

Filtration of Hydrotreater Feed Streams for Catalyst Process Protection

Introduction

Hydrotreating, catalytic hydro-desulfurization, is a refinery process that effectively reduces impurities such as sulfur in petroleum fractions that are obtained from the distillation of crude oil. The process also improves gas oil quality by reducing nitrogen, oxygen, metals and waxes, providing important protection for the catalysts in reformers, cat crackers, and hydrocrackers. To prevent fouling of expensive hydrotreater catalysts, filtration of the petroleum fractions, to reduce solid and semi-solid contaminants, is essential. The benefits of efficient gas oil filtration include:

- Reduction of catalyst bed fouling,
- Avoiding gas oil flow rate reduction caused by increasing catalyst bed differential pressure
- Extended catalyst service life, and
- Reduced heat exchanger fouling

Refiners can achieve efficient hydrotreater performance, increase production, and realize significant maintenance cost savings by using efficient filtration systems. This Customer Application Brief (CAB) provides filtration recommendations that, when implemented, will achieve optimal hydrotreater performance.

The Process

In the hydrotreating process, the gas oil inlet stream, typically naphtha, kerosene, diesel or other gas oil from the crude oil distillation column, is mixed with hydrogen gas, heated, and fed to the fixed bed catalyst hydrotreater or reactor (Figure 1). The reduction of sulfur is primarily a function of pressure, temperature, catalyst activity, hydrogen purity, and the hydrogen/gas oil ratio. The high temperature and pressure reaction generates hydrogen sulfide from sulfur compounds in the gas oil feed and ammonia if nitrogen compounds are in the feedstock. The hydrogen sulfide and ammonia gases are removed in a distillation column (fractionator) following the high/low pressure separator after the hydrotreater reactor.

The Problem

Fluid and gas streams entering the hydrotreater, typically gas oil coming from the crude distillation column and hydrogen gas, contain solid and semi-solid contaminants originating in upstream units, tankage, and piping. These contaminants, if allowed to enter the hydrotreating system, will detrimentally impact the productivity and operating efficiencies of the refinery. Typically the upper layers of the catalyst bed are graded in particle size and will tolerate a small amount of fouling (see Figure 2). As the fouling progresses however, differential pressure across the reactor will increase. Contaminants entering the hydrotreater will foul the hydrotreater catalyst bed resulting in:

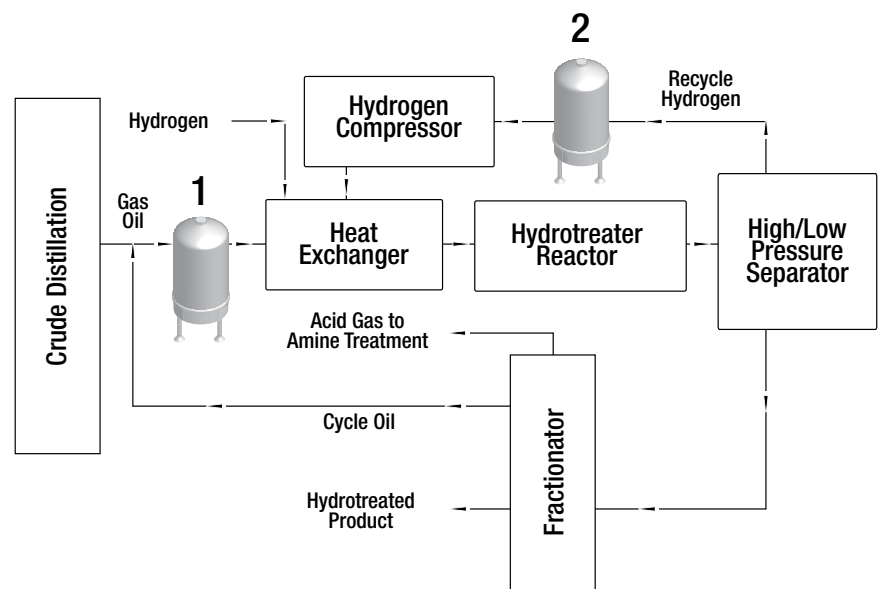


Figure 1. - Generic Hydrotreater Process

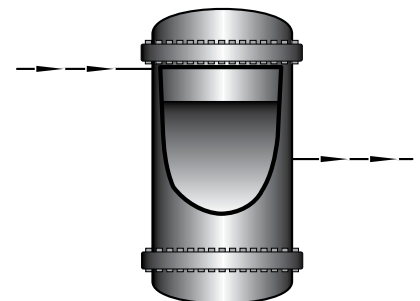


Figure 2. - Catalyst Bed Fouling

- Catalyst fouling and an increase in differential pressure across the reactor. The higher differential pressure will lead to a reduction in recycle hydrogen compressor performance subsequently leading to a reduction in recycle hydrogen rate causing the refiner to reduce gas oil throughput in order to maintain the proper hydrogen to gas oil ratio. This reduction in gas oil through-put is a direct loss of revenue and is the single most important factor for refiners in hydrotreating.
- Catalyst fouling will eventually cause catalyst deactivation (coking). Low H₂:gas oil ratios usually require that refiners raise temperatures in the reactor to compensate. If the temperature is elevated long enough, deactivation occurs. Eventually the increased difficulty of making on spec product and the increased deactivation from coking will result in taking an unplanned shutdown to replace fouled and deactivated catalyst.



Reactor catalyst fouling and deactivation may force an unplanned shutdown of the reactor to permit reduction, or “skimming” of the prematurely fouled section and catalyst replacement. Although many hydrotreating catalysts have an expected life of three years, it is not uncommon for refiners to take two unplanned shutdowns of approximately 10 days each within this time frame, resulting in tremendous loss of revenue! As catalysts become more sophisticated and expensive, it becomes even more critical to protect hydrotreater catalyst beds so they can remain in service as long as possible without the need to replace fouled catalyst.

- For example, the value of catalyst in a 40,000 barrel per day hydrotreater reactor is approximately \$300,000. Typically 20% of a fouled catalyst bed would be skimmed resulting in catalyst replacement costs of \$60,000.
- 10 days of downtime and lost production would be required. That is 400,000 barrels of product lost. If valued at \$20/barrel, this is an \$8 million loss, not including 10 days of labor and maintenance costs.

Additionally, contaminants in hydrotreater feed streams can cause problems for heat exchangers and hydrogen compressors that lead to costly repairs or downtime.

- Particles in hydrotreater feed streams can cause fouling of heat exchangers that heat gas oil fractions to the required reaction temperatures. Solid and semi-solid contaminants build-up on heat exchanger tubes leading to maintenance downtime for heat exchanger repair or replacement.
- Contaminants present in the hydrogen gas can cause excessive hydrogen compressor wear resulting in high maintenance and downtime costs.

The Solution

3M Purification absolute-rated Betapure™ BK series depth filter cartridges are very effective at protecting refinery hydrotreating processes. The combination of high efficiency and rigid media construction ensures effective particle reduction and high dirt holding capacity without the danger of particle unloading during operation. 50-70 micron absolute rated Betapure BK series filters are recommended for protection of heat exchangers and hydrotreater reactors (see Figure 1). A high temperature cartridge is available for applications operating between 250 - 300°F.

