refiner hoped to get more FCCU conversion. Through the first six months, the catalyst is performing as expected, and the refiner is observing increased FCCU conversion. The DN-3310 is achieving a 16° F denitrification activity advantage compared to the previous catalyst load (Figure 1). All other performance parameters for this unit have met the refiner's expectations.

Figure 1

CENTINEL GOLD DN-3310
Commercial Unit Proven Activity Benefit
Compared to CENTINEL DN-3110



CENTINEL GOLD DN-3310 can help refiners generate additional margins from the FCCU operation in two ways. First, like the case above, the catalyst can be used to push denitrification and aromatic saturation to higher levels to increase FCCU conversion. Alternatively, DN-3310 can be used to upgrade additional volumes of low value feeds while maintaining equivalent FCC conversion. Examples are shown in Figure 2. Either way, this new technology will increase the value of the FCCU.



Figure 2

Extract Maximum Value from the FCCU with CENTINEL GOLD

	Previous CENTINEL Technology	DN-3310 CENTINEL GOLD	DN-3310 CENTINEL GOLD
FCC Pretreat Feed Properties			
% CGO	30	30	40
Feed S, wt%	2.5	2.5	2.6
Feed N, ppm	2000	2000	2300
Feed Aromatics, UV wt%	16.0	16.0	16.4
Products S, wt%	0.2	0.18	0.2
Product N, ppm	1000	800	1000
Product Aromatics, UV wt	11.0	10.6	11.0
Expected FCC Conversion Improvement	Base	- + 1.0	Equal to base

Assumes equal cycle life

With the advent of Ultra-Low Sulphur Diesel (ULSD), the FCC Pretreat unit has become an even more critical asset for many refiners. By applying CENTINEL GOLD DN-3310 in the FCC Pretreat unit, refiners can significantly reduce the LCO's nitrogen content, and address the challenge of desulphurising this very difficult stream to 15ppm sulphur (Figure 3). This can mean less capital investment to meet ULSD demand, or it can be the difference between producing diesel product and cutter stock.

Figure 3

Reduced LCO Nitrogen Content with CENTINEL GOLD

	Previous CENTINEL Technology	DN-3310 CENTINEL GOLD
FCC Pretreat Feed Properties		
% CGO	30	30
Feed S, wt%	2.5	2.5
Feed N, ppm	2000	2000
Feed Aromatics, UV wt%	16.0	16.0
Products S, wt%	0.2	0.18
Product N, ppm	1000	800
Product Aromatics, UV wt	11.0	10.6
LCO Nitrogen Content, ppm	600	500

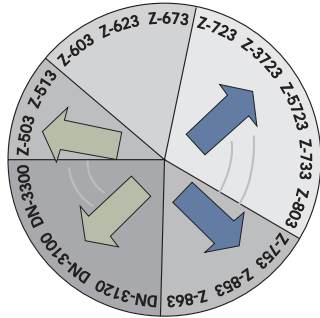
Assumes equal cycle life

For more information on CENTINEL GOLD DN-3310 or other Criterion products, please contact your Criterion Catalysts and Technology representative.



