Advantages of high-throughput comparative catalyst testing for naphtha reforming changeouts

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Each catalyst changeout gives a key opportunity for a refinery to steer the performance and profitability of a particular unit. Given the substantial costs associated with catalyst procurement (typically in the range of $10-20 million)[1] and the continuously evolving fuel standards, emission policies, and feedstock composition, reliably selecting the optimal catalyst for a refinery unit remains a multifaceted challenge. Over the past decade, Avantium's Refinery Catalyst Testing (RCT) service has supported refineries in derisking the catalyst selection process through efficient and reliable comparative catalyst testing.

In the Netherlands, the expression of 'measuring is knowing' (Dutch: 'meten is weten') is part of the vernacular of companies committed to making data-driven decisions. Within the niche context of refinery catalyst changeouts, using objectively measured data – such as performance, selectivity, and stability – that compares multiple catalyst options (including multiple catalyst vendors and systems per vendor) and employs the refinery's own feed will provide the best insights into which catalyst is most suitable for the next changeout. This article highlights how Avantium's RCT services have recently supported refineries in navigating the multiple catalyst proposals for their continuous catalyst regeneration (CCR) reforming catalyst changeouts.

CHALLENGE: COMMITTING TO A LONG-TERM CATALYST CHOICE

The key objective in the catalytic reforming process is to convert naphtha fractions into high-octane aromatic hydrocarbons as selectively as possible. In addition, the reforming unit is the main hydrogen producer (for use within or outside of the refinery) and provides chemical feedstock for downstream petrochemical processes.

Earlier works have shown that an increase of 0.5 wt% in C_{5+} yields can have an annual gain of $1 million. For hydrogen yields, and in particular for those refineries that are hydrogen constrained, a 10% increase in hydrogen production can lead to an annual value increase of around $10 million.[2] Despite reforming catalyst changeouts being less frequent than those of other units within the refinery, independent catalyst testing is a vital step to ensuring up to a decade of maximum profitability and value from a reforming unit.

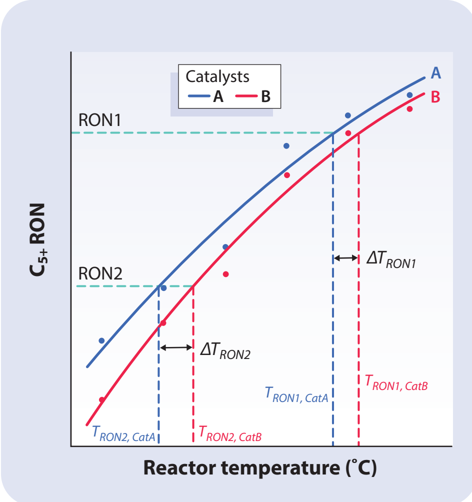

Figure 1 Octane sweep of catalysts A and B (conditions in the range of RON 85-110, temperature 450-520°C, $\Delta T_{RON1} > \Delta T_{RON2}$)

APPROACH: HIGH-THROUGHPUT TESTING WITH AVANTIUM'S REFORMING TESTING SOLUTIONS

Avantium employs a 16-reactor high-throughput catalyst testing setup that is optimised for naphtha reforming catalyst testing. Rather than simply comparing a single catalyst system per vendor, its comparative test designs for both semi-regenerative (SR) and CCR typically include multiple proposed solutions from each catalyst vendor. Each reactor has individual temperature control, along with harmonised feed and pressure controllers, to ensure direct comparisons between catalysts.

Given the varying product yield desires from different refineries, Avantium's systems rapidly measure and monitor C_{5+} yields, aromatic yields, and hydrogen production using online gas chromatography (GC). An automated feedback loop between the GC product analysis and reactor temperature enables operation at a constant Research Octane Number (RON) (iso-RON), with temperature adjusted per reactor (and therefore per catalyst) to maintain the target RON.

For naphtha reforming projects, Avantium's dedicated testing systems are compatible with all naphtha reforming processes, requiring as little as 20 litres of refinery naphtha feed. Its methodology is independently validated by leading global catalyst vendors, including UOP and Axens.

