

Leading-Edge Technology Combined with Team Approach Achieves Winning ULSD Solution for Preemraff

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Summary

This paper outlines how teamwork and leading-edge technology were combined to turn a problem into an opportunity. In 2005, Preemraff faced the challenge of achieving 10 ppm ULSD product Sulphur. Working closely with Criterion resulted in them not only meeting this challenge, but also achieving higher throughput and higher profit, with a payback in less than two months.

Preemraff Gothenburg is one of two refineries in the Preemraff group, producing MK-3 Diesel and MK-1 Diesel. MK-3 is a standard EU ULSD Diesel for export and MK-1 is a Swedish Class 1 Environmental Diesel for the Swedish market. This MK-1 Diesel has a total aromatic spec of 5 vol%. To achieve this aromatic spec, the MK-1 Diesel is treated in an ABB Lummus/Shell/Criterion licensed SynSat unit, consisting of an HDS reactor to remove Sulphur and Nitrogen species and a countercurrent HDA reactor to reduce the total aromatic content.

Criterion Catalysts & Technologies and Preem had been working closely together optimising the SynSat unit over the last decade since it had been commissioned, so when changes were required to be made, the good relationship enabled fluid information exchange and strong communication.

The MK-3 (ULSD) product Sulphur spec was to be reduced from 50 ppm to 10 ppm and Preem also had a desire to increase feed severity and MK-1 production to meet an increasing market demand.

Criterion and Shell Global Solutions proposed a solution based on installing the most active Centinel Gold catalyst with a higher aromatic saturation function and new HDS reactor internals to improve reactor volume usage. A single proposal encompassed all the modifications, and concept to implementation was achieved in less than seven months.

Since the revamp, the MK-3 product Sulphur has been reduced to 10 ppm, the feed severity has increased, and the MK-1 production has increased by 20%. In addition, the improved density reduction with Centinel Gold has increased product volume swell. The payback time for the project was less than two months.

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Table of Contents

- 1 Summary
- 2 Preemraff SynSat Unit Operating Modes
- 3 Criterion and Preemraff Relationship
- 3 Operating Strategy Study
- 4 Centinel Gold and HDS Reactor Internals Option
- 6 Objectives Met
- 7 Conclusion and Acknowledgements

Name	Description	Specification
MK-1	Swedish Environmental Class 1 Environmental Diesel	Product Sulphur = 10 ppm Max T95 = 320°C Max Total Aromatics = 5 vol%
MK-3	Standard European ULSD Diesel	Product Sulphur = 50/10 ppm Max Density = 845 kg/m ³ Max T95 = 360°C

Table 1
The specification of both MK-1 and MK-3 Diesel

Preemraff operates a SynSat unit to achieve a low product aromatic spec Diesel, working closely with Criterion Catalysts & Technologies

The SynSat Unit operates in two modes to produce a standard European ULSD (MK-3) and a Swedish low aromatic Diesel (MK-1). The low aromatic Diesel utilises a countercurrent HDA reactor to reduce total aromatics to less than 5 vol%.

Preemraff Gothenburg is one of two refineries in the Preemraff group, both based in Sweden. The Gothenburg Refinery is a 120,000 barrel/day hydroskimming refinery processing a blend of low Sulphur North Sea crudes. The refinery produces two types of Diesel from the single unit as described in Table 1.