Criterion / Zeolyst Hydrocracking Catalysts And Technical Services

Dial-In the Catalyst for Your Needs

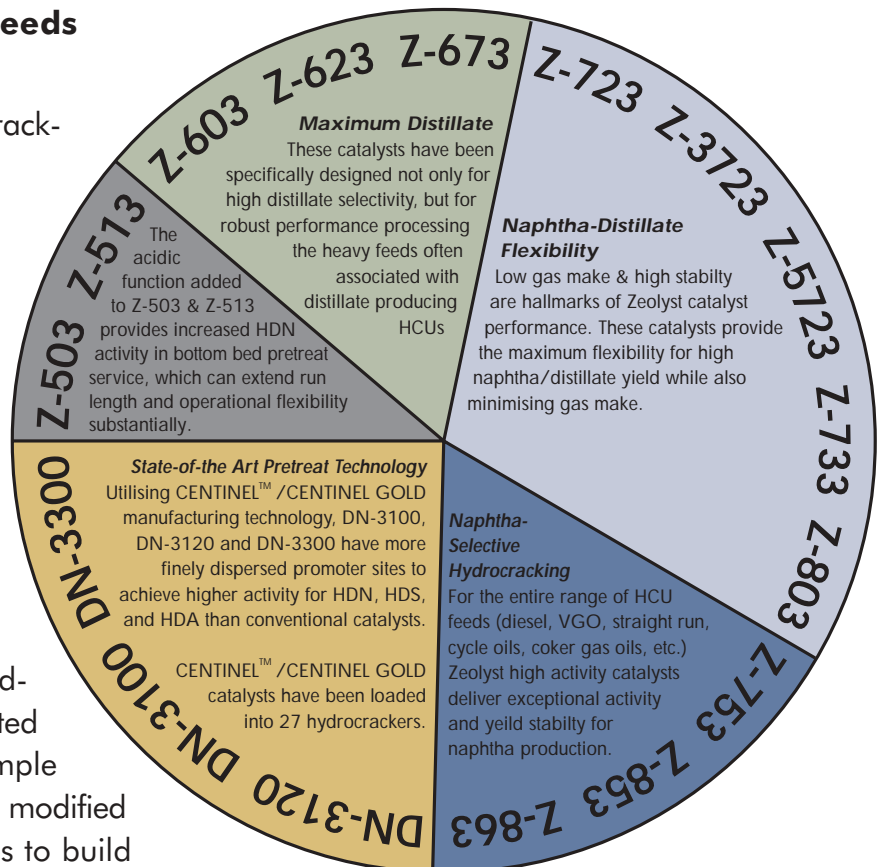


on the strengths of the previous loading. In the first cycle of operation, a stacked loading of Z-763 over Z-753 was used. Z-763 provided greater activity and tolerance in higher nitrogen slip environments while the Z-753 provided high naphtha yield and excellent naphtha quality. While this package exceeded previous cycle performance,

Customised Hydrocracker Loadings In Response to Customer Needs

Criterion and Zeolyst have one of the widest portfolios of hydrocracking catalysts in the industry. We take the time to get a complete understanding of the needs of each customer, and then design a customised catalyst loading to achieve the customer's goals. This customised loading can utilise stacked beds of catalysts as well as individual, customised catalyst formulations.

Our ability to prepare a catalyst loading plan specific to the individual customer needs is best illustrated by the following commercial example in which the catalyst package was modified for each of three operating cycles to build





we asked what further improvements would be profitable for the customer. The answer: higher naphtha selectivity. Z-723, a medium activity, naphtha-/distillate-selective catalyst was loaded for the next cycle to provide higher liquid yield. Its reduced activity was offset by loading our highest activity catalyst, Z-863, in the top bed with Z-763 loaded in between for activity grading. This loading increased naphtha yield by 10 vol% absolute while also increasing catalyst stability for an increase in cycle length of almost 200 days. For the third cycle, further increased profitability was driven by decreased hydrogen consumption. Therefore, we customised the formulation of Z-723 to reduce the hydrogen uptake while maintaining its high selectivity and stability.

On the pretreat side, this customer required high severity hydrotreating while also being heavily constrained by heat balance. Using our package of varying activity pretreat and bottom bed acidic catalysts, we designed pretreat catalyst loadings which provided the required activity and matched cracking catalyst cycle lengths, thereby utilising catalyst value to its fullest.

This customer example demonstrates how we provide unique and individualized catalyst solutions based on the specific needs and situations of our customers. Please contact us so that we can work with you to develop the right solution to fit your needs.



