Unlocking catalyst performance

William Duke and Austin Schneider, Crystaphase Technologies, Inc., USA, review the use of reticulated ceramics in reactor top bed grading schemes to prevent unplanned unit shutdowns due to excessive pressure drop buildup.

Refiners would not consider using 25 year old catalyst technology in their reactors, yet many are still employing 25 year old conventional reactor top bed grading technology, such as wagon wheels and active rings. Now there is the option of replacing these materials with reticulated ceramics with the benefit of keeping the reactor operationally reliable under increasingly severe conditions and a measurable result of longer unit cycle lengths. However, the true value of reticulated ceramics is their ability to improve operational reliability so the refiners gain more control of their units, meaning less downtime, better scheduling and improved economics.

Crystaphase Technologies Inc. currently provides reticulated ceramics to more than 150 reactors worldwide in the form of CatTrap® technology. These reticulated ceramics are offered in a wide range of pore sizes specifically designed to filter particles in a target size range between 1 - 2000 µm. The key to this filtration capability is the tortuous path created by the internal pore structure that readily captures particulates inside the ceramic. The use of large sized ceramics allows for open channels between the porous disks, so that even after the internal voids of the ceramic are filled with particles, there is no restriction of flow. Consequently, the technology does not contribute to a significant increase in pressure drop, even at end of run.

Refiners today are required to meet a number of objectives, each having a direct and significant impact on the financial performance of the site. Among the highest priority objectives are:

- Minimising health, safety and environmental incidents.
- Producing the highest value product mix.
- Maximising production with the existing equipment.
- Maximising the operational reliability of equipment.

These objectives create many challenges for the refiner as they are interrelated and, in some cases, dynamically opposed. One such challenge stems from the operation of hydroprocessing units that are being pushed beyond their original design. These units are typically processing feedstocks that are different from design, running feed rates considerably higher than design, and operating at a higher severity to meet strict product specifications. If these units are able to achieve the projected cycle length while maintaining these different parameters, the refinery stands to achieve its operational goals.

However, with today's higher product severity, many of these units are not able to meet their projected cycle length, resulting in an unplanned unit shutdown. From lost production to additional unbudgeted maintenance costs, shorter than predicted unit cycle lengths and the resulting unplanned shutdowns are one of the most costly events to occur at a refinery. Lost production due to unscheduled shutdowns or slowdowns of refinery equipment and process units remains an ongoing problem, with average losses in potential capacity of 3 - 7%.

Excessive pressure drop is the most common cause of these unplanned shutdowns. This problem is further compounded by the difficulty in predicting the magnitude and rate of change of pressure drop buildup. Severe cases of pressure drop buildup can cause a unit to undergo an unplanned shutdown in a matter of weeks from the time the problem is identified. Some of the potential causes of excessive pressure drop buildup include:

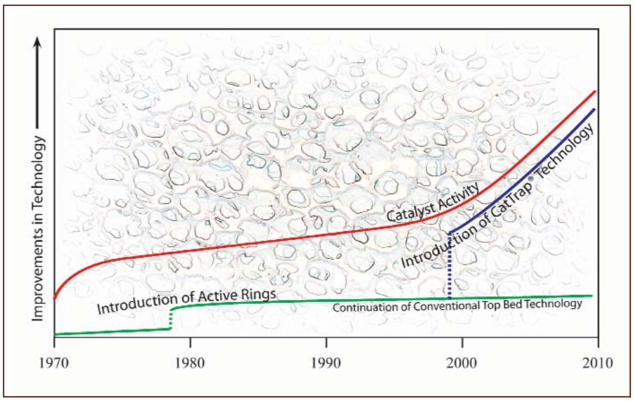


Figure 1. Progression of top bed technology over a 40 year span.

