CATALYST LOADING: A CRITICAL VARIABLE

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In today's world of ever tougher and more stringent fuel specs, all aspects of the process must be utilised to the fullest extent for the entire operating cycle. 100% catalyst utilisation is critical. There are numerous external and internal factors that significantly affect unit performance. Internal factors that can affect catalyst utilisation are catalyst type and quality, reactor internals efficiency, and catalyst loading and startup. This article will focus on catalyst loading and its effect on overall unit performance.

Catalyst loading is often taken for granted. Too often the importance and value of catalyst loading is not understood by those responsible for the task. The consequences of 'getting it wrong' are also not recognised. More often than not, price is the driving factor when selecting a loading company. There is also a tendency to allow the turnaround budget to set the actual schedule. This is definitely one case where cheapest is not always less costly.

Experience has shown that an improper catalyst load, or a catalyst load that is not optimum, will always have an adverse impact on unit performance. An improper load will prevent the unit from performing to its fullest extent and negate the effects of superior catalyst quality. Product quality, run life, and unit capacity will all be adversely affected. Even if there is no apparent, readily measurable, detrimental effect, a load that is not optimum will result in an under utilised catalyst and failure to meet unit operating objectives, at the very least.

With more and more ULSD units coming online, catalyst utilisation is becoming ever more critical. A small error in loading (such as resulting inconsistent densities) can cause channelling within the catalyst bed, high radials temperature differences, and hot spots. Chevron Lummus Global (CLG) has seen extreme cases where, due to inconsistent densities, a significant portion of the catalyst had apparently never been exposed to hydrocarbons, even after one year of operation. This has been observed and confirmed during the catalyst unloading process. The catalyst was free of carbon and appeared as new. Perhaps most importantly of all, improper catalyst loading can lead to the unit being operated at the edge of safe operation limits, and still being unable to meet operating objectives. Hot spots and thermal excursions for even small unit upsets or feed changes can be a result of improperly loaded catalyst.

Conversely, proper catalyst loading will result in much better use of reactor capacity, longer cycle lengths, lower catalyst attrition, low radial spreads, and the best utilisation of the loaded catalyst.

UNIT DESCRIPTION

The Port Arthur hydrocracker is a CLG design that was commissioned in January 2001. The unit was designed for 35 000 bpsd of a mix of 80% Maya and 20% Arabian light based feeds. Products are heavy naphtha, Kero, diesel, and FCC feed (650 ˚F and unconverted oil). The unit is a two stage recycle configuration. The first stage reactor has seven beds and is one of the largest diameter hydrocracker reactors in the world today. This high severity operation requires full utilisation of the catalyst and reactor hardware to achieve operating objectives and attain maximum profit. The unit is currently in Cycle 3 since original startup in 2001.

PROBLEMS ENCOUNTERED

Shortly after Run 2 startup, high bed outlet radials were observed in the first stage reactor. As the run progressed, it became increasingly difficult to operate. Peak and delta bed temperatures approached the maximum allowable with radial spreads approaching 100 ˚F. Quench moves in certain beds became increasingly unresponsive. Feed rate and severity was limited due to these conditions.

It is significant that despite the poor individual bed distribution, the interbed Nautilus internals were very successful in bringing the bed inlet radials back to within expected design variance. Catalyst retain samples kept from Run 2 loading were carefully examined and no unusual characteristics were observed. All of the catalyst was well within

