

# Protect desulfurization catalyst with prefiltration systems

Suspended solids in refinery feeds foul critical desulfurization catalysts and heat exchange equipment and rob refiners of potential profits

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Tremendous investments are made on desulfurization systems. Modern refineries will increasingly use fixed-bed catalytic reactors, hydrogen and specialized catalysts to upgrade hydrocarbon fractions and to remove sulfur compounds. The estimated returns for these capital projects hinge on achieving runlengths and equipment availability for the new installations. Thus, efforts to ensure processing availability and equipment uptime are just as critical as installing new processing methodologies.

**'Dirty' feeds.** Catalysts are very vulnerable to the negative effects from fine-sized solids suspended with hydrocarbon feeds. Suspended particles as small as 1 to 5 micron ( $\mu\text{m}$ ) can adversely impact normal process flow, throughputs, reactor conversion efficiency and unit run times. Many sophisticated reactors and their catalysts require protection from fine-sized solids. These micron-sized solids will not pass through depth-type catalyst beds without depositing within the interstices of the catalyst packings. To ensure that desulfurizing catalysts function as designed, particulate filters can easily be installed to protect the reactor—thus enhancing the refiner's yields and lowering total operation costs.

In the presented case history, an Eastern Canada refiner was plagued with processing limitations stemming from a high concentration of fine-sized particle in the feed to a distillate hydrotreating unit. Recognizing that suspended solids were a bottleneck, a prefiltration system was installed to protect the distillate desulfurization reactor. This proactive installation was intended to improve catalyst utilization and runlengths, mitigate poor fluid distribution and/or prevent unscheduled shutdowns due to high pressure drop, reduce the fouling rate of the catalyst, lower fouling on unit heat exchangers and, thereby, improve the profitability of this refinery.

## REACTOR PROTECTION

Fine-sized solids present in hydrocarbon feeds originate from raw crude oils. In addition, these solids are the resultant from corrosion of upstream process equipment. Incompatible feed components can also contribute particles such as complexes or agglomerates that act as large-sized particles. Typically, suspended particles range in size from sub micron to 300  $\mu\text{m}$  with reactor concentrations varying from 0.5 to 500 ppm (wt) or even greater. Fine suspended solid particles are known to negatively impact the performance of fixed-bed hydroprocessing reactors. Concerns on how to protect these fixed beds are elevated when feeds are combined, or originate from large charge drums, where changing liquid levels can result in slugs of fine suspended solids from the bottom of a tank. These solids are fluidized into the reactor feed, and

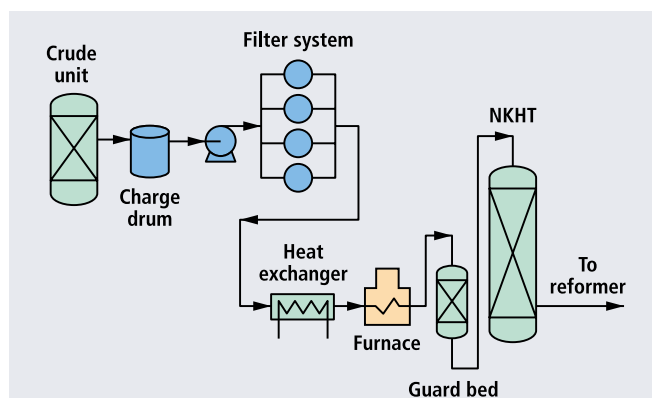


FIG. 1. Typical NKHT process schematic.

thus, cause flow-restricting crusts to form at the interface of larger-sized guard catalysts and reactive desulfurization catalyst layer.

**Refiner's experience.** A Canadian refiner had experienced several naphtha-kerosine hydrotreating (NKHT) reactor campaigns where rapidly increasing differential pressure drop across the guard bed and NKHT bed was common, even at startup. Feed to the NKHT unit is a product from the atmospheric crude distillation unit (CDU). It is pumped directly to a storage tank, from which it is then pumped through a heat-exchanger train, a furnace, guard bed (vessel filled with spent catalyst) and then sent to the NKHT unit. At this facility, NKHT feed flowrate is 33,000 bpd, with a density of 0.77.

A restrictive differential pressure drop of over 80 psid was realized over a two to three week operation. Particulate analysis by the refiner's laboratory confirmed that the feed hydrocarbon contained a high concentration of fine-sized particles that were depositing within the depths of the NKHT catalyst. This action directly contributed to the unit's flow restriction. These trapped particles consisted primarily of FeS, with minor concentrations of FeOS, Cr, Mn and Si. In the most recent case, the feed contamination required replacing the "guard bed" catalyst (Fig. 1) every 18 months and the NKHT unit catalyst every 36 months.

Refinery management had anticipated an uninterrupted unit runlength of 60 months, based on the projected NKHT catalyst activity for distillate feedstocks. The shorter runtime, unscheduled maintenance and loss of production seriously impacted this refinery's profitability.



FIG. 2. Installation of the high-flow filter assembly.

**Early findings.** Following a preliminary investigation and review of the reactor's feed chemistry, the NKHT process engineer contacted filtration experts to obtain a second opinion. To improve operations, the refinery had to determine the source for these suspended solids, quantify damage to the reactor catalyst and consider possible resolutions to the short runtime and high differential pressure trends.

Filtration experts completed a process survey and evaluated the many contributing aspects to the cleanliness of the entire process. After a thorough study, additional fluid samples were collected and analyzed to confirm the results of the refiner's laboratory. Table 1 lists the findings from the fluid samples' analysis and typical particle size distribution of suspended solids found in the NKHT feeds.

