Question 88: What is your experience with feed-side fouling on combined feed/effluent (CFE) exchangers? What is the foulant? How often do you clean them and what cleaning techniques do you use? On Texas Towers (vertical shell & tube exchangers), how do you extract the bundle from the shell if it gets stuck?

NEWTON (Roddey Engineering Services, Inc. Engineering)
I'm just going to deal with Roddey Engineering's experience. I know some people on the panel have different experiences. But as far as feed effluent exchangers go, and especially Texas Towers, we have seen significant fouling on all that we've dealt with. Pretty much every refinery that has one, they do not clean the tower.
Typically, the foulant is a polymer plus corrosion product (iron sulfide/iron oxide) coming from upstream units and is especially prevalent when you bring in feed from tankage. Along with normally monitoring for fouling factors, we've seen the fouling being exhibited during the regen of semi-regen units, which has been evidenced by long purge times and high SO2 readings coming when you're back purging out of the compressor discharge. So the suggestion I have is: If you have a semi-regen unit, log how long it takes to purge and your SO2 readings and compare those from cycle-to-cycle in case you want to see what kind of fouling may be building up on your feed effluent exchangers.

As far as prevention goes, if you're bringing feed from tankage, it's best to go through the naphtha hydrotreater stripper. This may help remove some junk, plus help remove water. I gave a P&P session on this in 2006 on how to operate naphtha hydrotreater strippers. So if you're interested in that presentation and how it affects reformer feed, you come see me afterwards and give me your card. I'll be glad to email that to you.

As far as cleaning goes, in our experience, most refiners don't clean it. They think it's too much trouble and too much planning to do that, but we recommend cleaning, and at least checking it, often. Our only recommendation for cleaning is taking the crane and the lance or a mole-type device, taking the cover plates off, flushing the exchanger out, and letting the water run out the bottom.

As far as chemical cleaning goes, we've had some clients try that. What happens is it doesn't really clean off everything. Once you start back up, it starts coming off of the feed effluent exchanger and it carries to the first reactor bed. You start getting pressure drop and maldistribution problems in that first reactor bed, so we don't recommend chemical cleaning.

As far as bundle removal, just don't do it. We have a refiner that we were working with who tried to remove the bundle. It got stuck and they had to bring in a whole new shell-and-tube exchanger. It may seem like you want to, but if you can get along without removing the bundle, just don't do it.

QUINTANA (Valero Energy Corporation)
Michael alluded to the fact that some of us have different experiences than what Roddey Engineering has seen. We've seen little feed-side fouling of our CFE exchangers, primarily due to the high velocities

on the tube side. But if any fouling were to occur, as Michael has indicated, cleaning in place with a lance, after removing the top and bottom cover plates, works best.

Extracting the bundles from vertical exchangers in situ is very difficult due to construction at the floating end. And if extraction is required for either cleaning or repairs, then this is best done during a turnaround by removing it to a shop environment. Some CFE bundles are actually not even designed for extraction where the shell girth flange that would normally be needed to extract it is eliminated to reduce cost of the exchanger and the potential hydrogen leak from it. If you have one of those and you do need repair, then you can take that to the shop and basically just cut the shell below the fixed tube sheet and then re-weld it after the repair is done to put it back together.

If the CFE is a Packinox exchanger, then you have feed spray bars underneath the bundle that can plug with salts. It should be equipped with feed filters to try to protect against it, but we had an experience where we had salts get through the feed filters and actually plug those spray bars. Often, those Packinox exchangers can be equipped with a back-flush system that works very effectively to clean them online.

If you have sweet naphtha feed from storage then, as Michael suggested, it's best to route it to the upstream hydrotreater. That is certainly our Best Practice: We never feed anything from storage direct to the reformer. We always feed it to the hydrotreater stripper upstream to ensure they have enough reflux to get rid of any water and dissolved oxygen, as well as any H2S from the hydrotreater itself. Our guideline is to consistently maintain a 0.2 to 0.25 reflux-to-bottoms ratio on that stripper column.

ZMICH (UOP LLC)
To follow-up a little bit on this and relay a little bit of UOP's experience here: We have heard and observed fouling on both the tube side or feed side and the shell side of vertical shell-and-tube combined feed exchangers, VCFEs. In general, on the feed side, the material is from charging feed from unblanketed storage. Both Michael and Javier have said that preferential route here is not to come from storage, and UOP agrees with that. You should process hot feed in the Platforming unit or reforming unit.

Cleaning of the tube side has been successful. My experience here has been with the high-pressure water lance. The system is set up so that you can remove the top flange and expose the tubes, and then the high-pressure water lance can be inserted to clean them out, basically.

Shell-side fouling is most often from PNA or heavy aromatic formation that deposits on the surface on the shell side of the exchanger. We have some experience of people trying to shift the dew point in the exchanger during shutdown to try to flush the exchanger and remove this material. Others have tried doing solvent flushes, a fill-and-drain-type of a procedure on the exchanger to try and clean it out. In any event, the material PNAs—polynuclear aromatics—are carcinogenic and people must wear proper PPE when doing these types of procedures.

As far as the bundle being stuck, UOP doesn't have any experience with the bundles being stuck that I'm aware of, but we agree that bundles should not be removed from the VCFE (vertical combined feed exchanger). It's very large; and if it has to be removed, it must be supported properly. If it's not supported properly, then you risk damage to the bundle and will have to buy a new exchanger.

