Julie Holmquist, Cortec, USA, explains how vapour phase corrosion inhibitor technology can help mitigate corrosion damage in fertilizer plants.

TAKING ACTION

Boilers, storage tanks, and insulated piping are familiar sights at fertilizer plants, and corrosion is their all-too-common enemy. Often, replacement of parts due to corrosion damage is a routine activity. While this is better than a full-scale emergency shutdown, preventing corrosion can make some of those repairs and replacements fewer and farther between. In contrast to many standard methods of protection that can be cumbersome or inadequate, vapour phase corrosion inhibitor technology changes the face of corrosion prevention by simplifying efforts in corrosion control.

A glimpse of corrosion costs in the fertilizer industry

Before examining the workings and potential applications of vapour-phase technology, it is helpful to get a perspective on some of the industry's corrosion costs and issues. A 2004 study of a fertilizer factory in India offers numerous examples. The review found that more than half of direct corrosion costs were attributed to equipment replacement, while 23% went towards maintenance painting, 15% to maintenance and repairs, and 10% to structural corrosion. Looking at sulfuric acid plant expenditures (all numbers rounded to the nearest hundred), researchers found it was common to regularly replace steam coils (US$65 200) and do patch welding on the boiler shell due to corrosion (US$3800). The acid drying tower, intermediate absorption tower, and final absorption tower tubes had to be replaced annually (US$9800). Patch repairs had to be done every year on an acid storage tank (US$6000), and in-plant pipelines had to be replaced once every three years (US$7600).[1]

Together, these costs easily add up to almost US$100 000, even though they do not represent every direct and indirect corrosion problem that did or could occur. Many other corrosion variables exist that could drive up costs by, for example, causing unexpected equipment failures and outages that lead to dramatic monetary losses from suspended production. Robust inflation over the last two decades would make those losses significantly higher today. Targeted corrosion prevention campaigns on key assets could therefore significantly reduce costs while also making life easier for maintenance personnel because of fewer corrosion-related repairs. While not applicable to every possible corrosion concern, vapour phase corrosion inhibitor technology offers inherent advantages for several key areas that are otherwise difficult to protect.

Vapour phase corrosion inhibitor technology

Vapour phase corrosion inhibitors (VpCI®/VCI) are chemical compounds that have an affinity to metal and an aversion to moisture. These inhibitors can be applied in many forms, both as solids (e.g. powder) and liquids (e.g. fogging fluid). The chemicals volatilise or vaporise, diffusing until they reach a state of equilibrium in an enclosed space. As these molecules disperse, they are attracted to metal surfaces where they adsorb and create a molecular layer that protects the metal from direct interaction with moisture and other corrosives. Under normal conditions, a corrosion cell would form in the presence of metal, oxygen, and an electrolyte; however, a VCI layer creates a barrier to this interaction, interrupting the typical electrochemical cycle that leads to rust and corrosion. Since VCIs can work in both the vapour phase and the liquid phase, they can be used to protect both empty void spaces and areas that are wet or filled with water (e.g. above and below the water level in a boiler). Unlike some technologies (e.g. nitrogen blanketing), VCIs do not require a constant airtight seal to be effective. While the space being protected should remain closed as much as possible to keep the VCIs from escaping, an adequate dose of VCIs will allow the molecular protective layer to replenish itself after the area is briefly opened and reclosed. These characteristics make VCI ideal for protecting hard-to-reach surfaces inside boilers, under storage tanks, and under insulation.