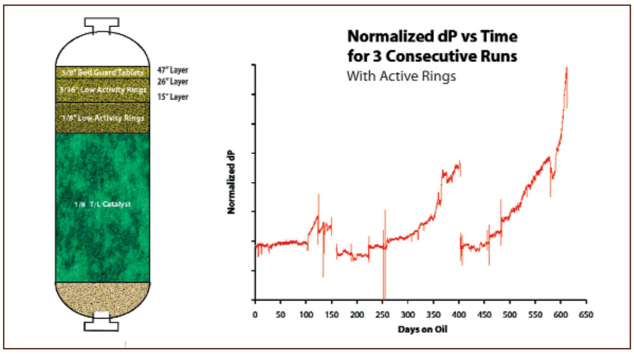


Figure 2. NHT with historical pressure drop problems incorporating large volumes of graded ceramics with undesirable cycle lengths.

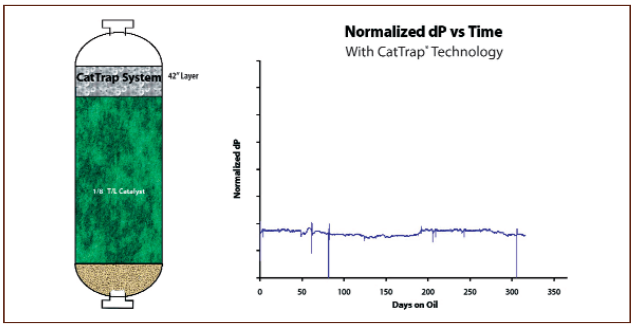


Figure 3. NHT incorporating a relatively small volume of CatTrap® with nearly zero pressure drop increase at more than 300 days.

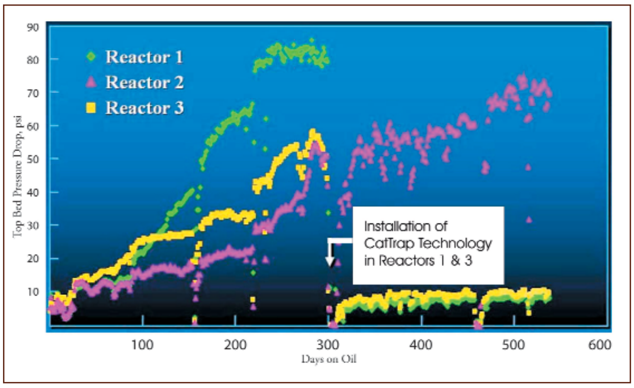


Figure 4. Hydrocracking unit loaded with CatTrap® into two of its three reactors. The two reactors with CatTrap® started up and ran after the skim with little/no pressure drop increase while the third continued to climb.

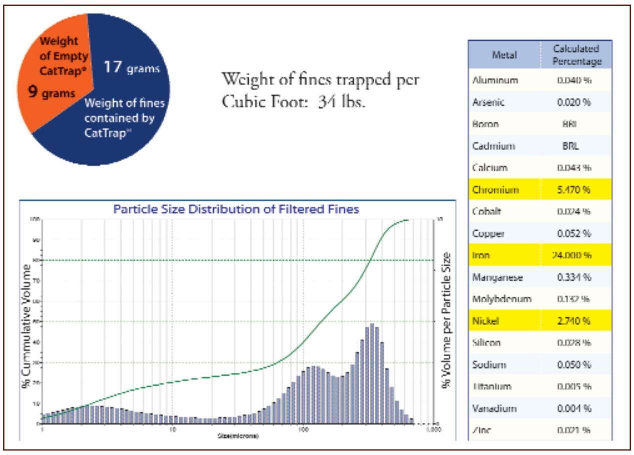


Figure 5. Example of analysis for actual CatTrap® samples removed from a reactor.

- Scale or debris at reactor inlet.
- Coke fines.
- Iron sulfide.
- Coking of feed.
- Distributor tray plugging.
- Failure of reactor internals.

Given the variety of causes of excessive pressure drop and the potential cost, it is critical to ensure the correct source is identified and mitigated.