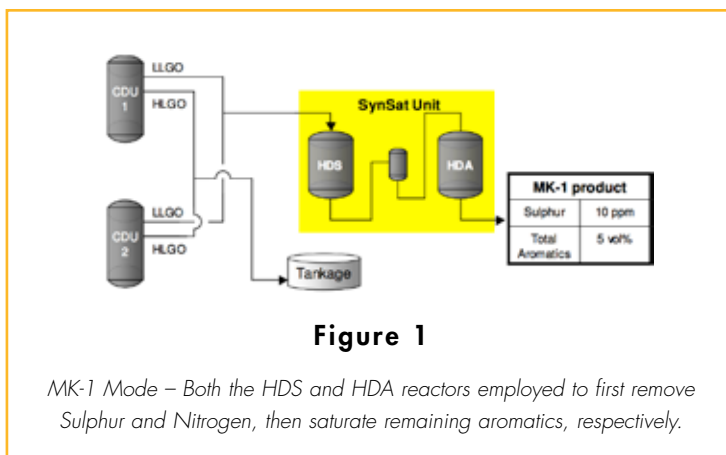
The environmental benefit¹ of MK-1 compared with Standard European ULSD (EN 590) is 10 ppm Sulphur for reduced SO_x emissions, 20% lower particulate emissions, 5% lower NO_x emissions, and it also has improved cold flow properties for the Swedish climate.

All MK-1 is for the Swedish market and all MK-3 is exported. With a growing diesel market in Sweden of 5–8% per year it becomes clear that more MK-1 is required to meet the demands.

Both MK-1 and MK-3 are produced in a SynSat unit. This ABB Lummus / Criterion technology primarily consists of a co-current 60-Bar HDS reactor (containing SC-1, a Ni/Mo HDS catalyst), interstage stripper and countercurrent HDA reactor (containing SC-4 Pt/Pd HDA catalyst). See Figure 1.

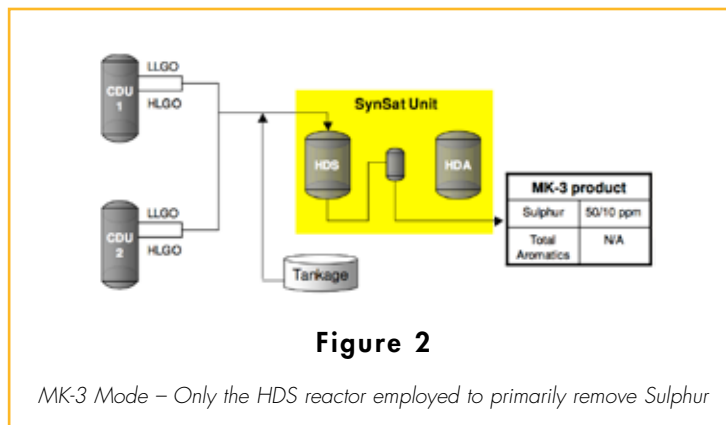
The SynSat unit is operated in two different modes, depending on whether MK-1 or MK-3 is being processed, as follows:

Only the LLGO from both fractionators is processed through the SynSat unit and the HLGO from both fractionators is sent to tankage to be processed during MK-3 mode. The HDS reactor is required to achieve a maximum of 5 ppm Sulphur and 5 ppm Nitrogen to prevent poisoning the Pt/Pd HDA catalyst. However, this is easily achieved due to the lower throughput and lower severity of the feed in HDA mode.



The HDA capability of the HDA reactor limits the unit throughput. To increase throughput and production of MK-1, either a more active HDA catalyst would have to be installed in the HDA reactor, more catalyst would have to be installed, or the ability of the HDS catalyst to saturate aromatics (HDA function) would need to be improved to relieve some of the HDA duty on the HDA reactor.

¹As tested by Preemraff



During MK-3 mode, all LLGO and HLGO from both fractionators was processed through the HDS reactor of the SynSat unit, as well as the HLGO that had built up in tankage during MK-1 mode.

HDS activity in the HDS reactor was primarily what limited the unit in MK-3 mode. To decrease product Sulphur to <10 ppm, increase feed severity (density and T95) and increase throughput, a much more active catalyst, would be required.

Criterion and Preemraff have had an excellent working relationship over the last 10 years. 'Cat-Checksm' performance reports and regular meetings to discuss Customer Value Propositions have enabled continuous optimisation of the SynSat unit.

