Polymer lining mitigates corrosion of Alloy 2205 in flue gas desulfurization units

A typical FGD unit. Photo courtesy of Sauereisen.

Sulfur dioxide (SO_2) is a highly reactive, toxic gas that is linked with a number of adverse effects on human health and the environment, and is a major contributor to acid rain. According to the U.S. Environmental Protection Agency (EPA), combustion of fossil fuels at power plants accounts for 73% of total SO_2 emissions.[1] The Electric Power Research Institute (EPRI) (Palo Alto, California) reports that most large coal-fired power plants, in response to strengthened National Ambient Air Quality Standards (NAAQS) for SO_2 emissions set by the EPA in recent years, have installed state-of-the art flue gas desulfurization (FGD) technologies to remove the SO_2 from the flue gas exhausted when coal is burned. Since 2004, many FGD components, such as absorber vessels, spray towers, tanks, and piping, have been constructed of duplex stainless steel Alloy 2205 (UNS S32205/31803) because of cost and other factors. The industry is finding, however, that within three months to three years of operation, many components of the FGD systems constructed of Alloy 2205 are experiencing severe corrosion.[2]

According to NACE International member Thom Johnson, corrosion industry manager, composite polymers with resin manufacturer Ashland, Inc. (Dublin, Ohio), a wet FGD unit removes or "scrubs" the SO_2 out of the flue gas with an aqueous "limestone" sorbent slurry comprised primarily of calcium carbonate ($CaCO_3$), with some calcium hydroxide [$Ca(OH)_2$] and magnesium hydroxide [$Mg(OH)_2$]. As the flue gas passes through the absorber vessel, it is sprayed with the alkaline slurry, which reacts with the SO_2 and forms carbon dioxide (CO_2), water, and precipitates such as calcium sulfite ($CaSO_3$) and magnesium sulfite ($MgSO_3$). The resulting liquid environment in the absorber also contains sulfuric acid (H_2SO_4) and hydrochloric acid (HCl). Johnson notes that the combination of the slurry's low pH, the presence of acids, and higher temperatures creates a very corrosive environment for metals.

Alloy 2205, which contains 21-23% chromium, 4.5-6.5% nickel, and 2.5-3.5% molybdenum, is a high-strength alloy designed for improved resistance to corrosion, stress corrosion cracking (SCC), pitting, sulfide stress cracking (SSC), and crevice corrosion in chloride environments, and is used in heat exchangers and pressure vessels. Its selection for use in FGD units was influenced by laboratory test results and early studies in the field that indicated it had good corrosion resistance when exposed to the environmental condi-

A power plant's FGD scrubber module shows signs of corrosion. Photo courtesy of Sauereisen.

tions in a FGD scrubber—temperatures of 130 °F (54 °C), pH between 5.5 and 6.5, and chloride levels up to 10,000 ppm.[3]

Industry, however, has reported widespread corrosion of the alloy in FGD units in the form of pitting, crevice corrosion, and SCC, with through-wall penetration observed in some vessels that were in service for less than a year, says NACE member Lake Barrett, sales manager with specialty coating manufacturer Sauereisen, Inc. (Pittsburgh, Pennsylvania) and a NACE-certified Level 3 Coating Inspector. The cause of the corrosion is still under investigation, but is believed to be a result of acid condensates formed during the scrubbing process and the creation of scale on the walls of the absorber vessel from precipitates that accelerated pitting and crevice corrosion, particularly in scrubbers with high concentrations of sulfates and chlorides.

"The precipitates cling to the absorber wall and electrochemical corrosion cells form in the underlying metal," Johnson explains. The corrosion varies from one system to another and is dependent on environmental factors such as gas velocity, acidity, dew point, temperature, wet-dry cycles, and chloride and fluoride concentrations. Results of an EPRI study indicate that factors contributing to the corrosion include a shift from natural and inhibited oxidation systems to forced oxidation systems, which led to an increased likelihood of scale forming on the absorber walls.[2]

Barrett comments that many power plant operators have chosen to rehabilitate the corroded interior walls of FGD absorber units with protective linings comprising novolac epoxy vinyl ester resins and glass flake or glass fiber, which will protect the underlying metal from further corrosion. These linings are specially designed to withstand the low pH, aqueous chloride environment found in FGD absorbers. He adds that the resins are resistant to higher temperatures, H_2SO_4, and HCl, as well as high concentrations of chlorides, and are frequently used in much more aggressive chlorine environments with HCl and sodium hypochlorite (NaClO). These linings incorporate the same epoxy vinyl ester resin technology used in FGD vessels constructed of fiber-reinforced polymer (FRP), which have been perform-

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ing successfully in the field since the early 1970s. The glass addition decreases the permeability of the lining and increases its flexural strength and abrasion resistance. "We knew from data with the FRP scrubbers that the Derakane† novolac epoxy vinyl ester resin would stand up really well to the environment," Johnson says, noting that the degradation mechanism for the polymer is inherently different than for metal—for the polymer to be attacked, its molecular bonds would need to be broken, and that doesn't happen in the environment that is corroding the metal alloy.

A variety of epoxy vinyl ester resin chemistries are available, and the selection of the appropriate resin for a lining is based on the chemical and physical environment in which the lining will be exposed, says Barrett. This includes the composition of the liquid and gaseous materials, maximum temperatures, temperature cycling, and abrasive material flow. For the FGD absorber, a novolac modified resin was selected over the Bisphenol A (BPA) resin due to its ability to withstand higher temperatures and more severe chemicals. To determine the performance of the resins in the FGD environment, the polymer was evaluated in the lab and tested in the field, Johnson notes.

Before a lining is installed, the surface of the vessel is prepared. This typically includes abrasive blasting to NACE No. 2/SSPC-SP 10[4] with an aggressive profile of 3 to 4 mils (76 to 102 µm), and repairing any corrosion damage. Once abrasive blasting is complete, the surface must be checked for chlorides and other contaminants that must be removed. Rehabilitated absorbers may have severely pitted surfaces that need to be filled with a material compatible with the protective novolac epoxy vinyl ester lining. New absorbers constructed of Alloy 2205 also can be lined so future corrosion is minimized.

The linings are normally applied with airless spray equipment, although the traditional hand-laid trowel application method can still be used. Typically the thickness of the lining system is based on the specific environment in the FGD absorber and can be anywhere from 60-mils (1.5-mm) thick, for less aggressive environments, up to 375-mils (9.5-mm) thick, which includes heavy duty fiberglass-reinforced mortar mat for more aggressive environments.

Novolac epoxy vinyl ester lining systems installed on rehabilitated Alloy 2205 FGD absorbers have been in use for several years now and have an expected service life of 10 or more years with regular maintenance.

This article is based on CORROSION 2013 conference paper no. 2105, "Epoxy Vinyl Ester Polymer Lining for Duplex UNS S32205/S31803 Alloy FGD Absorber Modules," by H.M. Ramsey, T.L. Johnson, and D.H. Kelley.

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†Trade name.

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