Lost production is typically the largest cost associated with excessive pressure drop, while in some cases, it is more cost effective to run the unit at reduced feed rates (thus lowering the pressure drop across the reactor) in order to meet the projected cycle length. It is generally more cost effective to shutdown the reactor for corrective maintenance, such as a top bed skim. Regardless of how the situation is handled, excessive pressure drop is costing the refinery millions of dollars in lost production each year.

The extent of the corrective maintenance can vary greatly, but at a minimum, the fouling solids must be removed from the reactor. Many cases involve vacuuming out the top bed catalyst material and replacing it with new material. Overall, the cost of additional maintenance and catalyst are minor when compared with lost production values but can easily be in excess of US$ 250 000 per event.

Typically, when a unit is required to shut down for a catalyst change-out, the refiner's main focus is to minimise downtime as much as possible. Despite the time constraint, more and more refiners are realising the value of going into the reactor to observe the catalyst unloading and to take samples. Standard visual and sample analysis of the reactor material as it is unloaded is critical in determining the proper top bed loading for a particular reactor.

With the introduction of CatTrap® technology, new methods have been developed to interpret unloading observations as well as analyse catalyst samples. A variety of analytical tools such as particle size analysis and scanning electron microscope (SEM) imaging are used to help identify and solve reactor problems, such as excessive pressure drop and maldistribution.

While these tools can help identify the operational root cause of the problem, these problems often cannot be solved without making a large capital investment in additional reactor hardware, such as feed filters and mechanical trays. The opportunity to use CatTrap® technology to establish a more rigorous and effective top bed system provides a cost effective solution to pressure drop and maldistribution. The CatTrap® solution also allows refiners the flexibility of adjusting their top bed load to meet future operational challenges.

While the introduction of graded active rings in the 1980s was an improvement, excessive pressure drop is still a problem in most refineries. Grading active rings by size and activity levels has become a standard practice after 25 years of optimising the use of these materials. They provide a higher void space than catalyst beds for trapping solids in the feed. Unfortunately, there is a limit to the amount of solids that active rings can handle. Many reactors are being exposed to higher levels of solids in the feed than these top bed systems can handle.

While the implementation of feed filters has helped remove a substantial portion of the fouling solids from the feed, a high concentration of smaller sized solids are still passing through these filters and agglomerating in the feed effluent heat exchangers and/or furnace tubes. Immediately downstream of the feed filters, it is not unusual to measure a high concentration of solids that are 1 - 20 μm in size, while measuring fines removed from the top bed of the reactor that are 1 - 1000 μm in size.

CatTrap® technology now plays a pivotal role in accomplishing refining objectives. The demand to improve reactor operational reliability drove the initial development and utilisation of reticulated ceramics.

More than 150 reactors are currently utilising CatTrap® technology to increase unit cycle length and to maximise the amount of catalyst loaded into the unit. It solves both problems of excessive pressure drop and gas/liquid flow maldistribution that are commonly caused by particulates in the feed. The technology has proven its capabilities in a variety of applications:

- Vapour, liquid and mixed phases.
- Hydrotreating.
- Hydrocracking.
- Isomerisation.
- Naphtha reforming.
- Sulfur recovery.

Naphtha hydrotreater

One unit utilising reticulated ceramics is a 30 million bpd naphtha hydrotreater, processing both coker and straight run naphtha. The original reactor load involved a comprehensive 88 in. layer of conventional inert ceramic wagon wheels and active rings graded by size and activity levels. According to the reactor's pressure drop readings, the past three cycle lengths were limited to 150 - 225 days on oil before shutdown due to excessive pressure drop (Figure 2). The top bed load was revised to replace the conventional materials with a 42 in. layer of CatTrap® technology. An additional 46 in. of catalyst was put back into the reactor. The reactor ran 300 days on oil until deactivation of the regenerated catalyst caused the reactor to shut down for catalyst replacement. No pressure drop increase was observed during the entire cycle (Figure 3). Currently, more than 40 naphtha hydrotreating units are utilising CatTrap® technology and experiencing similar results.