Criterion Catalysts For Hydroprocessing of Lubricating Oils and Waxes

Process Descriptions

Criterion has a long history of providing catalysts to lube refiners. Prior to the formation of Criterion, the Royal Dutch/Shell Group developed numerous catalysts effective in lubricating oil production. The best known of these, 424 and 454, remain in service after many years of successful use. Criterion 424 has been very effective for hydrofinishing and for pretreatment of lube distillates. Criterion 454 has been used successfully for over 20 years in lube hydrocracking units around the world.

Hydrofinishing

This application includes both the finishing of oils previously refined by solvent extraction or hydrocracking and the hydrotreatment of straight-run lube distillates into finished lube products. These lube products include both naphthenic and paraffinic oils. While severity can vary widely in pressure, space velocity and temperature, lower temperatures are preferred to minimize viscosity loss and minimize product PNA content. The main objectives are color improvement as well as the saturation of aromatics and olefins and the removal of sulphur, nitrogen and oxygen. Criterion has historically supplied numerous catalysts for this application, such as HDS-3, HDS-9, HDN-60 and 411. Criterion's highly successful 424 and DN-190

have seen extremely wide usage in lube and wax processing. Criterion now offers CENTINEL products, including DN-3100 and DN-3110, in addition to DN-200, a very successful and versatile catalyst that has seen extremely widespread use in FCC feed pretreatment.

Pretreating

The same catalysts used for hydrofinishing are also very effective for pretreating lube oil fractions prior to further processing. Such pretreating prepares the oil for processing over catalysts sensitive to sulphur and nitrogen, most typically for the production of FDA quality oils and waxes as well as for pour point reduction.

VI Improvement by Hydrocracking

This process, first commercialised in 1970, can produce Group II and III lube oils. In this process, a low to moderate conversion hydrocracking step replaces solvent extraction for increasing VI and removing undesirable components. This process can economically produce lube oils from a wider variety of crude oils and at higher yields than is possible with solvent extraction. In addition, such a hydrocracker can also economically complement an existing solvent extraction unit. Criterion continues to install its long proven 454 for use in these lube hydro-



crackers. In addition, Criterion has very successfully introduced new catalysts delivering improved performance for lube hydrocracking without the need for fluorine promotion. These new catalysts are very successful operating in four dedicated lube hydrocrackers. Shell Global Solutions offers this technology for license.

Food Grade Oil and Wax Production

Food grade oils, originally produced by acid treating, are now most commonly produced by high severity hydrogenation. Criterion's catalyst offerings for this process include both high activity hydrotreating catalysts for the initial processing of the feedstocks for these products (see pretreating catalysts, above), and extremely high activity finishing catalysts capable of surpassing demanding FDA specifications. High activity finishing catalysts include both Criterion noble metal catalysts and KataLeuna nickel catalysts. The noble metal catalysts offer very stable operation with resistance to poisoning by sulphur and nitrogen. Nickel catalysts offer excellent performance in units with very low sulphur content feedstocks. Criterion's catalysts have enabled white oil refiners to increase throughput, improve product quality, and significantly extend cycle lengths. Lyondell Licensing offers their Duotreat Process for the production of these oils.

Catalytic Dewaxing and Wax Isomerization

Criterion supplies the catalysts used by Shell Global Solutions International in the technology areas of catalytic dewaxing and of isomerization/conversion to produce lubricants of exceptional quality.

Lube Oil and Wax Refining Technologies

In addition to offering catalysts and catalyst related technical services to the refining industry, Criterion cooperates with Shell Global Solutions to offer refiners the latest in process technology. Shell Global Solutions not only offers refining process technology licenses, but also customised engineering technical services that can support all aspects of a refiner's operations. Shell Global Solutions is a leader in lubricating oil and wax production and in refining technology, with technology offerings including hydrocracking, wax isomerization and conversion, hybrid technology for debottlenecking lubricating oil production facilities, and hydrofinishing. Criterion also maintains an alliance with Lyondell Licensing, providing catalysts for Lyondell's Duotreat technology for the production of FDA oils and waxes. Lyondell is a technology provider with a long history in both lube hydroprocessing operations and licensing. Criterion personnel can discuss your refining needs with you, enlisting the aid of these technology providers as needed to assist you in reaching your refining goals.