Based on these findings listed in Table 1, the project team recommended installing an absolute rated 10-micron filtration system. Such a system would be designed to remove all potentially damaging suspended solid particles, and more specifically, the corrosion products that were suspect to causing the premature rise in ΔP across the entire NKHT circuit. The typical total suspended solids (TSS) ranged from 0.3 to 3.0 ppm (wt) in the sampling.

**Possible resolution.** The engineering staff worked closely with the filtration team throughout the entire project to devise a low-cost, easy-to-install filtering solution. The team elected to use high-flow filter elements, designed for efficient fine particle separation, and high-volume hydrocarbon service (Fig. 2). The high-dirt capacity filter elements are manufactured with a proprietary glass fiber media offering a 10 μm absolute rating, with a Beta value of 5,000. This media offers optimized dirt capacity with significant removal efficiency of particles easily trapped by the NKHT hydrotreating catalyst bed. A sharp removal efficiency "cut-off" allows the filter media to only trap damaging particles, while allowing finer

TABLE 1. Typical particle size distribution (PSD) of suspended solids in the NKHT feeds

Micron size	Percent of population, %
Below 5 micron, μm	71
5-10	18.25
10-15	5.0
15-25	3.75
25-50	1.0
50-100	0.55

\* Particle analysis is by ASTM D 4870-92—Procedure for optical identification of suspended solids.

\*\* The procedure is careful to avoid distortion, or formation of particulate clusters, which are normal in the feed conditions.

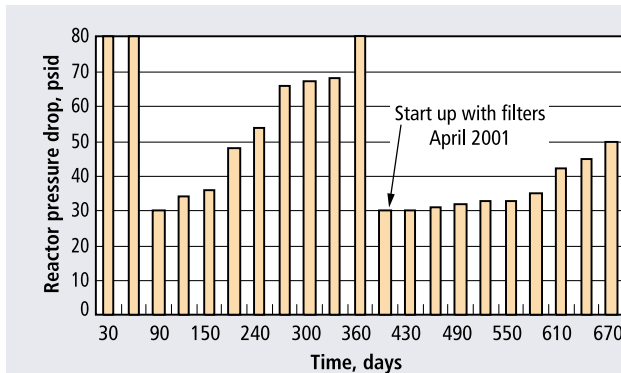


FIG. 3. Pressure drop curve—before and after filter system was installed.

non-damaging particles to pass through. Pore-size selection and consistent particle separation is critical to achieving the desired bed protection with attractive economy of use.

**Refinery's results.** The prefiltration scheme was installed at the refinery in March 2001. The project included two parallel trains of four ASME coded pressure vessels, mounted with the appropriate manifolding, isolation valves, for uninterrupted reactor-bed protection and easy online cartridge changeout. An April 2001 startup progressed without incident while the reactor and guard-bed pressure drop remained constant without the normal immediate pressure drop increase. Initial observations confirmed that the particulates alone were the probable cause for the pressure-drop problems experienced in previous startups.

The source of these particulates is believed to be from feed drums, where fluid volumes vary widely during the planned turnaround. The particulates in normal flow conditions separate in a fine layer within the reactor bed at or near the interface of distribution catalyst and finer-sized catalyst reactive layer. It is hypothesized that the particles, as small as 2 μm, can bridge across a 40-μm flow path through the depth of the catalyst packings. The bridging effect occurs more frequently when these fines have a higher concentration in the feed. When pressure drop builds, a feed shutdown is required to relieve this temporary flow resistance. Under these conditions, the reactor is isolated and allowed to cool. A high-velocity-reverse-flow skimming procedure is applied. Installing the prefiltration system has completely eliminated this routine. The April 2001 startup was the first unit

TABLE 2. Return on investment for prefiltration system

<b>Costs</b>		
Filter system installation		\$90,000
Filter cartridge consumption (5 yrs projected)		\$250,000
Change out labor (5 manhours/changeout every 8 weeks)		\$13,000
<b>Total</b>		<b>\$353,000</b>
<b>Direct benefits to refiner</b>		
Avoid 2 startup shutdowns, cooling and skimming		\$1,800,000
Avoid 1 catalyst changeout (2/3 of \$600,000)		\$400,000
Increase refinery throughput plus 850 bpd over 5 years		\$1,800,000
Reduced heat exchanger maintenance		\$40,000
<b>Total</b>		<b>\$4,040,000</b>
<b>Benefit of filter system</b>	\$4.04 million/60 months	\$67,333/months
<b>Payback period</b>	\$353,000/\$67,333	<b>5.24 months</b>

startup where immediate  $\Delta P$  increase was not experienced (Fig. 3).

A less obvious advantage from the filtering system was that the NKHT preheater heat-exchanger train now operates with no signs of pressure drop increases—a traditional concern for operators. The pressure-drop profiles for the NKHT reactor and exchanger train were obvious bottlenecks for this refinery. Following the improved performance of the NKHT unit, the Canadian refiner was able to raise processing capacity from the CDU—an increase in flow of 700 to 1,000 bpd was realized. This process improvement was an indirect benefit from the filtration system on the NKHT reactor feed.

**Overview.** Refiners will be investing heavily to produce cleaner fuels. Efforts to preserve the integrity of these critical processing systems are as important as the selection of the major licensed methodologies to produce cleaner fuels. This case history demonstrates the added value from prefiltration systems on hydrocarbon feeds.

In this example, the refiner should achieve the five-year runlength for the NKHT hydrotreater reactor catalyst along with other benefits as shown in Table 2. These other benefits are:

- Present reactor startups now avoid costly shutdown and catalyst skimming procedure
- Consistent feed quality to the NKHT reactor improves catalyst performance and unit performance
- Heat exchanger fouling is minimized
- Improved flow through heat exchangers and the NKHT reactor allows for additional crude oil processing at the CDU. **HP**



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