Hydrocracker

Another unit utilising reticulated ceramics is a 60 million bpd hydrocraking unit that converts distillate feedstocks into naphtha product. Utilising a layer of conventionally graded materials, the unit ran for 300 days before being shut down for excessive pressure drop. At end of run, the pressure drop across the unit's cycle limiting reactor was approximately 80 psi. This reactor (Reactor 1 in Figure 4) was skimmed and the top bed load was revised to replace the conventional materials with a small layer of CatTrap® technology. The unit ran for approximately one year on oil until catalyst deactivation caused the unit to shut down. During the entire run there was only a marginal increase in pressure drop (< 2 psi).

Flow distribution

Reticulated ceramics are also utilised for improvements in flow distribution, particularly microdistribution. Microdistribution refers to the lateral and volumetric dispersion of the feed through the top bed material after it is distributed by the tray.

Crystaphase Technologies, Inc. conducted cold flow tests in order to determine the liquid dispersion properties of the various top bed materials. These tests were conducted in a 1 ft diameter vessel with material layer depths of 6 and 12 in. Using a single point flow, the liquid disperses as it travels through a layer of test material. The exit flow rate is measured at more than 250 points across the cross section of the vessel.

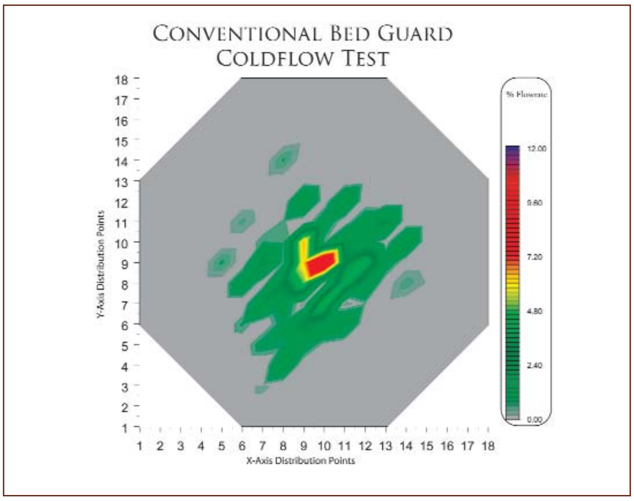


Figure 6. Cold flow test performed on conventional bed guard material. Note the strong flow through the centre, indicating little/no flow distribution.