Criterion's Syn Technologies for Clean Fuels Production



Technology for Diesel Production.... Today and Ready for Tomorrow

Criterion and its team members have a wealth of experience in the distillate market segment including millions of pounds of products currently in ultra low sulphur diesel service as well as more than 13 years and more than 1.2 million barrels per day of processing capacity using Syn Technology which is licensed to third parties by Criterion's marketing alliance team member, ABB Lummus Global Inc. Syn Technology units have been producing ultra low sulphur diesel product since the first unit started up in 1991 on feeds ranging from straight run distillates to heavily cracked blends consisting of up to 80% Light Cycle Oil and Coker Gasoil. A key feature of the various Syn processes is that they all operate under moderate pressures thus maximizing distillate yield and cost effectiveness.

Future

We all know that the one certain constant is change. Syn Technologies provide "no regrets" solutions that consider possible future specifications and process unit utilisation in order to avoid stranded investments. Commercially proven Syn Technologies are well positioned to help refiner's produce future potential diesel specifications such as lower aromatics and higher cetane, should they be legislated.

Commercial Experience

Syn Technology solutions are commercially proven with 17 Syn Units currently in operation and 6 scheduled to startup over the next 2-3 years.

Syn Solutions

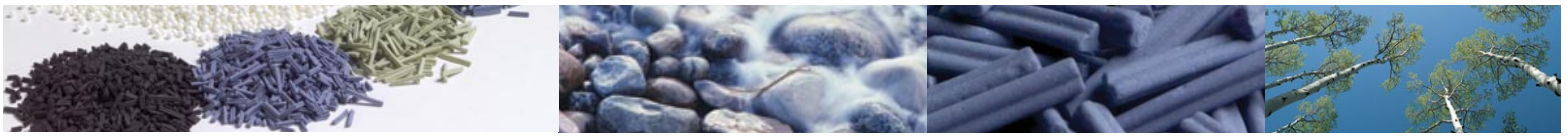
There are four basic types of Syn Technology

- Syn HDS - Ultra Low Sulphur Diesel < 10ppm
- SynShift - Ultra Low Sulphur Diesel < 10ppm
 - Density Reduction for improved blending
 - Cetane Improvement
 - Aromatics Reduction
- SynSat - Ultra Low Sulphur Diesel < 10ppm
 - Low Total Aromatics
- SynFlow - Ultra Low Sulphur Diesel < 10ppm
 - Low Total Aromatics
 - Cloud Point Improvement

Making it all work

The key is the collaborative relationship between refiners and our Syn Technology Project team. There is no substitute for listening to your needs and developing the best distillate clean fuels process plan.





Catalytic Reforming of Naphtha

From CCR catalysts to new fixed bed catalysts, Criterion provides leading-edge high performance reforming catalysts. Criterion's catalysts provide exceptional surface area stability and attrition resistance. With these catalysts, a significant boost in reformat and hydrogen yields is achieved. Providing the refiner with economical solutions through catalysts to improve unit performance is our goal. Through innovative R&D, Criterion has the full range of reforming catalysts to add value for the refiner. Whether the goal is increased throughput, higher octane, or upgrading lower quality feedstocks, we can supply a catalyst to fulfill your needs.

We supply a variety of naphtha reforming catalysts for fixed bed (semi-regen and cyclic) and moving bed units. Criterion began manufacturing reforming catalysts for the extremely demanding cyclic-type reformers in the 1950's. Our unique manufacturing process enables us to make catalysts that have both high start-of-run C5+ yield and the best yield stability in the industry, which means they produce more octane-barrels per cycle than any other catalyst. Despite the long existence of reforming technology, we continue to achieve significant catalyst performance breakthroughs. Recent developments during the past 2 years have demonstrated C5+ yield gains of as much as 2 volume percent compared to our previous generation catalysts. These are our current key products.