The SynSat unit was built in 1996 to meet the MK-1 Diesel spec and since then, Preem and Criterion have maintained a close working relationship throughout this 10-year period to ensure the unit has been optimised over this time. This working relationship includes: (1) Regular Cat-Check Reports every few months, (2) Regular Tech Service meetings at the refinery, (3) Value Creation meetings and constant information sharing. These are described in more detail below:

(1) Ca Check Reports – These are monitoring reports, which are produced every few months based on standardised Cat-Check data as supplied by Preem. The entire unit operating data is uploaded to in-house monitoring tools, which allow efficient detailed analysis and swift generation of Cat-Check reports. These reports establish whether or not Preem's SynSat unit goals are being achieved. Customer Value Propositions (CVPs) are then recommended to further improve profitability.

(2) Tech Service meetings are held at Preemraff Gothenburg three times annually to discuss the Cat-Check report, confirm the unit objectives for the future, share information, and discuss ways to further improve the operation of the SynSat unit.

(3) The Criterion dedicated Value Creation Team is in regular discussion through visits and meetings with the Preemraff Group (both Gothenburg and Lysekil Refineries) to try to improve overall refinery margins, through evaluation of the refineries at a higher level than individual units.

The strong links between Preem and Criterion and technical knowledge built up over time were to prove useful when changes were required to be made to the SynSat unit operating strategy.

With reducing ULSD product Sulphur spec and a desire to improve profitability, a future operating strategy study had to be undertaken.

The product Sulphur specification in MK-3 mode was to be reduced from 50 ppm to 10 ppm, and other opportunities were also identified to increase profitability. These included a desire to process a more severe feed and to increase the production of MK-1 to meet the increasing demand.

In summary, Preem had the desire to achieve the following in the short time frame available:

- Reduce MK-3 product Sulphur from 50 ppm to 10 ppm
- Flexibility to treat more severe feedstocks
- Increased throughput in MK-1 mode to produce more Swedish Class 1 Diesel

In the TGU, the tail gas is typically heated in a gasfired reducing gas generator (RGG) burner prior to entering the reactor.

Criterion, with the backing from Shell Global Solutions, worked closely with Preem to evaluate numerous possible solutions to reduce product Sulphur, while increasing feed severity and throughput. Having had the benefit of a very close working relationship over the last decade, trust levels were very high, information sharing was fluid, and communication was excellent. This made it possible to instantly start looking for solutions in the seven-month timeframe available from concept to implementation.

A combination of Centinel Gold catalyst technology and HDS reactor internals replacement were considered the best option to meet Preem's future objectives.

A solution was proposed by making changes to the SynSat unit by installing a more active catalyst and completely overhauling the HDS reactor internals, as well as other hardware changes. The resulting benefit would be not only a more active catalyst, but the ability to load more catalyst into the reactor.

Centinel Gold technology catalyst to increase activity in the first reactor.

The latest Centinel Gold NiMo catalyst was installed in the reactor to increase the RVA (relative volumetric activity) by more than 100%. This HDS activity advantage is equivalent to doubling the volume of the old catalyst. This change alone was enough to decrease the product Sulphur from 50 ppm to 10 ppm, a WABT increase requirement of about 18°C. In addition, the increased aromatic saturation capability of Centinel Gold NiMo catalyst meant that additional HDA was performed in the HDS reactor.

HDS reactor revamp with new internals to increase catalyst volume and improve flow distribution.

The latest innovative Shell Global Solutions internals were installed to increase the effective catalyst volume by 28%. The modifications were as follows, and are depicted in Figure 3 below:

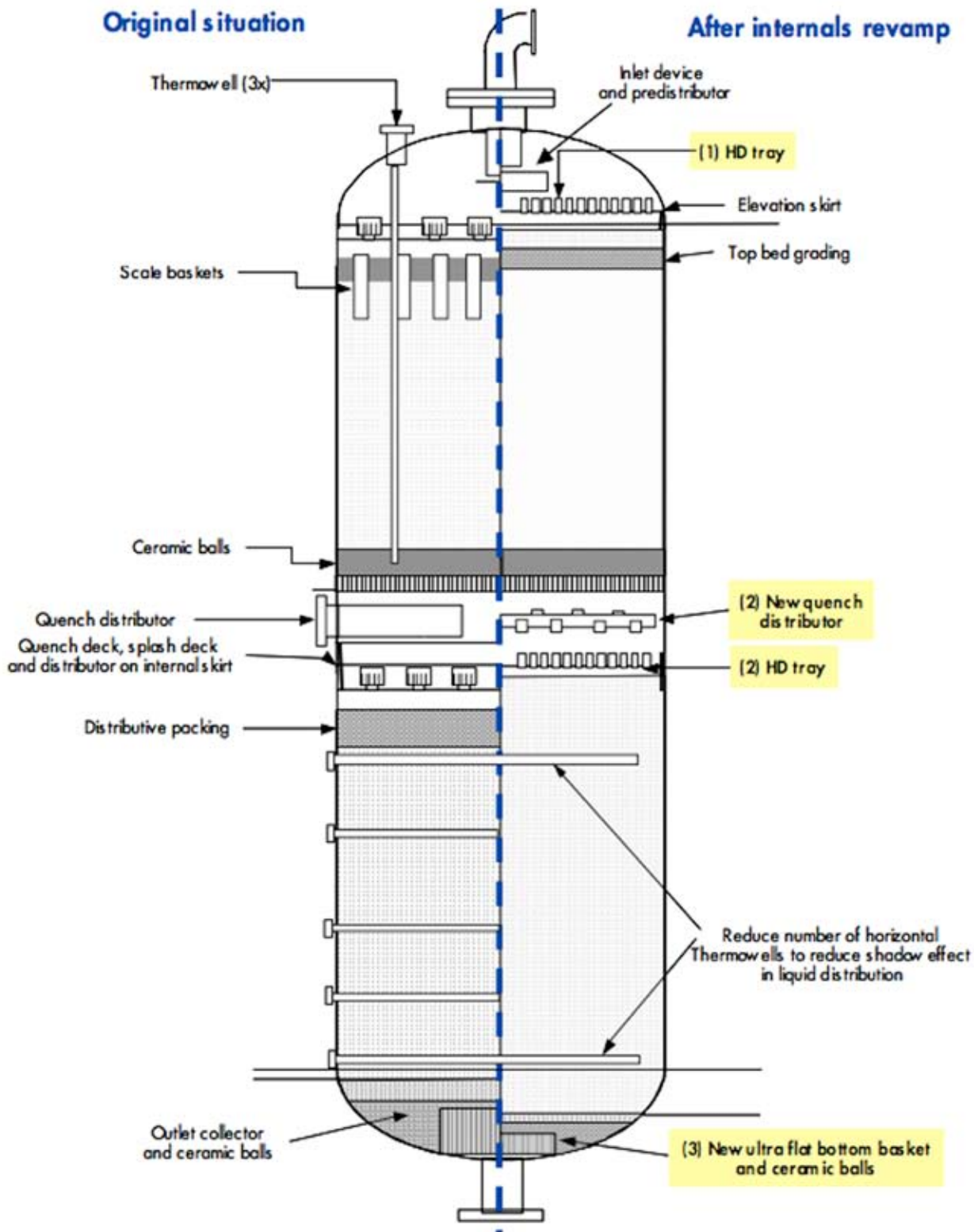
	Old HDS Catalyst	Centinel Gold Catalyst
HDS Relative Volumetric Activity (RVA)	100 (base)	>200
HDA Relative Volumetric Activity (RVA)	100 (base)	128
Product Sulphur (ppm)	50	10
Density Improvement (feed – product, kg/m ³)	Base	Twice Base

Table 2
Comparison of the old HDS catalyst with the new Centinel Gold catalyst

1. Shell Predistributor / HD trays installed in top beds – to improve flow distribution, catalyst utilisation, and enable catalyst to be loaded closer to the trays
2. Shell Simple Quench Box – to improve redistribution into the second bed, improving catalyst utilisation
3. Ultra flat bottom basket – to enable catalyst to be loaded deeper into the reactor