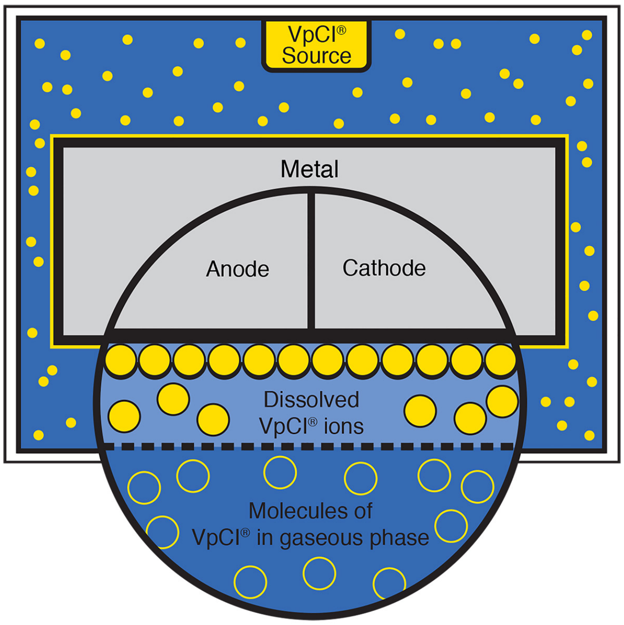

Figure 1. VCI conceptual illustration shows how VCI molecules (represented by yellow dots) diffuse throughout an enclosed space and form a protective molecular layer on the surface of the metal. Image courtesy of Cortec.

Steam boiler layup

Steam boilers are among the core drivers of fertilizer plant production processes because they create steam to heat chemicals and stimulate reactions. These multi-story boilers may need to be shut down periodically for inspection or maintenance. While suspended operation may be ok during scheduled plant turnaround, it is unacceptable when a boiler unexpectedly malfunctions and upsets the productivity of the whole plant. Having a backup boiler for redundancy is therefore ideal, since production will stop otherwise. In either case, it is important that the offline boilers remain rust-free so they can start up on short notice without any corrosion-related complications.

Shutdown and layup are sensitive times for boilers because the normal chemical water treatment programme is no longer in circulation. Furthermore, any residual moisture in a drained boiler makes a prime corrosion starting point. Boilers in wet layup, while sometimes protected below the water level, must battle moisture and condensation at the top of the boiler where the treated water cannot reach. Resulting corrosion products can clog the system, and, worse, lead to leakage and premature failures and repairs as the boiler tubes and walls experience thinning or pitting, ultimately shortening the service life of these high-dollar assets.

Common methods of corrosion protection include nitrogen blanketing for drained boilers and high pH and sulfite treatment for boilers in wet layup. The former is intended to ensure the absence of all oxygen inside the boiler, but nitrogen purge is expensive and must be redone if pressure is lost. The latter requires frequent monitoring to maintain the proper balance of chemicals; otherwise, protection is null. Furthermore, these wet layup chemicals do not protect in the vapour-phase.

An easier, more cost effective, and more reliable method of dry layup is to apply vapour phase corrosion inhibitors when boilers are shut down and drained for a turnaround, a process that may last a few days or many weeks. A VCI fogging fluid is ideal for boilers larger than 10 000 gal. (38 000 l). The vapour-phase action allows the corrosion inhibitors to travel part way through the void space on their own inertia. To complete the application, a fan can be placed at the opposite end of the system to create an air current that pulls the inhibitors through the rest of the void. These VCIs typically do not need to be removed before refilling and starting the boiler.

For wet layup, a VCI liquid can be added to the feedwater and pumped through the system. The main advantages of this method over sulfites or high pH

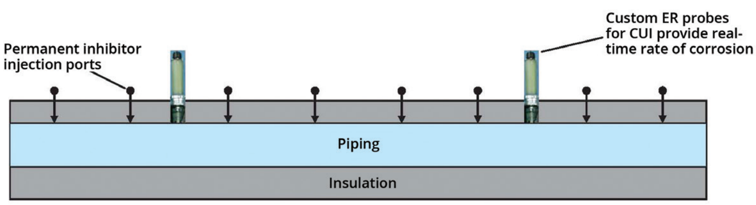

Figure 2. A schematic showing how a VCI CUI inhibitor can be injected into insulated piping at regular intervals for protection of the metal surface below the insulation. Image courtesy of Cortec.

levels are that much less monitoring is required and the VCIs protect the vulnerable areas of the boiler above the water level, as well as those in direct contact with it. If the boiler needs to be kept on low fire for standby, a VCI water treatment that remains effective up to 302°F (150°C) can be used. This way, the water does not have to be completely reheated before the boiler can be restarted, saving time when unexpected emergencies arise. VCIs are compatible with most water treatment chemicals and typically do not need to be flushed before returning the system to service.