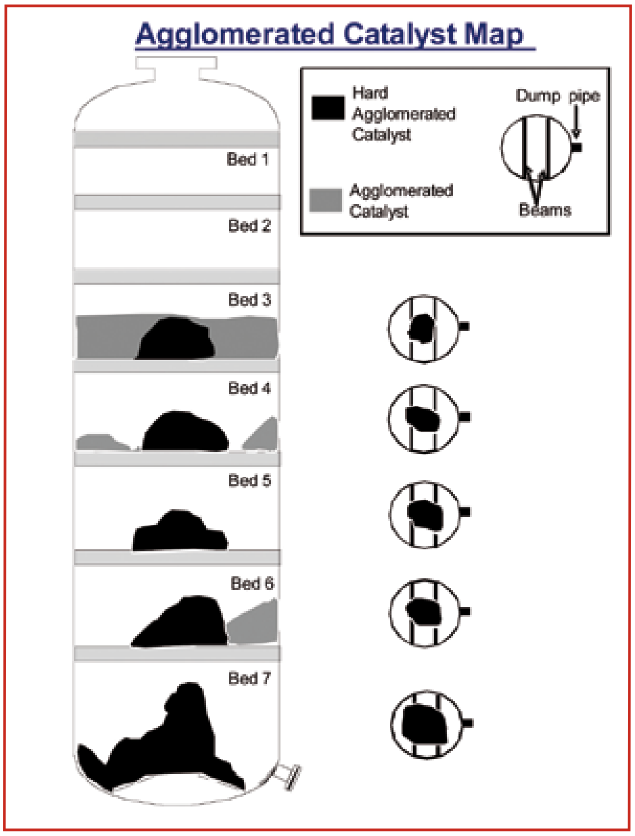

Figure 1. Agglomerated catalyst map.

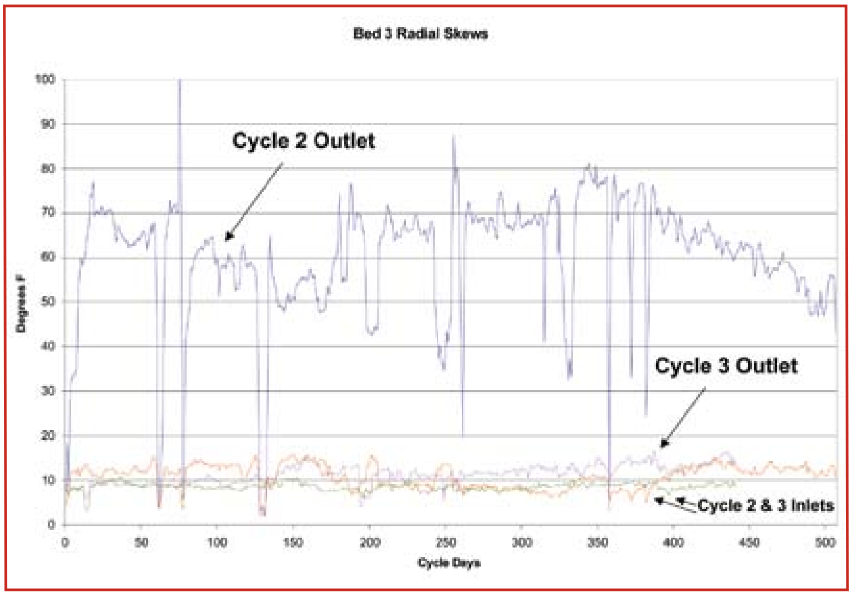

Figure 2. Comparison of Cycles 2 and 3.

Table 1. Operating conditions of the Port Arthur hydrocracker

Operating cycle	Feed rate	Radials	Yields	Peak catalyst temps	Other
Run 2	Limited to 88 - 90% as run progressed. Could not run light feed (LGO, LCGO)	Up to 100 ˚F	Unable to achieve full yield slate due to axial temperature restrictions (100 - 105 ˚F)	825 ˚F+, as had one runaway in Bed 4 (R-1000). Restricted temperatures to 800 - 810 ˚F max.	Reactor unresponsive to quench moves in Bed 2 - 4
Run 3	Able to achieve 100%+	<10 ˚F	Normal yields achievable	812 ˚F in lower beds depending on feed	Reactor responsive to quench moves

design specifications. The startup procedure for Run 2 was reviewed and found to be as required. Startup data was scrutinised and appeared normal. The causes of the high radial temperature differences and hot spots could not immediately be identified.