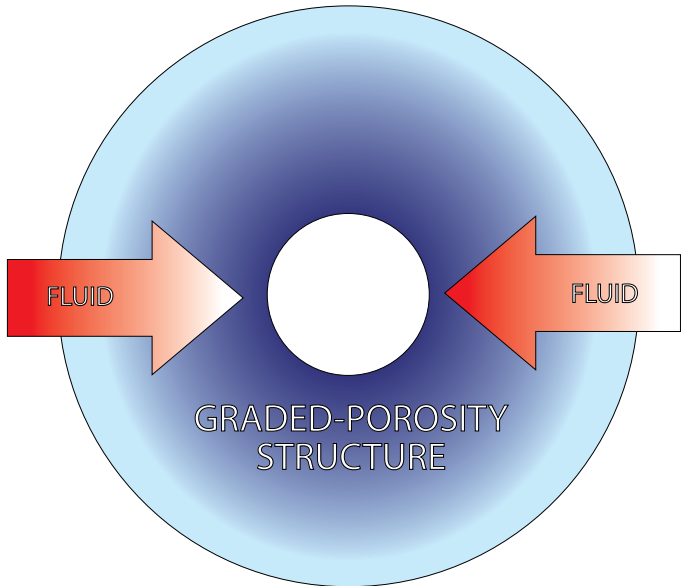


Figure 3. - Graded Pore Structure

Betapure PK series filter cartridges are recommended to protect the recycle hydrogen compressor. Both Betapure BK series and Betapure PK series filter cartridges are manufactured using a process that achieves a true graded pore structure with a clean and smooth inside diameter eliminating the need for a center core. Figure 3 illustrates that the openings between the fibers become progressively smaller as the fluid flows from the outer surface to the inner core of a graded porosity structure. Each fiber is locked in this arrangement by a thermosetting binder to create a rigid structure. The overall effect is to sort, classify and stop particles by size as they progress

through the cartridge. Larger particles are trapped in the upstream region of the filter and finer particles towards the inner core of the filter. Contaminants at or near the filter's absolute rating are removed in the inner section of the filter cartridge.

Both Betapure™ BK series and Betapure™ PK series cartridges also feature an optimized groove pattern that increases the surface area by over 65% when compared to smooth cylindrical cartridges (Figure 4). The grooved surface prevents premature blinding of the outer surface by large particles and allows full utilization of the depth structure. Maximum surface area with a true graded pore structure means that Betapure BK series and Betapure PK series can provide greater service life of three times or more than competitive filter cartridges of comparable efficiency.

Betapure™ BK & Betapure™ PK Series Features—Advantages

- Absolute rated, minimum Beta 1000, (99.9% reduction efficiency), for consistent particle retention performance throughout the filter's life
- Rigid resin bonded structure, for no by-pass or unloading at high differential pressure
- Grooved surface with true graded porosity structure, for long service life
- 300°F Betapure BK series high temperature option, for broad petroleum fraction compatibility

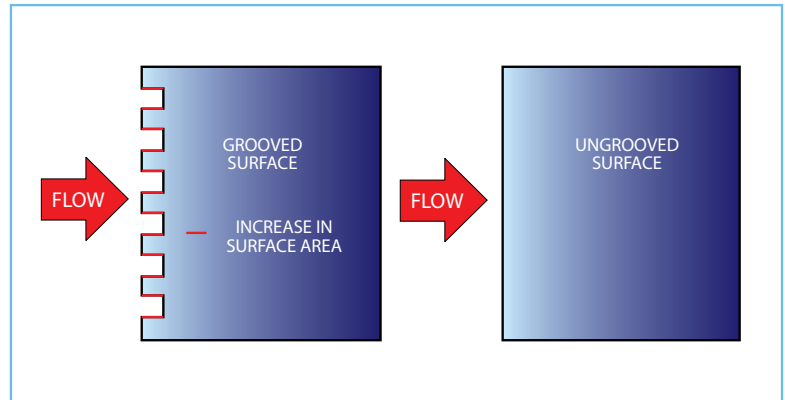


Figure 4. - Grooved Structure

Betapure BK series and Betapure PK series filter cartridges provide the consistently high quality performance required to effectively protect hydrotreater catalyst beds from particle fouling. The result is consistently high gas oil rates, less downtime, lower catalyst replacement costs, and improved heat exchanger protection.

Table 1. - Hydrotreater Filtration Recommendations

Filter Location Fig 1.	Stream Filtered	Recommended 3M Purification Filter (With high temperature option specified)
1	Gas oil feed	50-70 µm absolute Betapure BK series
2	Recycled hydrogen	20-µm absolute Betapure PK series

Absolute-rated, 50 µm 3M Purification Betapure BK series is recommended for optimal refinery hydrotreater catalyst protection. Specific recommendations are shown in Table 1.

Conclusion

Refiners can significantly improve the performance and operation of hydrotreating processes by upgrading existing filtration systems using absolute rated Betapure BK series and Betapure PK series filters. Critical hydrotreating processes are seriously compromised by not filtering the gas oil stream ahead of the hydrotreater reactor.

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