AST bottom protection

Aboveground storage tanks (ASTs) are another common sight at fertilizer plants. With ASTs in general, a natural disadvantage for maintenance and inspection is the inability to see what is going on underneath the tank, i.e., if corrosion is occurring. Moreover, the tank bottom can be a natural place to trap moisture, and, in some regions, high chloride conditions in the air and soil make the environment extra corrosive. It is also difficult to conduct tank bottom repairs once a tank is in service because the tank must be drained and, even then, the area underneath the tank is relatively inaccessible.

Historically, AST bottoms have been protected using cathodic protection (CP) systems, which usually require a continuous supply of power. However, sometimes the power is turned off or the tank needs to be retrofitted. Another problem is that tank bottoms can be uneven and may not be in full contact with the sand pad carrying the CP current, leaving patches of the floor that are unprotected.

VCIs provide an excellent supplement to CP. They can be injected underneath the tank as a powder or a slurry whether or not the tank is in service and filled. This eliminates costly bills to empty and raise the tank. Furthermore, the vapour-phase action allows corrosion inhibitors to diffuse into hard-to-reach pockets that may go unprotected by CP.

After many years of field trial, the use of VCIs under ASTs has become an industry standard. This is evidenced by its prominence in two recent documents: API Technical Report 655, 'Volatile Corrosion Inhibitors for Storage Tanks,' released in 2021, and AMPP SP21474-2023, 'External Corrosion Control of On-Grade Carbon Steel Storage Tank Bottoms,'[2 3] released in 2023 with a section on VCIs. As time goes on and more long-term data unfolds, this method is only expected to become more established due to its practicality and effectiveness.

Corrosion under insulation (CUI)

One of the most recent advancements in applied VCI technology targets CUI prevention. CUI is insidious because insulation not only traps moisture to breed corrosion but also hides corrosion once it starts beneath the insulation. The seriousness of the damage or danger ranges from minor to life threatening depending on what the vessels or piping contain and how far corrosion progresses. According to a review in the oil and gas industry, CUI is blamed for approximately 40 – 60% of piping maintenance costs.[4] If costs are this high in the petroleum sector, it would not be surprising to find similar results in fertilizer production, a related chemical industry.

In addition to being difficult to detect, CUI is hard to counteract. While coatings and inhibitors exist that may slow the inception and propagation of CUI, they usually need to be applied at the same time as the insulation. This makes it difficult to mitigate corrosion on pipe, tank, and equipment surfaces that are already covered with insulation. Removal and replacement of insulation is neither practical nor cost-effective unless the risk is serious enough to warrant such an operation.

Cortec has considered the CUI problem for many years and found VCIs to be a promising technology for protection of surfaces that are already insulated. Conceptually, the vapour-phase action of VCIs allows them to be injected into insulated material, enabling them to travel through the insulation or along the interface where the metal and insulation meet, leaving behind a protective molecular layer. The obstacle is the high temperature cycling on some piping and equipment that is difficult for most organic VCI chemistries to survive. Cortec therefore set out to find an injectable VCI formulation that could withstand relatively higher temperatures than the company's first iteration.

The result was an injectable VCI with temperature stability above 600°F (316°C), nearly twice as high as the previous injectable corrosion inhibitor. The inhibitor was laboratory tested for its ability to migrate through vapour space and form a protective, corrosion inhibiting film on a metal surface. In addition to showing migration and corrosion inhibition, the chemistry exhibited extremely hydrophobic properties, which, although not the chief mechanism for corrosion protection, are definitely advantageous for inhibiting the effects of moisture ingress and condensation.[5] A further advantage was that the product used renewable feedstock, allowing it to receive the USDA certified biobased product label.[6]

Turning the promise of vapour-phase protection into a reality

While it is impossible to eliminate the presence of all rust, many technologies exist to help mitigate the problem in critically significant areas. Vapour phase corrosion inhibitor technology is one of those chemistries that offers important advantages for those who own and maintain fertilizer production facilities. Directing this technology towards boiler layup, AST bottom protection, and CUI, fertilizer plants can protect themselves from several potentially serious losses of production time and asset value. WF

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