Question 8: With respect to hydrogen purification pressure swing adsorption vessels, what are the best practices regarding inspection? Can their working life be extended beyond design with vessel inspection?

Vern Mallett (UOP)

The intent of a thorough vessel inspection would be to assure that the effects of corrosion, fatigue service, or other operating conditions have not deteriorated the integrity of the vessel. The inspection would determine if the vessel wall thickness has been reduced below the minimum required, or if cracks have developed in any vessel parts. The priority for determining fatigue related cracks would be to inspect the vessel interior, giving special emphasis to the inside weld surfaces. A thorough magnetic particle examination would be highly recommended. We would also suggest checking with local authority, code, or plant requirements about permitting continued use.

UOP recommends that PSA adsorber vessels be periodically inspected to determine if cracking or other potentially harmful defects are present. Typical inspection periods customers have used are in the 2-5 year range. The inspections typically concentrate on the inside weld surfaces, although defects could occur anywhere. Inspection methods that are typically used are magnetic particle inspection (MT), ultrasonics (UT), and less frequently acoustic emissions. A wet magnetic particle examination of all weld internal surfaces is the most thorough method.

Performing external UT while the vessels are online can be considered a good screening method. Ultrasonics will detect imperfections that are within the vessel material and can detect most crack indications on the inside surface. UT requires more operator experience than MT and even an experienced operator might not pick up internal surface cracks which are not very long (less than 1/2") or not very deep (less than 1/16"). If an internal surface indication is detected or suspected with UT the refiner then can consider unloading that particular vessel for an internal exam with MT. Note that if an indication is detected by UT you would not know if it was new or an existing flaw unless a baseline UT exam or “fingerprint” had been performed during fabrication.

Additionally, a thorough inspection should reveal the actual minimum thickness of the vessels as well as any defects which would require repair. Actual thickness measurements might verify that there is more material than the original design. This could be due to various "design factors" that would have been used in the original material order (i.e. extra thickness above our specified minimum, round-offs, tolerances being on the plus side, and corrosion allowance that might be reduced).

This method of extending service life has been effectively used by other UOP Polybed™ PSA System owners and in fact it is not uncommon for PSA adsorber vessels to operate trouble free for 20-30 years. If the life of the PSA adsorbers is extended by the above mentioned, it is then recommended that periodic examinations of the vessel be rigorously continued.

We also share with customers UOP's co-authored ASME paper, "PSA Vessel Technology: An Overview". This provides a good background of PSA, evolution of our fatigue design, in-service inspection techniques, and repair of PSA vessels.

Dan Webb (Western Refining)

We conduct regular external inspections. The feed to the PSA will be free of water and other corrosive elements except for unit upsets. We do internal inspections as mandated by OSHA regulations. We would have to dump the vessel and perform an internal inspection then reload it, and as stated above we would recommend replacing all of the media.

Randy Peterson (STRATCO)

Fouling in the DIB column is almost always caused by salt deposits. These salts are typically sodium sulfate and sodium sulfite but can also contain calcium or magnesium if the effluent treating water is not demineralized. If these water-soluble salts are present in the DIB feed, the water will evaporate once inside the column leaving the solids behind. The salt deposits are typically found on or near the feed tray.

The long-term solution is to make changes to the effluent treating system. The quickest operational change is to increase the water makeup rate to the system to dilute the aqueous salt concentration. Monitor conductivity in the water effluent and maintain a level less than 5000 ?mhos/cm (microSiemens/cm) to minimize salt carryover.

Properly designed and functioning water wash static mixers are very important to wash any salts out of the tower feed. A retrofit of coalescing media should be considered in all effluent treating vessels to minimize carryover of the salt-containing aqueous phase. If the unit does not have a water wash downstream of an alkaline water wash, a water wash coalescer with static mixer should be considered.

Improving the water quality with softer water can also help. However, it is important to note that some refiners have experienced foaming problems in their water washes when using water that is too soft. Mixing a little hard water with the demineralized (soft) water typically solves the problem (40-50 ppm total hardness in the makeup water is a good target).

A quick fix to improve DIB operations while running is to perform an online water wash. Although this carries some risks, several refiners have successfully restored column operations. The typical method is to add water to the column feed. In doing so, the salts fouling the feed tray are made soluble. The salts are then carried away from the feed tray and redeposited on nearby trays as the water evaporates. This is not a permanent solution as the salts typically remain in the column until washed properly off-line. It is best to add the water as close to the tower feed nozzle as possible to avoid stagnant pools of water in the feed line which can lead to corrosion in low points.

Reboiler Fouling

Reboiler fouling is almost always caused by ineffective effluent treating. If the reaction intermediate esters (typically propyl or butyl sulfates) are not decomposed within the treating system, they enter the DIB and travel down the tower. When they reach the hot reboiler, they thermally decompose releasing

SO_2 while the organic component fouls the reboiler tube bundle. An indication that this is happening is low pH and high iron in the DIB overhead accumulator water draw. The evolved SO_2 and water forms corrosive sulfurous acid. A good target pH is 6.5 – 7.5 with less than 10 ppm iron.

To avoid reboiler fouling, an increase in the temperature of the effluent treating water wash temperatures (>120 F) may help break the esters down. Typically, new static mixers, designed specifically for immiscible fluids, are required.

Some refiners report success with online water washing of the reboiler. Either water is directly added to the reboiler hydrocarbon inlet or enough water is added to the feed so that water goes down the column to the reboiler. In many cases, the boiling water breaks up the foulant and sends it downstream. If not severely fouled, the reboiler performance is restored. Care should be taken with the resulting wash water as it will have low pH (1-2) and will contain solids. In severe cases, the tube bundle requires pulling and hydroblasting to mechanically remove the foulant.

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