Several factors cause deterioration of critical process equipment in process plants. The options widely utilized for restoration include conventional repair or replacement. Nonmetallic composite materials can be utilized as an option to restore equipment integrity. This article discusses the material degradation aspects in critical streams such as the cooling water system and hydrocarbon pipelines at a Saudi Arabian gas plant. Nonmetallic composite coating materials play a vital role in corrosion protection and life extension of core components.

CASE HISTORY

Role of Nonmetallic Composites in Gas Plants

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Uthmaniyyah Gas Plant (UGP) in Saudi Aramco’s Southern Area Gas Operations is one of the largest gas processing plants in the world. UGP was commissioned in 1981 as part of the master gas system (MGS) plan to process associated gas from oil wells, and it gradually expanded to process non-associated gas (Khuff) received from gas wells. The gas plant also produces sales gas, natural gas liquids (NGL), and sulfur, and often operates at full capacity to accommodate increasing demand for sales gas and NGL. Process streams such as the cooling water system, buried hydrocarbon piping, and other pipelines are integral parts of plant operations, and interruptions to these critical streams, from equipment deterioration as a result of corrosion, could limit plant operations and lead to significant revenue loss, depending on the feed rate and other variables.

Metallurgical Aspects of Core Components

The core elements of a typical cooling water system include the cooling water heat exchangers, cooling tower, concrete basin, and associated piping. The heat exchanger is a critical component of a cooling system, and is carefully designed to transfer heat from the process stream to the cooling water. Heat exchangers can have different designs, but shell-and-tube units are the most common type used in the plants. Several factors are considered when selecting heat exchanger materials. These include temperature, the chemistry of the process stream, and the cooling water. In general, carbon steel (CS) can provide optimum life in treated cooling water applications. CS has been the primary choice of material in cooling water system exchangers, especially for the shell, tube sheet, channel, and channel cover. Copper and its alloys, such as aluminum-bronze, Cu-Ni, and stainless
Corrosion Management

The materials used in cooling water systems are susceptible to deterioration by the environment and operating conditions. The mode of attack and its severity can vary, and is determined by factors such as system design, temperature, flow rate, water chemistry, concentration of corrosion, alloy composition, wet-dry cycle, operating pH range, effectiveness of bactericide, cycles of concentration, and blowdown practices.

Although corrosion inhibitors, anti-scalants, and biocides are commonly used for corrosion control, both open and closed systems experience corrosion as a result of the chemistry and quantity of make-up water added to the system. Open recirculating (evaporative) and once-through systems are exposed to large quantities of suspended solids, water-borne contaminants, and solutes; these factors lead to significant fouling and corrosion challenges. Closed systems (non-evaporative), however, do not have such problems because they experience little or no water loss and are not exposed to waterborne contaminants.

In the cooling water heat exchanger, the tube sheet, baffle, and bundle can be subjected to different types of damage-causing mechanisms such as localized corrosion, stress corrosion cracking, dealloying, and microbiologically influenced corrosion. As the corrosion concerns are complex, the option of corrosion management varies with respect to the type of cooling water system and other factors. Corrosion, scale, sludge, algae, and fungal growth are the common inherent problems in cooling water systems. Monitoring data reveal that these corrosion challenges are more specific to open cooling water systems as opposed to closed cooling water systems, which are less prone to corrosion.

Cooling Water Heat Exchanger Tube Sheet Restoration

In spite of the ongoing corrosion mitigation efforts, the CS sections experienced deterioration to varying degrees. When the tube sheet experienced localized corrosion (Figure 1), the traditional repair approach was to replace the tube sheet, which required removal of the tubes and extended down time almost equal to the time required to retube the tube sheet. Instead, a nonmetallic composite coating system was applied in-situ as an innovative and cost-effective option to restore the integrity of the tube sheet (Figure 2).

The nonmetallic composite system applied in this rehabilitation consisted of filler, intermediate heavy-build vinyl ester resin-based glass-flaked material, and a reinforcing veil coat. Prior to application, it is crucial to remove the contaminants on the tube sheet, such as chlorides, and perform surface preparation by abrasive blasting. This nonmetallic composite system was reevaluated after three years of continuous operation, which confirmed satisfactory performance with optimum corrosion protection. Subsequently, the turnaround cycle was proposed to be extended from 36 to 60 months.

Restoration of Cooling Tower

The majority of the cooling towers in Saudi Aramco are made of wood with a preservative treatment. Because of ageing, delignification, and biological attack, the wood experienced serious deterioration (Figure 3).
These blades have experienced failure which, in most cases, has been attributed to fatigue. Such failures led to not only operational interruption, but also unsafe conditions. The aluminum blades have been replaced with nonmetallic composite material. Nonmetallic composite fan blades will be required in new construction to enhance safety and equipment reliability.

**Enhanced Protection for Concrete Basins**

As part of the ongoing efforts toward the use of nonmetallic composite materials, every possible opportunity is captured to deploy composites for corrosion protection. In line with this approach, the existing cooling tower concrete basins that experienced deterioration at the air/water interface were restored by conventional repair, and composite laminates were installed to provide further reinforcement and prevent recurrence of the deterioration. Sacrificial anodes were installed in the submerged sections of the concrete basin to protect the rebar.

**Enhanced Protection for Hydrocarbon Pipeline Transition Points**

Most buried CS piping has an external coating system and cathodic protection (CP). A chemical inhibition program is used for internal protection. Each pipeline has an aboveground-to-below ground transition point and the external protection at the transition point has been asphalt and concrete. Significant external corrosion from shielding and abrasion has occurred at these transition points, and nonmetallic composites were installed to enhance external protection at these points. The application comprises fiberglass laminates soaked with a two-component epoxy system that, after curing, forms a nonmetallic sleeve (Figure 6).
The composite material was applied at the transition points of incoming hydrocarbon condensate piping and evaluated after eight consecutive years of operation. This evaluation revealed satisfactory performance—the sleeves protected the line even without CP.

Conclusions

Almost all process industries have cooling water heat exchangers, cooling towers, and numerous buried pipelines with transition points as integral parts of the plant operation. Material degradation of this equipment and its components in existing operating facilities can be complex. Therefore, timely remedial actions are required to ensure operational reliability. At UGP, nonmetallic composite materials have been successfully used as an innovative and cost-effective option for restoration. Nonmetallic composite materials play a vital role in these applications and help to enhance safety and reliability.

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FIGURE 6

Nonmetallic sleeve for transition point protection.