FRANCOIS REVERDY (Alfa Laval Inc.)

This topic was treated in 2004 at the Annual Meeting. It was NPRA paper #AM04-42 in which we presented a statistical review of historical data regarding the frequency of fouling. I've gone back and double-checked those numbers, and they are still pretty representative for today.

At the time, we had done a worldwide survey of cleanings performed in 2001, 2002, and 2003. So we had a three-year database. That yielded a rule of thumb that cleaning was statistically required once every 10 years and that decontamination for inspection was statistically required once in between, meaning once every five years. By decontamination, I mean chloride removal and degassing.

Feed side fouling and effluent side fouling are quite different. On the effluent side, we've seen primarily salt deposition over the years, not too much PNA evidence. Feed side fouling is more complicated and involves salts, iron oxides, iron sulfides, and gummy compounds. We've even seen coke deposits, on rare occasions, in the upper ends of the exchanger (in the hot section). It's rare, but it can happen.

Most of these feed-side fouling cases originated from contaminants in the liquid feed or in the recycle gas. Because these contaminants often come from multiple sources, fixing the root cause, in our experience, is not always straightforward. Statistically, we see feed-side fouling at a few sites, but we do see it recurring at some of these very sites, which indicates that the root cause of the problem can be hard to fix.

The primary cleaning agent would be water for salts. If we have iron compounds, it would be typically a cocktail of citric acid, EDTA or other chelating agent. If we have greasy materials, we would use toluene or warm light cycle oil. When we have coke deposits, the only option is a controlled burn, which we talked about yesterday at the Q&A on hydroprocessing. That procedure is performed in situ and does not require removal of the plate from the plate bundle. It is rather quick (two to three days of cleaning time), simple (involves only nitrogen, steam, and air), and very effective.

ZMICH (UOP LLC)
I would just like to make one additional comment. I don't know, specifically, what the average frequency is for combined feed exchanger cleaning in a reforming unit. What I will say is that it's common for refineries to monitor what they call the ROT minus HIT—the reactor outlet temperature and the heater inlet temperature—as an indication of how the exchanger duty is and how the exchanger is performing. Eventually, you'll run into a bottleneck in the charge heater, the fired heater duty requirement, and an inability to maintain your target temperature in Reactor One. At that point, some people consider doing this cleaning of the exchanger or they're forced to shift duties to downstream reactors. So, monitor reactor outlet temperature/heater inlet temperature is the bottom line.

RICK WHITAKER (Valero McKee)
Is there any concern about the number of temperature cycles that you might go through and the potential for any leaks around the flanges on the combined feed exchangers?

QUINTANA (Valero Energy Corporation)
I'm not sure that it's a question of number of cycles but rather how fast the cycles occur. One thing that we've seen in some of our units is that when we have a compressor trip, for example, and a trip to the heater, depending on how long the unit is down before it is restarted, once you restart the compressor, if the heaters have cooled off sufficiently, you can propagate quite a disturbance all the way through the reactors. When we monitored this closely in some of our units, we have seen that the outlet temperature

from the last reactor feeding the hot side inlet of the combined feed exchanger can actually change very dramatically. In one case, we saw it change by an excess of 350ºF in less than three minutes. So, it's the degree of the change that you get on that restart that is important to monitor. And so certainly, that kind of stress from that rapid change can certainly impact the potential for leaks around the CFE.

We are in the process of looking at our procedures—Rick, we will be sending it to you as well—to try to come up with a means of preheating the firebox before restarting the compressor, if the unit's been down a long time, in order to minimize the potential for that disturbance, minimize the severity of that disturbance, and therefore limit the impact of such an event.

KAISER (Delek Refining Ltd.)
Not only do you have to think about leaks to the external atmosphere, you also have to consider the thermal cycling on the expansion baffles and things like that. It's probably not uncommon for that method to also generate leaks in that and generate feed-to-effluent exchanger leaks, which lead to the obvious performance degradation inside the unit.

KEVIN PROOPS (Solomon Associates)
I'll date myself. Somewhere in the 1990s, the leaks on flanges question came up for reformers and I believe the panel recommendation at the time was to make sure you have rain shields on everything because the most damaging cooling that you saw was from severe weather impacts causing rapid quenching of those flanges. So without getting in it too deep to any details, if you go back and look years ago, you'll find some discussion on that.

FRANCOIS REVERDY (Alfa Laval Inc.)
I want to stress the point and agree with Javier Quintana. Our experience is that, yes, after an upset, a shutdown, and a restart, you can see some very, very rapid temperature gradients in the order of hundreds of degrees in a few minutes, especially in cooling mode. That can really be tough, mechanically, for the equipment. So one has to have a bit more sophistication in the procedure for restarts under those circumstances. Please give us a call or call your licensor for that. It's very important.

ANDREW LAYTON (KBC Advanced Technologies, Inc.)
I'd just like to mention that thermal cycle is an issue to consider for the radial reactors as well because that thermal cycle, particularly the case you mentioned where you have the furnace shut down for a longer time: When you restart that machine, the regular reactors have the same effect as the exchanger. And if you have a really poor compressor reliability or a power supply issue, you can find that really you should be looking at those regular reactors every four or five regens rather than seven or eight regens. In fact, it's probably a reasonably good practice to take thermal cycling into account in planning when to inspect the scallops in the internals because many people leave it one or two regens too long.

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