Figure 3

Hardware changes to improve effective catalyst utilisation



	Before revamp	After revamp
(1) MK-3 Product Sulphur (ppm)	50	10
(2) MK-1 Throughput	Base	20% increase
(3) Density Upgrade	Base	100% increase

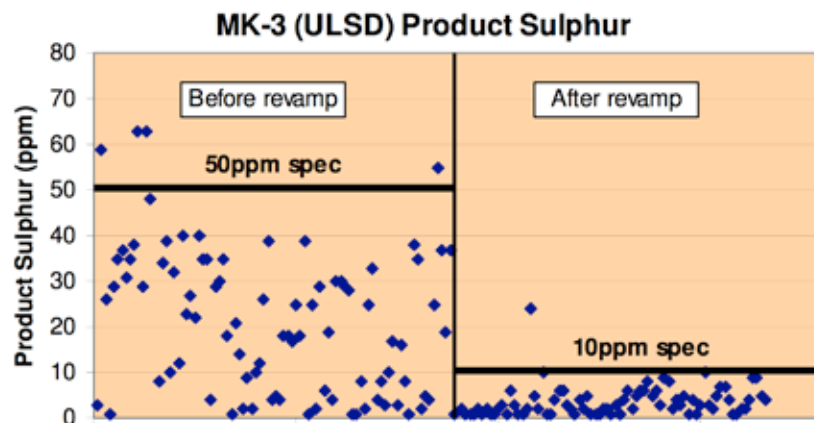
All Preem's objectives were achieved, and in some cases exceeded.

The combination of the high activity of Centinel Gold catalyst and hardware modifications have enabled the following changes to be made to exceed Preem's objectives:

1. MK-3 mode (ULSD) product Sulphur has been reduced from 50 ppm target to 10 ppm target. See Graph 1 below.
2. MK-1 Swedish Class 1 Diesel production has increased 20%, mainly due to hydrogenation of aromatic compounds in the HDS reactor, relieving some of the duty of the HDA reactor (slight reduction in Sulphur and Nitrogen to the HDA reactor also has an impact, due to reduced poisoning, but this is less significant).
3. The product density reduction has increased by 100% in MK-3 (ULSD) mode. See Graph 2 below. This is due to increased PNA saturation with Centinel Gold. This improved density reduction gives Preemraff the benefit of additional product volume swell as well as the flexibility to treat a more severe feed.

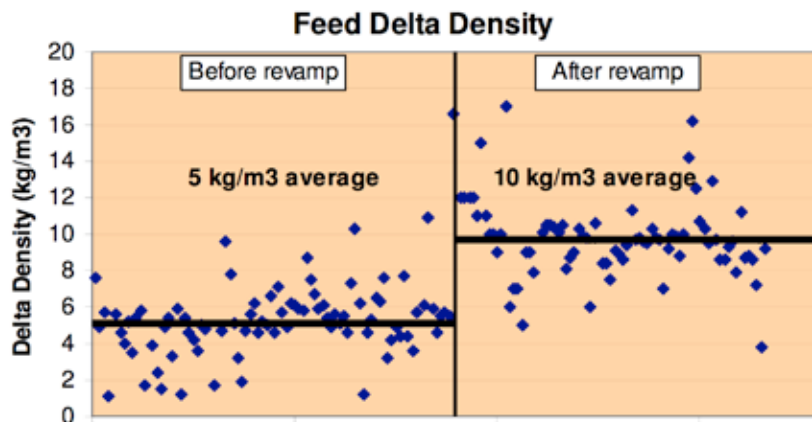
Graph 1

MK-3 mode (ULSD) product Sulphur target has been reduced from 50 ppm to 10 ppm



Graph 2

The product density reduction has increased in MK-3 (ULSD) mode due to increased PNA saturation with Centinel Gold, incurring a product volume swell



Conclusion

Teamwork and leading-edge technology were combined to turn a problem into an opportunity. Working closely with Criterion resulted in Preemraff not only meeting the challenges of tighter product specs, but also achieving higher throughput and higher profit, with a payback in less than two months.

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