PS-40

Our PS-40 reforming catalyst is designed to maximise C5+ yield and enable higher throughputs and/or higher octane production in continuous catalyst regeneration (CCR) reforming units. It incorporates the strengths of Criterion's earlier generation PS-10 and PS-20 catalysts, providing all-around excellent operability and the greatest amount of C5+ product. The alumina support for all these catalysts is designed to resist losses caused by abrasion and crushing, thereby minimising the addition rate for make-up catalyst. The support's design also reduces the rate of surface area decline (better activity maintenance) and improves chloride retention (reduced downstream corrosion and reduced chloride chemical costs). Additionally, improvements incorporated into PS-40's formulation have reduced the degree of paraffin cracking, which results in more hydrogen and C5+ reformat and less coke make. PS-40's capabilities make it particularly well suited for CCR reformers constrained by the quantity of coke that can be burned per hour in the regenerator. Since its introduction in 1998, PS-40 has established itself as the industry benchmark.



PR-11

Maximum yields within fixed bed reforming units are achieved by using a staged, synergistic system of catalysts to promote the desired reactions at the optimum reactor position. PR-11 is designed for the first and second reactors of the unit ("front end") where naphthene dehydrogenation is the desired reaction. This platinum/rhenium catalyst, developed by Criterion for coke stability and sulphur tolerance, also inhibits the undesired hydrogenolysis reaction (breaking of carbon-carbon bonds) that opens the naphthene rings and consumes hydrogen. The benefit to the refiner is a higher overall naphthene ring conversion to the preferred products - aromatics and hydrogen.

PR-9

This platinum/rhenium catalyst is designed for use in fixed bed reforming processes. When a staged catalyst system is utilised, this "back end" catalyst is often used in the third and fourth reactors with PR-11 in the first two reactors. PR-9 has been designed to reduce paraffin cracking, which is most likely to occur in the back end reactors. As a result, it preserves the hydrogen produced in the lead reactors and boosts the C5+ yield.

Important:

All information contained in this document is considered accurate at the time of the testing, based on the equipment, and specific conditions and other limitations during the testing process. It is being furnished upon the express condition that the user will make its own assessment to determine the accuracy and applicability for the user's particular purpose.

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PR-29

Criterion's PR-29 platinum/rhenium catalyst is also a "back end" catalyst used in fixed bed reforming processes. In addition to the reduced paraffin cracking advantage of PR-9, this skewed metal formulation (lower platinum, higher rhenium) promotes less dealkylation of aromatics. This provides the benefit of higher yields of C8+ aromatics and reduces the formation of benzene.

Our catalysts are backed up by extensive technical service including guidance on operating and regenerating catalysts as well as performance monitoring and advice on unit optimisation to increase profit.

As with all our application lines, outstanding catalyst performance is only half of the solution we provide to improve your reforming operations. Careful technical analysis and guidance built on years of experience in many different situations is the other half of the answer we provide to ensure you realise maximum benefits from our state-of-the-art catalysts.



Worldwide Offices:

HOUSTON:

16825 Northchase Dr, Suite 1000
Houston, Texas 77060-6029
Telephone: (281) 874-2600
Facsimile: (281) 874-2641

CANADA:

Suite 810, Centre 104
5241 Calgary Trail Southbound
Edmonton, Alberta T6H 5G8
Canada
Telephone: (1) 780-438-4188
Facsimile: (1) 780-438-3473

UNITED KINGDOM:

1650 Parkway
The Solent Business Park,
Whiteley, Fareham,
Hampshire, PO15 7AH
England
Telephone: (44) 1 489-881881
Facsimile: (44) 1 489-881882

SINGAPORE:

298 Tiong Bahru Road
#07-03 Central Plaza
Singapore 168730
Telephone: (65) 6276-3627
Facsimile: (65) 6276-7455

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