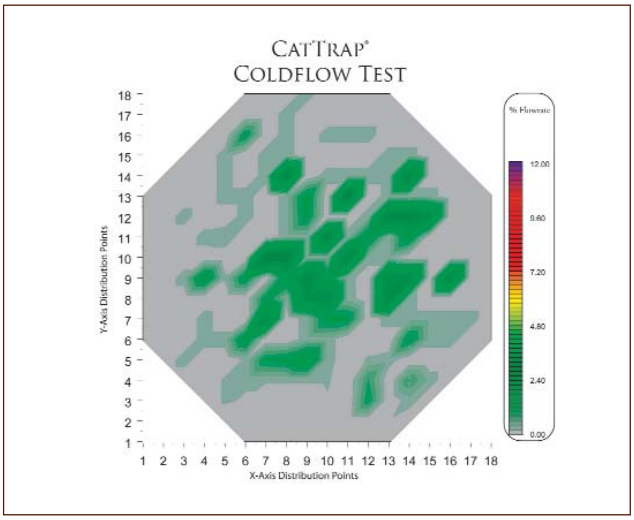


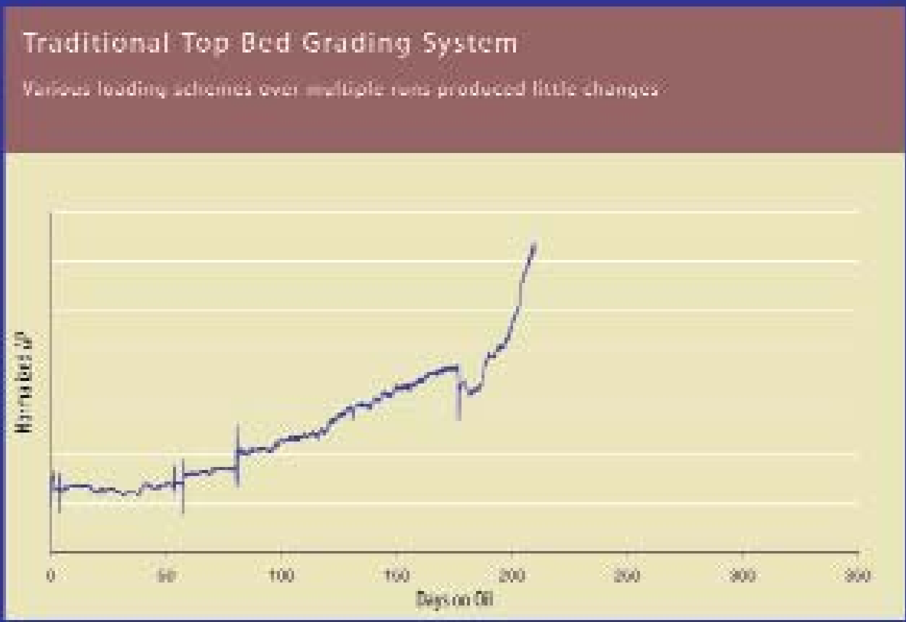
Figure 7. Cold flow test performed on CatTrap® technology. The data indicates a smooth, large lateral dispersion, demonstrating a broad flow distribution.

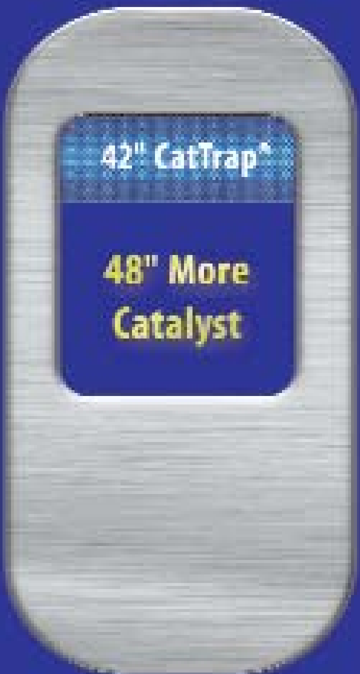
The most common type of top bed material used for flow distribution improvements are bed guard (commonly referred to as wagon wheels, medallions, etc.). The cold flow test data on bed guards (Figure 6) indicates a high level of flow through the centre of the vessel. A noticeable difference is observed in the cold flow results using reticulated ceramics. With CatTrap® technology (Figure 7), the data indicates that the flow is more evenly dispersed across the vessel. Overall these results revealed that reticulated ceramics have a better microdistribution at the top of the reactor than any other top bed material.

Conclusion

By pushing hydroprocessing units beyond their original design, refiners are increasing the profitability of their operation while simultaneously increasing the difficulty of maintaining operational reliability of the unit. Incorporating reticulated ceramics, such as CatTrap® technology, into the reactor load ensures a long and reliable cycle length by minimising pressure drop buildup and improving microdistribution. This in turn is helping refiners realise their goal of operational excellence by minimising lost production and maintenance costs. ■

Increase Your Reactor Cycle Length





CatTrap® Technology utilizes Reticulation Technology™ in a new, proven approach to top bed reactor pressure drop control applicable in both vapor and liquid phase reactors. Successfully proven in over 160 commercial reactor installations since its introduction in 2000, CatTrap® Technology surpasses the inherent limitations of classical top bed systems. By upgrading these classical systems with CatTrap® Technology, the superior filtration performance results in a longer run life for your reactor.

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