Case histories from the sulfuric acid industry

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Softened refractory

Sulfur and spent acid regeneration furnaces are generally lined with refractory to provide thermal protection to the steel shell, in addition to keeping the heat within the furnace. The lining usually consists of two layers of refractory bricks or monolithic refractory. The insulating layer, which is closest to the steel shell, provides most of the thermal gradient while the hot face layer, which is exposed to the process, provides thermal resistance, chemical resistance, mechanical stability and abrasion resistance.

Fig. 1: Hot face layer subsidence

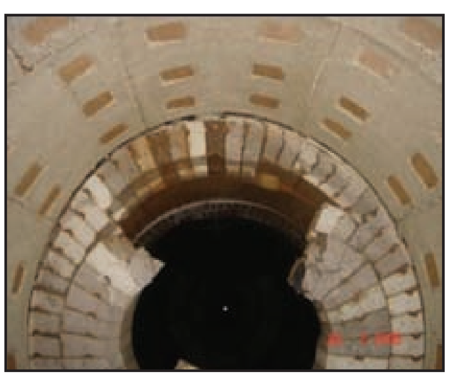

Fig. 2: Furnace choke ring failure due to refractory subsidence

Selection of the lining materials is critical for the longevity of the lining system and the steel shell. The materials and thicknesses of the insulating and hot face layers are selected to ensure the layers are kept in compression during operation and to ensure that the steel shell temperature is high enough to prevent condensation of acid vapors while preventing excessive strength loss of the steel shell.

Refractory material selection is normally based on the maximum service temperature that is listed on the refractory data sheet. Basing the selection entirely on this information, however, could lead to disastrous consequences. One has to also consider the atmosphere in which the refractory operates. For example, a 60 percent alumina brick that has operated successfully in a 2,250 degrees F (1,232 degrees C) sulfur furnace may not necessarily work in a spent acid regeneration furnace at the same temperature.

In addition, one has to consider the volume stability (refractoriness under load) of the material. All things being equal, the refractoriness under load, although tested in air, provides the best indication of the performance of the refractory material against similar materials. Of course, there is no substitute for a cup test. This test provides an indication of the material's resistance to the damaging effects of slags or molten ash in your process.

Lesson learned

When selecting refractory materials, do not rely just on maximum service temperature data. Also consider the proper steel shell temperature, the atmosphere in which the refractory operates, and the volume stability of the hot face layer. Not considering these factors could lead to the refractory failures shown in Figures 1 and 2.

Falling object

Plant stacks are designed as self-supporting, all-welded steel structures. They are equipped with a tuned mass damper near the top (Fig. 3) or with guy wires (Fig. 4) to minimize movements from high winds or seismic loads. Because of their height, they are usually fabricated in manageable sections, so they can be shipped to the site for assembly. To speed up the erection process, one designer had a better idea: bolt the sections together instead of welding. So, bolting flanges were welded to each section prior to shipping to the site. The bottom section was bolted onto the foundation and the other sections were bolted one on top of the other. The bolted joints were sealed with RTV silicone; no gaskets were installed.

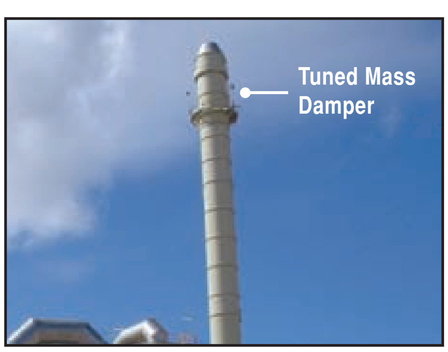

Fig. 3: Freestanding stack

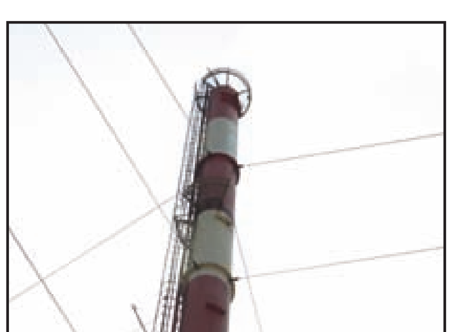

Fig 4: Guyed stack

The stack was in service for eleven years until one morning the top section was found lying at grade between the intermediate and final absorbing towers. The bolts were corroded. Luckily, the fall did not damage any property or take a human life.

Lesson learned

Like any acid plant equipment, inspection and maintenance of the stack is necessary for trouble-free operation. Bolts have to be inspected and replaced as required; guy wires have to be lubricated every three years and inspected with an electromagnetic flux sensor for discontinuities.

New designs have to be fully vetted for operability, maintainability and safety implications before implementing the design change.

More is not necessarily better

Plate & Frame exchangers are compact in size because of their high heat transfer coefficient. They require turbulent flow to reduce fouling, which interferes with heat transfer. Plate & Frame exchangers are usually provided with an in-line spare, so one could easily make a switch should the other need to be overhauled for mechanical cleaning.

Maintaining the design flow rates, especially in the waterside, is required to minimize fouling, as shown in Fig. 5. And bypassing or throttling the water flow during cold weather to control the acid outlet temperature will do just the opposite–increase fouling. A similar effect happened in an acid plant where the operator placed the in-line spare in service with the running unit because the unusually hot weather was affecting the cooling water inlet temperature. The thought process was: more area is better. While the strategy worked for a while, the reduced cooling water flow caused heavy fouling in the waterside, necessitating emergency cleaning.

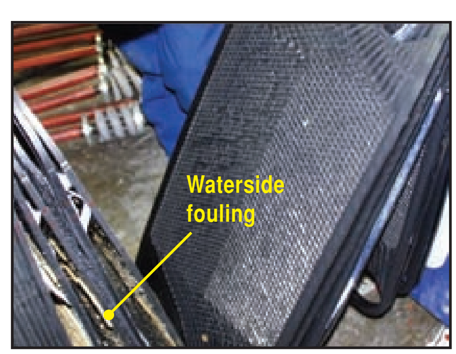

Fig. 5: Plate & Frame exchanger showing condition of plates in acid- and watersides

Lesson learned

Always maintain the design water flow into the exchanger to minimize fouling. Installing strainers upstream to capture piping corrosion products and debris is highly recommended.

Lost in translation

Engineering an acid plant within a project complex usually involves working with the major engineering contractor in charge of the whole complex. The technology provider's scope of supply is usually limited to the acid plant's battery limits, while the major engineering contractor does everything else. Even with fully defined division of responsibilities in place, there are always things that can fall through the cracks when the responsibility for a piece of equipment is shared. While this is not common, critical information that is transmitted by one office can be missed entirely by the other office.

Such is the case with an acid cooler that was used for preheating boiler feedwater. The acid cooler was within the acid plant's battery limit, but the boiler feedwater system was within the scope of the major engineering contractor. And although the data sheet clearly specified the acid pressure to be higher than the boiler feedwater pressure, the major engineering contractor overlooked this information. The project went on and the discrepancy was not caught during the hazard and operability review (HAZOP).

Less than three years after commissioning, an incident involving the acid cooler occurred. The operators never knew that the cause of the incident was the acid cooler because the pH probe in the waterside that was supposed to provide early warning of a tube breach never went off. The boiler feedwater pressure was found higher than the acid pressure. The incident caused damage to the economizers and boiler feedwater piping system.

Lesson learned

To ensure critical information is not missed, HAZOP reviews must be attended by all disciplines that share responsibility for the same equipment.

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