A critical step, particularly for CCR catalyst benchmarking, is an octane sweep in which each catalyst system is exposed to a stepwise temperature increase and RON measurement. This results in a temperature vs RON profile that is vital to ensuring that any iso-RON measurement is initiated at start-of-run (SOR) conditions with minimum catalyst deactivation. Particularly for

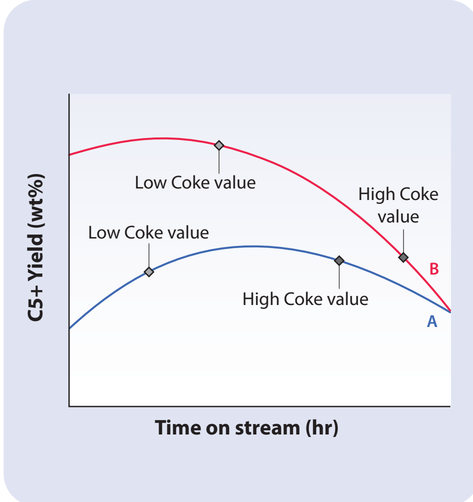

Figure 2 C_{5+} yield vs time on stream for two different catalysts (aromatics and hydrogen yields also measured)

DID YOU KNOW? FOR NAPHTHA REFORMING PROJECTS, AVANTIUM'S DEDICATED TESTING SYSTEMS ARE COMPATIBLE WITH ALL NAPHTHA REFORMING PROCESSES, REQUIRING AS LITTLE AS 20L OF REFINERY NAPHTHA FEED

CCR catalyst comparisons in fixed beds, the rapid catalyst deactivation (alongside the evolving catalyst selectivity at increasing coke content) necessitates an octane sweep prior to any iso-RON study. The importance of performing both tests for CCR catalyst comparison based on a recent project with a European refinery is highlighted below.

CCR CATALYST SELECTION: POWER OF COMBINING OCTANE SWEEP WITH ISO-RON MEASUREMENTS

Figure 1 shows an octane sweep for two CCR reforming catalysts, labelled A (blue) and B (red), within a test programme for a refinery customer. Each curve represents the octane sweep profile for a catalyst, with experimental data points plotted along the fitted trend lines. By running multiple temperature setpoints per reactor, the sweep captures catalyst response to severity changes, offering insights into activity, selectivity, and stability. Two horizontal dashed lines indicate target RON levels (RON1 and RON2). Vertical dashed lines show the corresponding temperatures required for each catalyst to achieve these RON targets. For both RON1 and RON2, Catalyst A required a significantly lower temperature to obtain the target RON vs Catalyst B. Lower required temperatures for a given RON indicate higher catalyst activity, while slope analysis reveals sensitivity to temperature changes and potential selectivity trade-offs.

The octane sweep provides the starting temperature required for the iso-RON tests. To best mimic SOR performance, these tests should achieve the target RON temperature without an induction period. **Figure 2** shows how C_{5+} yield evolves with catalyst time on stream (TOS) for the same two CCR reforming catalysts, as shown in the octane sweep. Both curves exhibit a typical trend: yield increases initially, reaches a maximum, and then declines as TOS progresses due to catalyst deactivation and coke formation. Two coke values (low vs high) are indicated on each curve. From the iso-RON run (**Figure 2**), we observe that despite requiring a higher T at target RON conditions, Catalyst B exhibits both a higher C_5+ yield as well as a slower coke build-up than Catalyst A. However, the C_5+ yield is more sensitive to coke content for Catalyst B than for Catalyst A. The catalyst selectivity evolution at constant RON with increasing TOS and coke content highlights the value of comparing CCR catalysts at the target RON and within tolerable coke limits.

This study highlights the trade-off between initial activity (octane sweep) and long-term stability (time on stream). This combined analysis is critical for CCR catalyst selection, as both SOR performance and coke management over time determine commercial viability.

Avantium provides the following studies for naphtha reforming comparative catalysts:
- **CCR reforming**: Octane sweep + iso-RON with coke impact study.
- **SR reforming**: Octane sweep + iso-RON and accelerated deactivation.

References

1 Tiago Vilela and Nattapong Pongboot, *PTQ Q2 2025*, 51-53.
2 Tiago Vilela, Nicolas Popoff, and Mark Moser, *PTQ Catalysis 2021*, 39-42.

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