Preventing a recurrence

The longstanding and very close working relationship between CLG and Valero (formerly Premcor) facilitated and simplified analysis and diagnosis of the operation. As a result, it was agreed to reload the reactors with fresh catalyst to correct the less than satisfactory operation. To prevent the problem from being repeated, and to help understand what went wrong in Run 2, Valero Port Arthur refinery contracted CLG's technical service group to manage the catalyst replacement for Run 3. CLG's responsibilities were to determine the cause of the problems in Run 2, prevent a recurrence, and ensure an optimum catalyst load for Run 3. CLG was also responsible for nominating a catalyst dense loading company that had the experience and dense loading capabilities to ensure an optimum catalyst load. CLG chose VAC-TECH (now known as HPA (S) Pte Ltd) as the loading contractor. CLG and HPA have been working closely together for several years to further develop and perfect the dense loading technology that was used in this catalyst load. A local general catalyst loading company familiar to Port Arthur Refinery was used as support for HPA. CLG representatives were onsite providing 24 hour coverage from the time the unit was shut down until restart. An organisation chart for the reactor turnaround was developed showing areas of responsibility. Names and 24 hour contact information were included.

CLG kept detailed records in the form of video, digital photos, and written documentation throughout the reactor turnaround. The catalyst unloading contractors were required to keep very detailed records of the condition of the reactors throughout the entire unloading process to determine the exact cause of the apparent channelling and maldistribution witnessed during Run 2. Diagrams were made at the end of each shift by the unloading contractors in conjunction with CLG personnel. After careful examination of these records it was determined that the primary cause of the problems in Run 2 was inconsistent loaded densities throughout most of the reactor; predominantly in Beds 3 and 4, where the highest radials were observed during Run 2. This was concluded based on inconsistent catalyst conditions observed while unloading. These inconsistent densities were attributed to improper dense loading, as illustrated in Figure 1.

To prevent a recurrence of Run 2 problems, strict criteria were set for the cleaning, inspection and reload of the reactors. Detailed checklists were developed specific to each bed of both reactors. After unloading was complete, the reactors were cleaned as is standard procedure. After cleaning, the reactors were inspected thoroughly by CLG and Valero personnel. Video and photographic records were made of the reactors. Once all parties accepted that the reactors were clean, mechanical inspections were performed. Some repairs were made to the screens on several beds and at the catalyst support cone at the bottom of the reactor. Packing was installed where needed. Again, detailed checklists were followed and completed during the mechanical inspections. Once all necessary repairs were complete, the reactors were readied for catalyst loading.

Catalyst loading

As with the cleaning and inspections, detailed loading checklists and loading diagrams were developed and discussed with all parties involved in the loading procedure. Manpower for the loading activity was discussed and agreed upon. Catalyst was spotted onsite. The supersacks were marked with fluorescent paint to identify the catalyst type and sack count. Plans for the frequency of density checks were made and agreed upon. Contingency plans were made in the case of abnormal situations. Catalyst retain samples were taken. The catalyst was field tested to verify previously targeted loading densities. HPA used a laser level for accurate markings on the reactor walls for expected levels of support media and catalyst. The bed thermocouples were mapped out with positions/heights recorded. The Hydropac dense loading machine was selected for use based on its unique design, which provides an even distribution of catalyst to the cross-sectional area of the bed. Due to the machine's design (it sits below the distributor tray) the beds could be dense loaded to their maximum potential. Utilising state of the art hardware and expertise, CLG was able to avoid the shadow effect (that can occur at reactor obstructions such as internal dumps pipes), which can lead to maldistribution and channelling. Catalyst loading proceeded smoothly and was completed on schedule even during some periods of light rain.

Unit restart

Startup procedures were reviewed and modified to help ensure proper catalyst wetting and sulfiding. Detailed records of all aspects of the startup were kept for review and troubleshooting in the event of unexpected occurrences. The startup proceeded smoothly and the unit was brought online without incident. Unit data at startup showed significant improvement in reactor performance. Catalyst bed thermocouples showed even distribution throughout the beds with no signs of channelling, as illustrated in Figure 2, which compares the two cycles.

Conclusion

At the time of writing the unit has been online for 18 months. It is performing very well and target operating conditions are being consistently met. Valero is now able to operate the unit at or above design conditions and well within safe operating limits, as illustrated in Table 1.

Although CLG had overall responsibility for the reactor turnaround, it was the true team effort with Valero, CLG and the catalyst loading companies that ensured success. Planning, communication and coordination were key success factors.